Restoring water cycles to naturally cool climates and reverse global warming.

Thank you for the opportunity for Healthy Soils Australia to contribute to your important forum.

Healthy Soils Australia is a network of leading innovative farmers from across Australia. Like your US Soil-age and Soils for Climate groups we champion practical solutions to regenerate our soil health and help address our critical; aridiification, water, food and climate change challenge.

In this Healthy Soils Australia works very closely with our ex Governor General, Michael Jeffery in his role as Australia's advocate for soil, in the regeneration of our soils, landscape and sustained future. His Soils for Life agency has documented leading case studies of some of these farming innovations.

Like the US and globally, we are focused on climate change and how it will impact farming and our capacity to supply our essential water, food, bio-materials and social stability for the future.

Specifically how our regeneration of our soils and landscapes can help mitigate and adapt to the now locked in dangerous feedbacks and extremes from our past land degradation and carbon emissions.

Why and how we must not just reduce future emission and draw down carbon back into our soils; but also restore the hydrological cycles which naturally cooled climates and the planet.

Our climate reality and challenge.

As demonstrated by Charles Keeling 50 years ago our oxidation of carbon from our landscapes over centuries has resulted in the abnormal continued rise in C02 level from 1750 as its lead symptom.

As demonstrated this rise in C02 resulted directly from the in-balance between our annual emissions from burning carbon and the reduced ability of our residual bio-systems to sequester it.

Global emissions from natural respiration and the burning of forests, degradation of soils and use of fossil fuels now far exceed the ability of our residual forests and landscapes to draw them down. This results in a net addition of some 10 billion tonnes of carbon (btC) to the atmosphere each year.

It follows that to return CO2 to former safe levels we need to bio-sequester this additional 10 btC/an plus an equivalent quantity of our past 'heritage' emissions back into our soil and biomass sinks.

However we have a more serious problem. This is because our past emissions and impaired heat balance has already locked in increased climate warming and hydrological extremes that key natural and agricultural bio-systems and the communities dependent on them may not be able to survive.

This is because the Earth's oceans act as a mass buffer that absorbs much of the C02 emissions and over 90% of the increase in heat; slowly re-equilibrating this back into the air but with lag effects.

As such we have already locked in a C02 rise to over 500 ppm and independent global warming and dangerous climate feedbacks and hydrological extremes that will intensify over the next decades.

These feedbacks and extremes are occurring now; increasing storms, droughts, the aridification of regions, wildfires and the collapse of agricultural and natural bio-systems and their communities.

Key regions be it SW Western Australia, the Mediterranean or the SW US are already in the front line; trying to survive these systemic climate changes and dangerous hydrological extremes.

No level of reductions in future C02 emissions or promises to do so can now prevent these extremes.

We may have less than 10 years to try to limit and buffer their impacts, but only if we can;

1. **Cool climates** to offset warming effects and avoid triggering these extremes.
2. **Draw down adequate carbon** into our soils to help restore natural hydrological processes.
3. **Reinforce the resilience** of natural and agricultural bio-systems to survive such extreme.

Humanities challenge, indeed imperative, and the focus of this conference is how can we do this? How can we restore the water cycles needed to cool climates safely, naturally and hopefully in time?

How can we avoid the dangerous fallback to the Faustian 'bargin' of geo-engineering and its risks?

The good news is 'we can do this'; as nature has done repeatedly, safely, practically and in time.

The bad news is that to do this we may need to think differently, to consider new options, to change.

To ask critically, what is causing our climate crisis; not just its symptom, the abnormal CO2 increase?

To ask how we have caused this? How to avoid it; by understanding what is its primary cause.?

To do this we must go back to basics; to Climatology 101 and the processes that govern the heat dynamics and balance of the blue planet? How we may have altered them so we can restore them?

The natural processes governing the heat dynamics of the blue planet.

Every day the Earth receives on average some 342 watts per square meter of incident solar energy. To maintain its stable temperature It also used to reflect or re-radiate 342 w/m2 back out to space.

Over the past 250 years we have impaired this balance by trapping an extra 3 w/m2, or 1% of the incident energy, in the Earth's atmosphere via our elevated abnormal greenhouse effect.

It follows that to restore our former safe climate we must enable an extra 3w/m2 of heat to escape back out to space as it previously did naturally. We have less than a decade to do this in.

For the past 4.2 billion years water, has governed over 95% of the heat dynamics of the blue planet. This is due to not just its volume given that 71% of the Earth's surface is covered by water to a mean depth of 4000 meters but also due to its unique molecular capacity to absorb solar radiation while in the liquid phase as well as more re-radiated infra red heat while in the gaseous water vapour phase.

It is the unique capacity of liquid water to absorb solar radiation and for water vapour to absorb re-radiated infra red heat, via the natural greenhouse effect, that has enabled the Earth to raise and maintain its mean temperature some 33oC above what it would be without these water effects.

This raised temperature enabled the Earth to sustain liquid oceans and for microbial life to evolve in them some 3.8 billion years ago. For the past 3.5 billion years this has been reinforced by aerosols from marine algae that increased the formation of marine hazes of water micro-droplets and aided the natural water vapour dominated greenhouse effect to regulate the Earth's liveable climate.

This in turn enabled symbioses of fungi and plants to colonize the land and form soils from 420 million years ago. These rapidly covered the 13 billion hectares of land surface with green forests.

The vast surface area of transpiring leaves in these forests enabled more water to be transpired and circulated in the atmosphere and reinforced the Earth's multiple hydrological warming and cooling processes, heat dynamics and balance. It also enabled the recovery and regulation of the climate.

While CO_2 levels also varied over these 4.2 billion years, from some 950,000 to as low as 100 ppm; as vast quantities were bio-sequestered initially into marine chalk, coral and limestone and then soil humus and fossil fuels and while these contributed to some 20% of the greenhouse effect, 95% of the Earth' heat dynamics and balance was, and still is dominated and governed by its hydrology.

Our human impact on these bio-systems, heat dynamics and its consequences

Over the past 10,000, but particularly past 300 years we have cleared and burnt forests, oxidised soils and created over 5 billion hectares of man made desert. This has greatly altered the capacity of over 70% of the land surface to; infiltrate and retain rainwater, shade, cool and protect soil surfaces from solar heating and erosion and sustain its former transpiration, cooling and cloud dynamics.

This degradation has greatly altered the Earth's natural hydrology, heat dynamics and climate.

Our burning and degradation of these landscapes has oxidized vast levels of carbon causing the abnormal rise in global CO_2 levels from 1750, 200 years prior to our accelerated use of fossil fuels. Even now wildfires annually burn some 300-400 mha emitting up to 8 btC/an. Stubble and grass fires may burn a further 2 bha and emit a further 4 btC/an. Combined with our emission of 8 btC/an from fossil fuels these have and will accelerate the recent increase in global C02 levels.

While climate policies focus on the abnormal rise in this CO_2 symptom from this oxidation this has masked the far more serious impacts this soil degradation has had on the Earth's hydrology. While people and bio-systems can survive in C02 levels of up to 10,000 ppm, we need water daily and may not survive the hydrological climate extremes that are already intensifying dangerously.

Similarly our policies also fail to recognize that, due to the ocean lag effects, we can not prevent the locked in hydrological consequences of our abnormal greenhouse effect or climate extremes by reducing future CO_2 emissions to any level or even drawing down carbon over the next decades.

We need far more effective responses if we are to avoid these dangerous pending climate extremes.

As in nature, we can now only do this by restoring the Earth's hydrological heat balance.

Restoring the Earth's natural, safe hydrological cooling processes and climate regulation.

Just as nature has done for 4.2 billion years, we too need to restore the Earth's heat balance.

To re-balance the 342 watts/square meter of mean incident solar energy that the Earth receives daily with 342 w/m2 of reflected solar energy or re-radiated energy emitted back out to space by returning the extra 3w/m2 that is currently being retained due to the abnormal greenhouse effect, safely back out to space.

To do this we simply have to restore some of the 10 natural hydrological processes that can readily and safely provide an additional cooling effect of some 3w/m2. These include natural processes to;

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.

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 as well as aid their retention of soil moisture.

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 and aridify climates.

5. **Reduce the surface heating of covered moist soils** and thus their re-radiation of the long wave infra red heat that drives the natural and enhanced greenhouse effect. This can safely **turn down the main variable governing the natural and enhanced greenhouse effect.**

6. **Reduce the length of time** that transpired or evaporated **water vapour 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. **Induce the formation of raindrops** from these clouds to remove the humid hazes but also 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. **Reopen night time radiation windows** that were 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 as climates aridify.

10. **Restore regional rainfalls by inducing the formation of low pressure zones** over cooler moist landscapes to aid the inflow of further humid air often from marine regions.

The physics and cooling potential of each of these natural processes are detailed in appendix 1. Collectively these natural hydrological processes are responsible for daily transmitting 342 w/m2 of energy back out to space and for both maintaining the Earth's raised safe temperature and climate.

As each 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.

Our critical practical action imperative; restoring the Earth's soil carbon sponge.

While restoring these natural hydrological processes seems complex, we can restore and rebalance them all simply by regenerating the area and longevity of green growth by our residual bio-systems.

To do that all we need to do is 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.

As in nature our key imperative must be to limit the oxidation and enhance the bio-sequestration of carbon into stable soil forms so as to restore the structure, health, productivity and resilience of soils and bio-systems and through that their hydrological cooling capacity.

Leading innovative farmers confirm that they can bio-sequester up to 10 tC/ha/an in many soils and regions. Strategies such as Regenerate Australia outline how this could be extended regionally in this case over 300 mha to regenerate the hydrology, resilience and productivity of Australia's rangelands.

Conversely if we continue to oxidize our soil carbon we will rapidly degrade the structure, health and productivity of our farmed soils, effectively turning them into hard, bare, hot wasteland as in deserts and much of our industrial agriculture. Such soils may lose 5-10 tC/ha/an and once exposed risk losing up to 200 tonnes of topsoil/ha/an from intense wind and storm erosion.

As our land management practices directly govern the rates at which carbon is oxidized and/or bio-sequestered, our land management also directly governs its hydrology, the longevity of green growth and thus; its direct influence in cooling regions and our climate.

Rather than being seen as a pollutant or problem we need to see C02 as a key natural resource, tool and building block to regenerate healthy soils, hydrologies, bio-systems and communities globally.

Innovative ecological grazing, cropping and shelterwood systems demonstrate how we can reduce this oxidation of carbon from biomass and soils and aid its bio-sequestration of stable soil carbon.

For example shelterwoods in urban and rural areas can greatly aid the effectiveness of each raindrop by reducing evaporation losses and enhancing water cycles. By aiding albedo, shading and latent heat fluxes they can help cool habitats by over 7 oC, as well as protect and cool soils, turn down the enhanced greenhouse effect and enhance the resilience and productivity of bio-systems.

Extended and integrated into our regenerative agriculture such ecologies are now critical to aid the structure, hydrology and productivity of soils and landscapes and their capacity to sustain growth and cool habitats, despite increased climate extremes.

This regeneration of our soils is now also critical to secure the water, food, habitat and social needs of our 7.3 and 10 billion projected people and to meet the UNs Sustainability Development Goals.

As such the health of our soils and landscapes must be seen as our key strategic natural asset and our key means to regenerate and secure our safe climate, wellbeing and social stability, globally.

We have the science, the innovations, blueprints and the clear self interest to make this change.

The UNFCCC in Paris may provide the policy incentive and carbon price to help in doing so.

What we don’t have is time. The pending climate extremes dictate we must act urgently, now.

However we can be confident that nature will again use these soil carbon regeneration processes to safely regenerate, rehydrate and cool its productive bio-systems and landscapes.

The only question is; will we help her and ourselves in this, or let her do it after but without us?

Walter Jehne

Healthy Soils Australia

Appendix 1

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

The processes governing the Earth's climate.

For 4 billion years the Earth has maintained a buffered temperature 33^{o}C above that expected just by physics. This elevated temperature has been due to the Earth's immense quantities of water, in its oceans, atmosphere ice and the on land and the unique capacity of water to absorb and transfer vast quantities of incident solar heat while in the liquid phase as well as re-radiated infra red heat while in the gaseous, water vapour phase.

This capacity of water to absorb heat contributed greatly to the Earth's natural greenhouse effect, its elevated buffered temperature and how water has governed 95% of the heat dynamics and climate of the blue planet.

In turn this hydrological component of the natural greenhouse effect was fundamental in the Earth being able to maintain and recover its buffered raised temperature; despite major planetary and volcanic impacts to the composition of our atmosphere, including changes in the carbon dioxide concentrations from some 950,000 to 100 parts per million, and the sun's ever increasing intensity or 'solar constant' over this 4 billion year period.

This buffered and elevated temperature also enabled the Earth to sustain liquid oceans and for life to evolve.

The scientific reality and our assumptions in developing and from greenhouse models .

Science has long confirmed that water and its hydrological and heat transfer processes are the dominant factor governing some 95% of the heat dynamics and climate of the blue planet. Indeed it was because water was such a dominant factor in the Earth's climate, including some 60% of the natural greenhouse effect, that it was assumed that man could not possibly have altered these dynamics in causing our recent climate changes.

As such explanations of the cause of our recent abnormal human induced global warming focused on the clear recent abnormal rise in CO2 levels confirmed 50 years ago by Charles Keeling and its natural greenhouse component effect rather than possible changes to hydrological processes and their heat effects.

Clear mathematical relationships had also been confirmed between the rise in CO2 levels, its greenhouse effect and global temperatures by Savantes Arrhenius. By contrast hydrological processes were 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.

The clear abnormal rise in CO_2 levels and the fact that it is a greenhouse gas, also made it easy to assume that this was the dominant and primary cause of any recent global warming. The fact that we had recently greatly increased our burning of and emissions from fossil fuel similarly provided a simple clear 'causal assumption' for the abnormal CO2 rise, even if CO2 levels had been rising since 1750, 200 years before large fossil fuel use.

Consequently most reseach to assess the impacts from the clear CO2 rise focused on modelling its component of the greenhouse effect; largely ignoring possible hydrological dynamics as an alternative causal factor.

However, even with these assumptions, this 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'.

This was done by assuming that the water vapour 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 rationalised 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 minor 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 vapour or as haze micro-droplets is governed not by the air temperature or the 400 ppm of CO_2 in the air; but by a balance of;

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 hygroscopically 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 till they are either re-evaporated into water vapour or 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.

Given their dominant effect on our climate and potential role in climate change, we need to better understand these hydrological processes in their own right as independent variables, particularly:

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

Understanding the key hydrological processes that naturally cool and govern our safe climate.

Every day the Earth, on average, receives 342 watts per square meter of solar energy in its troposphere. To sustain its stable climate over 4 billion years it has also had to re-transmit 342 w/m2 daily back out to space.

To date we have impaired the escape of some 3 watts per square meter or some 1% of the incident global solar radiation back out to space. This in turn has induced our observed warming and dangerous extremes.

Given that a range of hydrological processes have governed the dynamics and balance of the Earth's energy absorption, reflection and re-transmission for this 4 billion years, it follows that we need to understand them and how we may have changed them to cause the 3 w/m2 warming and the projected hydrological extremes.

Whether we can restore these natural hydrological dynamics and in so doing restore a safe natural cooling effect of some 3 watts per square meters to restore our former safe climate, at global scales and in time?

The following outlines the published science behind each of the hydrological processes known to contribute to the Earth's heat dynamics, cooling and climate and how our changes to them may have contributed to the recent abnormal climate changes. How our regeneration of these processes may enable us to safely and naturally reverse the causal factors and thereby safely cool the climate?

How the regeneration of natural hydrological processes can safely cool climates. How to:

1.Regenerate the Earth's soil carbon sponge so as to retain rainfall, sustain transpiration and cool climates.

As outlined above hydrological processes have governed the natural heat dynamics and climate of the blue plant for over 4 billion years. Clearly for these processes to function they need abundant, sustained 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 the Earth's primary heat sink and source of most evaporation and rain, much of the incident solar energy impacting this two dimensional water surface is absorbed and not all available for evaporation. This limits the relative effectiveness of the oceans in cooling the planet via fluxes of latent evaporated heat.

By contrast forests for example, often have leaf areas 10 times greater than their land area that can transpire far greater volumes of water, for longer, than evaporation from equivalent water surfaces. In so doing such forests can transfer much higher quantities of latent heat from the surface into the air to cool that surface.

However for forests and land vegetation to do this they need water that has to come from their soils.

This was not possible till 420 million years ago when first fungi and then plants extended over the bare land leaving behind organic detritus which formed soils. These soils enabled plants to colonize over 13 billion hectares of land greatly increasing the availability of water for evaporation as well as plant transpiration.

As these plants colonised and extended over this land they drew down many thousands of billion of tonnes of carbon from the air into these soils, forming 'soil carbon sponges'. As each extra gram of carbon could retain up to 8 grams of extra soil water, these 'sponges' radically changed the availability of water for plant growth.

In doing so soils fundamentally changed the Earth's hydrology. Instead of running off, 1 meter of rainwater could often be retained in these 'in soil reservoirs', feeding springs, wetlands, lakes and rivers and enabling productive bio-systems to transpire, grow and extend globally. This additional soil water and the bio-systems and extended transpiration that it enabled, further altered the Earth's heat dynamics, cooling and climate.

To a large extent these soil carbon sponges and bio-systems and hydrology that they enabled created and governed our relatively stable buffered Holocene climate. They also underpinned the sustained availability of 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, our climate, its ability to cool regions and sustain essential water, food, habitat and social needs.

It follows that if we are to restore our safe climate we must regenerate the processes that previously governed these former bio-systems, their hydrology, heat dynamics, cooling and safe climate. As nature did, we can only do this by regenerating the Earth's soil carbon sponges so as to supply the water needed to regenerate these bio-systems and the cooling that our future depends on.

To do that we must restore the capacity of our residual bio-systems to sustain plant growth so as to draw down carbon from the air back into our soil carbon sponges.

Innovative land managers are doing this, 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 innovations so as 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 the regeneration of natural hydrological processes can safely cool climates. How to:

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

Depending on where you are, from 0 to 60% of the incident solar energy reaching the Earth is returned from that surface back into the atmosphere as fluxes of latent heat as water is either evaporated or transpired from that surface. Globally on average 24% of the energy reaching the earth is re-transferred via these fluxes.

These fluxes of latent heat contain the energy that is needed to turn that water from its liquid surface state into its gaseous water vapour phase. Depending on initial water temperature close to 600 calories of heat may be needed for each gram of water to be evaporated or transpired from that surface. As this heat has to come from that environment, it naturally cools that habitat as that heat is transferred into the air via these fluxes.

While this latent heat is re-released when that water vapour re-condenses to form clouds, this occurs in the air with much of it being dissipated back out to space. As such it cools the surface it came from and the planet.

These fluxes of latent heat naturally cooled the oceans, land surfaces but particularly well vegetated regions. Tropical forests can be 15^{o}C cooler than adjacent cleared areas due largely to their different latent heat fluxes. Forested urban areas in Canberra on hot days can be up to 7^{o}C cooler than nearby urban areas without trees.

While the absorption of solar energy by the oceans and its re-release as latent heat fluxes via the evaporation of water has been critical for billions of years in regulating the global climate, this has not changed greatly. However the balance between the absorption and return of heat via such transpired latent heat fluxes has changed markedly on land and contributed significantly to its warming, aridification and climate extremes.

By clearing some 75% of the Earth's primary forests, oxidising most of its soils and creating over 5 bha of man made desert and wasteland, humans have significantly impaired the Earth's former natural transpiration rate and capacity. These reduced cooling latent heat fluxes have significantly warmed many surface environments.

Conversely by regenerating green vegetated landscapes we can restore these cooling latent heat fluxes to rapidly and safely cool regions. This can be done readily by regenerating urban and rural shelterwoods whose wind exposed leaf areas may be 10 times greater than the area on which they are growing and are able to transpire water and cool regions more than by evaporating water from a two dimensional surface.

Consequently despite the Earth's natural, and now residual, forest area being much smaller than its oceans, the regeneration of such shelterwoods must be a key priority if we are to safely cool regions and our climate.

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

Thus the extent, effectiveness and longevity of the cooling latent heat fluxes also depend on the water status of our soils and the ability of their soil carbon sponges and 'in-soil reservoirs' to hold and supply that water. As we degrade these soil carbon sponges and 'in-soil reservoirs' via our land management they cannot now hold and sustain the plant water supplies needed to sustain the former cooling latent heat fluxes. This applies particularly to the large increase in our degraded regions with less reliable rain much of which may run off.

It follows that we need to regenerate these natural soil carbon sponges and 'in soil reservoirs' so as 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 heat cooling effects that naturally regulated our former safe climate.

How the regeneration of natural hydrological processes can safely cool climates. How to:

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

Every day an average of 342 watts of solar energy enters each per square meter of the Earth's troposphere. Every day throughout its 4 billion years the Earth has re-transmitted equivalent heat back out to space so as to regulate and maintain its stable temperature and climate.

The Earth has done this partly by reflecting from 0-250 w/m2 of this incident energy directly back out to space via dense clouds with high albedo that naturally covered 50% of its surface area (# 7). Up to 70w/m2 of this solar energy may also be absorbed by humid haze micro-droplets in the air resulting in global dimming (#4).

However even with these cloud and dimming effects large areas of the Earth's surface may still receive up to 300 w/m2 of incident energy.

Most of this incident energy is absorbed by the oceans to either heat the water and/or enhance evaporation (#2). The energy incident on land is either; reflected, used in evaporation or transpiration or absorbed by soils.

What happens to this incident energy on land can profoundly influence the Earth's bio-systems and climate.

Areas with light coloured perennial ground cover such as snow and ice may reflect 90% of this heat back to space, while light or glaucous vegetation and litters may reflect up to 40% of it. Dark green vegetation may reflect much less absorbing up to 90% of this energy. This may be needed and advantageous in high latitudes or where there is abundant soil water to sustain transpiration and latent heat fluxes that can transfer up to 200 w/m2 of it into the air without leading to the heating of soils.

What is critical in sustaining healthy bio-systems and our stable climate, but not widely recognized, is to limit the excessive heating of soils. Bare dry exposed soils often absorb over 90% of the incident solar energy. Without cooling heat fluxes the temperature of such exposed soil can reach 60°C on hot days.

Any heating of soil above 30 °C can have profound adverse effects on the microbial health, hydrology and nutrient dynamics and thus their bio-productivity. This can have major adverse climate implications (# 5).

Conversely shading and insulating soils, via plant and litter covers can keep them cooler, ideally below 20 °C even on hot days. This can significantly reduce both the natural and human induced greenhouse effect (# 5).

The protection of soil surfaces by perennial vegetation can also greatly reduces their vulnerability to erosion by wind and water. Erosion from rain splash and sheet runoff may be minimal on covered soils where rain can infiltrate into organic soil sponges and in soil reservoirs. However, our clearing of vegetation, soil degradation and annual crops often expose soils to long bare periods, greatly increasing runoff and erosion rates and risks. The destruction of vegetation covers also increases the exposure of soil surface to wind and desiccation stress.

Similarly while soil fungi can aid the aggregation and stability of soils to wind erosion, dry bare soils without such fungi and aggregates often rapidly desiccate and erode, producing vast could of fine dust aerosols (# 4). 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 topsoil and thus available nutrients and soil carbon via such erosion. We now often have to farm residual sub-soils in a far more aridifying environment.

While not an obvious factor in the heat dynamics of the blue planet, how we manage our soils is important as it directly influences many of these more dominant other hydrological processes. It is also fundamental as it is the variable that we directly control at grass roots farmer and community level and on every square meter of our finite global soil resource.

How the regeneration of natural hydrological processes can safely cool climates. How to:

4. Limit dust levels and the formation of water micro-droplets in the air that absorb solar radiation.

Of the 342 watts per square meter of incident solar radiation that enters the Earth's troposphere each day up to 70 w/m2 may be absorbed by water micro-droplets in the air. These naturally warm the air and climate.

The level of, and warming by, these water micro-droplets has increased significantly over the past decades as evidenced by 'global dimming', and the 15-20% reduction in solar energy reaching many land surfaces.

Given their beneficial cooling latent heat fluxes (#2), we may not want or be able to limit the vast quantity of water vapour that is evaporated and transpired daily into the air. However, can we limit the recent abnormal increase in and persistence of these haze micro-droplets so as to reduce their contribution to global warming?

This warming can result from two sequential processes. First by the liquid micro-droplets absorbing incident solar radiation and as they evaporate by the resultant water vapour absorbing re-radiated infra red energy from the earth in the dominant water vapour component of the natural and enhanced greenhouse effect.

The formation, level and retention of these micro-droplets is governed largely by the presence of two types of aerosol nuclei.

The first are small (less than 0.2 microns) micro-nuclei that are formed naturally by plants and algae from a range of volatile compounds. These are naturally abundant particularly in marine and forest air and form persistent humid hazes of liquid water micro-droplets. Because of their small size and electrostatic charge, these micro-droplets may stay suspended as they are too light to fall out of the air under gravity as rain

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 is critical in maintaining the Earth's humid atmosphere and its ability to absorb solar radiation. Together with the natural greenhouse effect; these hazes have helped maintain the Earth's temperature at some 33^{o}C above base levels, enabling the Earth to sustain liquid water, its hydrological heat dynamics and for life to evolve.

Humans have greatly increased the addition of these micro-nuclei to the air; via the 3-5 billion tonnes of fine dust aerosols that are added annually due to our land degradation and desertification. Billions of tonnes of carbon and pollution particulates are also added from our burning of 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' over large regions as well as the warming of the air and a reduction in the rainfall of up to 30%. Where they form acid rain this has further degraded bio-systems and their capacity to bio-sequester carbon. These increased humid hazes 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 the additional haze and pollutant micro-nuclei. Most importantly we need to re-vegetate and cover bare soils so as to limit our increased dust emissions and production of these haze micro-nuclei. We also need to filter particulate emissions from industry and fuel use.

We can also limit their effect by naturally removing these humid hazes; and thus their warming and aridifying effects from the air. This involves restoring a second group of precipitation nuclei that naturally coalesce millions of these haze micro-droplets into larger cloud and then raindrops and then precipitate them from the air as rain. The microbial ecology of this process, which also induces cooling clouds and rain, is discussed in #7.

How the regeneration of natural hydrological processes can safely cool climates. How to:

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

All incident solar radiation that is not absorbed by these humid hazes, reflected by cloud or surface albedos or transferred back into the air by latent heat fluxes will normally be absorbed by the soil surface and warm it. This heat will then be re-radiated back into the air, not as the short wave radiation but as infra red heat.

The amount of heat re-radiated from a soil, or any ‘black body’ is governed by physical laws that dictate this is related to the 4^{th} power of its temperature. Thus a soil at a higher temperature will re-radiate vastly more infra-red energy relative to what that same soil would if it was cooler.

This is fundamental as the magnitude of the natural and enhanced greenhouse effect depends 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 gas molecules present in that air.

To date our climate change policies and planned responses have focused largely on the warming effect from the abnormal rise in the concentration of a minor greenhouse gas, CO_2, from 300 to 400 ppm this century.

In doing so, we have largely ignored the independent role that changes to water vapour concentrations, that may be up to 50,000 ppm and may govern 60% of the natural greenhouse gas effect, may have had.

More fundamentally, we have also ignored the factors that govern how much infra red heat is re-radiated from the Earth back into the air, even though this determines the size of, and drives the Earth’s greenhouse effect. In doing so we have ignored the simple scientific and practical reality that by keeping soil surface cool we can;

Effectively ‘turn down the re-radiation of heat’ that drives the natural and enhanced greenhouse effect.

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

As it will take centuries to return atmospheric CO_2 back to pre-industrial levels and given that dangerous climate extremes well before then risk collapsing our bio-systems, economies and capacity to avoid such meltdowns, we need to critically consider these options to safely cool our climate, urgently.

By limiting how much solar radiation is absorbed by our soils, we can reduce soil temperature by up to 40^{o}C over vast areas; thereby greatly reducing the infra red heat being re-radiated from the earth. As this drives and governs the size of our enhanced greenhouse effect we can effectively ‘turn it down’ by keeping soils cool.

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 CO_2 in the atmosphere and its minor contribution to the natural and abnormal human induced gas component of the greenhouse effect. Certainly we must draw down carbon from the air back into our soils so as to restore the Earth’s soil carbon sponges, rainfall retention, hydrological cooling and to restore our essential productive bio-systems.

These natural soil and hydrological processes have been responsible for maintaining the balance between the natural greenhouse effect and the offsetting hydrological cooling effects for some 4 billion years. Given our climate crisis we need to critically examine how these same processes and balances can used to restore and secure our safe climate. We have no other viable option to secure either our safe climate or future.

How the regeneration of natural hydrological processes can safely cool climates. How to:

6-7. Coalesce the warming hazes of micro-droplets into clouds with enhanced albedo and cooling effects.

As outlined in #2 and #4 above vast quantities of water vapour are transpired or evaporated into the air daily. Up to 50,000 ppm of water may be in the air either as water vapour or liquid micro-droplets at any one time. The quantity and length of time this water is retained in the air depends on the level of micro-nuclei in that air and their production via natural aerosols or by our eroded dust, pollutants or particulate emissions.

As the 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 hazes and pollutant smogs. These hazes and smogs warm the atmosphere by absorbing solar radiation while in their liquid phase causing them to evaporate and further warm the air by absorbing re-radiated infra red heat while in their gaseous phase.

While the latter is the dominant water vapour component of the natural and enhanced greenhouse effect both of these heating processes contribute to the recent abnormal warming and increased climate extremes.

These persistent humid hazes have also contributed to the aridification of large regions via 'humid droughts'. These are caused by the inability of the charged micro-droplets to coalesce and then precipitate from the air and result in the persistent high humidity but reduced rainfalls of up to 30% recorded in many regions.

Clearly we need to try to reduce these warming drying hazes by restoring the former processes that did this. 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 must be overcome by stronger hygroscopic forces. Natural precipitation nuclei; primarily ice crystals, specific salts and certain highly hygroscopic bacteria can do this and 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 form dense clouds with high albedo that reflect more of the incident solar radiation back out to space. Such clouds naturally covered 50% of the planet and reflected on average 120 w/m2 of solar radiation back out to space. However the extent, duration, reflectivity and thus these cooling effects have declined suggesting that we have impeded the effectiveness of these microbial precipitation nuclei in coalescing and removing these hazes.

Our clearing and warming of over 50% of the land surface has certainly increased the re-radiation of heat into the atmosphere and impeded the formation and effectiveness of the ice nuclei. Our clearing 75% of the Earth's primary forests 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, their ability to reflect solar radiation back out to space and with lower rainfalls at regional, continental and global levels.

While much scientific evidence substantiates this understanding, there is still much detail that we don't know. However we need to understand and restore these natural hydrological cooling processes, particularly what governs the natural production of the microbial precipitation nuclei, their cloud cooling and rainfall induction?

Understanding and regenerating the natural biological and hydrological processes that have governed the Earth's heat dynamics and climate for some 4 billion years must not be seen as geo-engineering, but rather as the simple restoration of the former natural processes and balances that regulated our stable climate. None of the natural regeneration actions being examined involve other than restoring the processes that operated safely in nature but which we have impaired; and now need to restore to secure our safe climate.

How the regeneration of natural hydrological processes can safely cool climates. How to:

8. Aid the nucleation of raindrops and rainfalls to sustain the Earth's hydrology and heat dynamics

We need to not just remove the warming humid haze micro-droplets from the air but in doing so to coalesce them into dense high albedo clouds that can help to cool the planet and then even larger droplets and rain.

This rain is 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 all life and our climate, rain cannot occur at will but only if specific hygroscopic agents and processes are present to coalesce the millions of small haze micro-droplets into cloud and then raindrops large and heavy enough to fall from the air under gravity. Understanding these agents and processes matters.

This includes better understanding 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 understand how the balance between these two opposing nucleation processes and their respective hydrological warming and cooling effects may have governed the Earth's heat dynamics and climate over the past 4 billion years. If so, what has been the effect of our 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 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 so as to restore our safe climate?

While the Earth's climate may initially have been based on physical processes, these haze and precipitation nuclei processes have increasingly become governed by biological agents; to the point where microbes may now regulate both the formation of haze aerosols and the hygroscopic bio-chemicals that coalesce many of the haze micro-droplets into raindrops and rain.

If so what do we need to know about these symbiotic microbial processes and feedbacks to practically and safely cool the planet in time to offset the pending dangerous climate extremes and their consequences?

How the regeneration of natural hydrological processes can safely cool climates. How to:

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

Many regions, particularly in the humid tropics, formerly had regular storms late each day that removed most of the warming humid hazes micro-droplets from the air. In effect this rain 're-opened' night time radiation windows allowing infra red heat to be re-radiated back out to space instead of being trapped by the hazes.

These regular late afternoon storms not only cooled these regions but also restored the soil water needed for our needs but more importantly for transpiration and its cooling latent heat fluxes the next day.

These late afternoon storms are now less frequent in many regions, often resulting in the systemic aridification and warming of these bio-systems.

As CO2 concentrations do not vary from day to night and given that the re-radiation of the infra red heat driving the greenhouse effect would be at its maximum each day in line with the surface temperature, the CO2 component of the greenhouse warming effect can be expected to be greatest during each day, not night.

In contrast to CO2, the water vapour content of the atmosphere, and thus its component of the greenhouse effect may vary widely each day; particularly where it may be removed each night as temperatures decline and the water vapour is condensed onto haze micro-droplets or dew on cool surfaces and removed as rain.

However where this condensation and/or removal of this water is impaired due to sustained higher night time temperatures, the availability of excessive haze micro-nuclei or the lack of hygroscopic precipitation nuclei, night time humidity may remain high, blocking most of the re-radiation of infra red heat from these sites. This would effectively close the night time radiation windows that had previously enabled this heat to escape.

The data on our recent abnormal global warming indicates that over 60% of the current 1^{o}C or 3w/m2 mean temperature rise can be attributed to a systemic global increase in night time minimum temperatures rather than a marked increase in day time maxima, as should be expected if CO2 was the key factor causing warming.

There is also no evidence that the reduction or draw down of carbon emissions would be effective in reversing the observed night time warming or in re-opening these radiation windows. Due to ocean lag and re-equilibration effects It may now be far too late for any such actions to be adequate or effective.

This indicates that much of the rise in night time temperatures attributed to the abnormal greenhouse effect may indeed be associated with hydrological dynamics of these climates and how we have impaired them. As such we may be able to safely restore these heat dynamics and climate balances by restoring these natural hydrological processes.

It may even be possible to rapidly and safely 're-open' these night time radiation windows by simply restoring the natural production of the hygroscopic precipitation nuclei needed to coalesce the warming humid haze micro-droplets into raindrops, as occurred naturally in the previous regular late afternoon rain storms.

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 CO_2 levels and its warming in time, we may be able to restore the Earth's natural hydrological and heat dynamics to offset this effect and cool the climate.

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

How the regeneration of natural hydrological processes can safely cool climates. How to:

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

The hydrological processes outlined above may operate not just at molecular and regional scales but also influence the climate and rainfalls at continental levels.

As global warming intensifies evaporation and thus rainfalls should increase, but not necessarily everywhere. This rainfall may also be more intense and unpredictable, destroying water supplies and critical bio-systems.

The increase in humid hazes may decrease rainfalls and aridify many regions. Large areas of dry degraded land will further heat up and desiccate, re-radiating vast quantities of heat and dust into the air that will intensify the greenhouse effect and climate extremes.

As these climate effects also increase the density and kinetic energy of gas molecules in their air they will mostly raise air pressure above these regions. As air normally flows from zones of high to low pressure this may result in outflows of air from above hot humid high pressure zones and block inflows of cooler moist air from zones of lower pressure.

At continental scales this can block moist monsoonal inflows, progressively aridifying these regions. The aridification of Australia and north Africa from 6000 years ago may have been linked to such rainfall changes.

Conversely regions, such as the Amazon basin, by creating its own low air pressure zones via its condensation of its massive latent heat fluxes may be inducing massive inflows of more cool moist marine air and thus rain.

Such natural pressure effects and feedbacks may have enabled the formation of rainforests, even on marginal soils, that would be more arid without these inflows. Once formed such rainforests may reinforce further cooling and lower air pressure via their latent heat fluxes, cooler soils, reduced heat re-radiation, cloud albedo and radiation windows.

Impairing the latent heat fluxes in these forests may limit these humid inflows and aridify these regions.

This contrast in the hydrology of bio-systems under different air pressures may help to explain the processes that create either semi-arid wasteland or verdant cool moist forest under high and low pressures respectively. Can we by managing these processes help to regenerate cooler moist bio-systems so as to cool the climate?

Could the natural process of hygroscopically coalescing the high pressure humid hazes into cloud and then rain, help to create the low pressure needed to trigger; moister, cooler and more bio-productive landscapes?

Can enhancing these hygroscopic microbial precipitation nuclei help induce such contrasting bio-systems?

While the removal of forests may be associated with the decreased production of these precipitation nuclei and the marked decline in the rainfall and aridification of regions and while the restoration of forests and such nucleation processes are associated with the restoration of regional rainfalls there is more we need to know.

We need to better understand how we can enhance these natural rainfall nucleation and hydrological processes to help to safely rehydrate, cool and re-vegetate vast areas of our degraded semi arid landscape.

While different from our status quo understanding from our climate models and assumptions we need to be prepared to critically evaluate all the evidence relevant to understanding this hydrological basis of our climate crisis; given that it may now be our only means to safely cool and avoid its consequences, hopefully in time.