C. Can we rehydrate landscapes to limit 'droughts' via practical soil regeneration processes?

The former analyses confirm how Australia's climate, rainfall and 'droughts' have and are changing. How this is linked to our land management and how such links have been ignored on the excuse that the systemic aridification of many regions are just symptoms of another temporary 'drought'. That there is nothing we have done or can do to change this; beyond pray that it will rain again, soon.

The analyses outline the various physical and biological processes that govern our rainfall and how our land management influences these directly to cause the observed systemic aridification, climate changes and increased 'droughts'. Indeed they confirm that the natural microbial processes that govern the regeneration of soils, their hydrology and the nucleation of humid hazes and rain account for much of our natural rainfall, climate and aridity. Furthermore that our changes to these processes via our land management can readily account for their recent abnormal changes including the warming, aridification and increased droughts in many regions.

This understanding of how key biological processes drive much of our hydrology and climate raise the prospect that we can use this knowledge to regenerate bio-systems, these processes and our former more stable rainfalls and climate. That we may be able to regenerate natural processes so as to reduce our increasing rainfall uncertainty and limit unexpected and acute 'droughts'.

Given that this is a radical proposition, the following analyses examines the evidence from history, science and leading field studies that confirm that we can indeed influence these climate processes via our wise land regeneration and thus help to rehydrate regions and limit the climate extremes and changes. The analyses examine each of these natural hydrological processes that govern 95% of the heat dynamics of the blue planet and how we have and can practically regenerate them in time.

1.Our practical options to restore the infiltration of rain into the Earth's soil carbon sponge.

Water has been fundamental in regulating the heat dynamics and climate of the blue planet for over 4 billion years. However to do this it must be available. On land, this water mostly comes from rain that has to be stored in soils so it is available to plants to enable these heat dynamics to function.

For rainfall to be available for the hydrological cycle that regulates the Earth's heat dynamics and climate it first needs to infiltrate into soils. Whether soil water is available or runs off back to the sea in erosive flood flows is governed by the soil's rainfall infiltration capacity or 'sponginess'. Healthy well structured soils mostly infiltrate over 90% of rainfalls while compacted degraded soils often infiltrate and retain under 10% of rainfalls; thereby accentuating their aridification and 'droughts'.

As such the structure of soil is a key determinant of a landscape's hydrology, health and climate. The structure of soils in turn is governed by how much organic carbon has been bio-sequestered into them by microbial processes that convert plant detritus and root exudates into stable soil carbon. The activity of these microbes thus often determines the carbon content, structure, hydrology and health of soils, their bio-productivity, resilience and key elements of their rainfall and climate.

Just as nature has done for 420 million years, soil formation, pedogenesis, is largely driven by fungi that convert plant carbon into humates and glomalin and sequester them into the mineral detritus from weathered rocks to create a loose open matrix of well structured healthy soil as a 'sponge'.

These soil sponges helped rain to infiltrate and made water available for plants and bio-systems to evolve and extend over the Earth's ice free land. The transpiration of that water by plants and its microbial nucleation in turn enabled Earth to balance its opposing warming via greenhouse hazes with the cooling effects from this transpiration, cloud formation and rain to regulate the climate. Our management of our soil structures and their hydrology similarly govern our future climate.

So what was the status of our historical soil structures and their rainfall infiltration capacities?

Australia's first peoples are known to have actively managed the landscape over their 60,000 years via a range of ecological grazing, food plant enrichment and 'fire stick' farming practices. These limited hot wildfires that would otherwise oxidize carbon from the soils and collapse soil structures. As a result the first European explorers in the 19th century consistently recorded the soils to be' soft deep well structured organic moulds' as confirmed in scientific carbon analyses since then (CSIRO).

These 'soft' well structured soils would have infiltrated most rainfall as evidenced by the dominance of minor surface streams and springs that drained into chain of ponds, swamps and inland deltas and the then rare deep incised erosion gullies. As most inland rainfall infiltrated the soil, and was used by the natural vegetation there were no fast flowing rivers draining to the sea with most being a series of calm water 'reaches' between shoals of sediment. Via these practices Australia's original land stewards sustained vast areas as productive well watered open grassy shelterwoods that were then used to establish Australia's sheep grazing and export industry and economy.

The evidence from pollen analyses, the extent and productivity of these grasslands and the large populations they sustained indicates that while rainfalls were variable, water was mostly available from these 'in soil reservoirs' to sustain the longevity of green plant growth with fewer 'droughts'. Much of the higher productivity and higher buffering of drought stresses in these former landscapes is likely to have been due to the much more extensive and deeper well structured soils.

Given this evidence, what have we done to our soil structures and their water holding capacities?

Detailed pioneer accounts confirm that within decades our overgrazing of these grasslands in dry periods resulted in; bare soils, the oxidation of soil carbon and their structural collapse. As the soil could no longer infiltrate rain much of it ran off to erode soils, litter and incise gullies in streams.

As water tables fell to the base of these deep gullies the perched former floodplains aridified and degraded. The microbial processes that had aggregated and aided the stability of soils also declined leading to the loss topsoil from wind erosion over vast areas. As the residual poorly structured bare sub-soils could not infiltrate as much rain when it fell and heated up dramatically they would have further declined in productivity increasing their vulnerability to, and intensification of, droughts.

While efforts sought to rectify this widespread acknowledged soil degradation, the investments in protective annual pastures, earthworks, cultivation, fertilizers and irrigation have often failed, as the shallow rooted 'improved' pastures fostered by this are far more prone to drought in dry periods than the former deep rooted native perennial grasses and trees more resilient to drought stresses.

Our overstocking of these 'improved pastures' has also accentuated soil declines as has the increase in soil cultivated for crops. As a result over half of Australia's residual agricultural sub-soils are now structurally degraded enabling them to infiltrate and retain perhaps 20% of their former rainfalls. Their aridification and compaction restricts root growth and their vulnerability to drought.

Given this reality has our soil and hydrological degradation contributed to aridifing our climate?

As detailed in the initial analysis, Australia's widespread structural degradation of its soils and thus hydrology has contributed greatly to its warming, the induction of dangerous climate extremes and its systemic aridification. While global warming has increased evaporation from the oceans and thus total rainfall, what matters is when, where and how that rain falls. More intense cyclones and rain in some or new locations may not be helpful. The variability and reliability of that rain is often critical to grow and finish crops. 'Droughts' may occur where these crop needs are not met, even if it rains.

As such it is we that often create and intensify our 'droughts' by degrading the natural resilience of bio-systems or fostering vulnerable crop and animal landuses that are incompatible with our now degraded, aridified and more variable extreme climate and rainfall conditions that we have induced.

While dry periods have and will continue to occur with increasing irregularity and intensity, the issue is how vulnerable our agricultural systems are to these new induced climate realities and droughts? Given that we are responsible for the induction of these new dryer conditions and responsible whether we can adapt to and survive them, the issue is how can we make ourselves response able? What can we learn from nature and our degradation of our bio-systems to reverse this urgently?

Can we regenerate these soils so as to help restore these hydrological processes and our climate?

Leading land managers in Australia and globally confirm that they can readily improve the structure of our soils and how this can rapidly improve the rainfall infiltration and resilience to help buffer and survive their inevitable increasing systemic aridification, climate extremes and droughts.

These leading land managers similarly confirm how we can do this practically and in time, as nature has done repeatedly over 420 million years by restoring the microbial processes that govern the accelerated bio-sequestration of carbon from plant biomass back into these soils to regenerate the Earth's soil carbon sponge.

A wide range of simple natural soil and compost management practices can aid this including;

- Limiting the cultivation and over-fertilization of soils that disturbs soil structures.
- Limiting the bare fallowing of cropped soils without plant roots to sustain structures.
- Allowing the existing plant roots to grow for longer and deeper.
- Enhancing perennial plants with higher root shoot ratios or deeper root penetration.
- Avoiding the burning or removal of plant litter and aiding its microbial incorporation.
- Creating surface litter traps and its breakdown in them to create water infiltration zones.
- Mulching soils to limit their aridification and the oxidation of surface organic matter.
- Incorporating composts by placing them on or working them into the soil surface.
- In compacted or hardpan soils carefully coring them to aid infiltration and their aeration.
- The careful use of sub soil rippers with following plant and compost treatments.

Local experiences and materials can help in defining the most relevant practices for each situation, with every gram of carbon incorporated into the soil aiding its structure and infiltration significantly.

2.The retention of rainfall in the Earth's 'in soil reservoirs', inland deltas and sub-soil aquifers.

While the blue planet has abundant water, 97% of it is in salty oceans and 2% is locked up as ice. While less than 1% of the Earth's water cycles through soils, plants and the atmosphere this governs over 95% of the heat dynamics and thus climate of the blue planet. As we influence what happens to this water via our land management, we also influence the Earth's heat balance and thus climate.

As nature did 420 million years as it evolved the terrestrial soils, hydrology and bio-systems; we now govern how much water is in this hydrological cycle, in which form and for how long; largely via our capacity to influence the infiltration, storage and transpiration of that water from the Earth's soils.

Our management of our soils governs how much water is available to sustain the longevity of green growth, transpiration and its cooling latent heat fluxes. Our management of soils similarly governs our emission of dust and microbial haze micro-nuclei that govern how much water stays in the air and for how long to produce the humid hazes that both warm and aridify regional climates. Our management of soil albedo and heat absorption governs how much infra red heat is re-radiated to drive the natural and enhanced greenhouse warming effects. Our management of our soils and forests govern the production of the natural ice and microbial precipitation nuclei that can transform the warming hazes into dense cooling clouds and then rain to sustain these hydrological cycles.

By influencing these soil and hydrological processes we now influence much of the natural balance between key determinants of the heat dynamics and thus future climate of the blue planet. Simply degrading the Earth's soil carbon sponge and 'in soil reservoirs' that make water available for these hydrological cycles can not just aridify regions but impair the natural hydrological dynamics that regulate much of the Earth's climate. Conversely by regenerating the Earth's soil carbon sponge and 'In soil reservoirs' we can rehydrate landscapes, restore these hydrological cycles and thereby buffer, cool and re-secure our former balanced climate, hopefully in time.

As in nature we can do this by regenerating the Earth's soil carbon sponge. By limiting our clearing, oxidation and degradation of soils and aid the regeneration of deep rooted perennial plants with high root shoot ratios to bio-sequester carbon back into these soils via the their symbiotic fungi.

As in nature we can do this practically, rapidly and at minimal cost as evidenced by case studies. For example the Dutch routinely accelerate the bio-conversion of anaerobic toxic sludge and silt from the Rhine into deep well structured organic polder soils of high productivity within just 10 years. Similarly the ecological grazing of rangelands in Australia has so improved the structure and in soil reservoir capacity of degraded soils within 20 years that their capacity to infiltrate and retain rainfalls and pasture growth now enables them to increase stocking rates by 300% and sustain these even during droughts relative to adjacent similar soils but under conventional grazing practices.

Lead farmers on marginal sandy soils in the northern WA wheatbelt by regenerating the structure, infiltration, water holding capacities of their in soil reservoirs now grow higher quality grain crops on as little as 150 mm/an of rain in contrast to adjacent conventional growers whose crops often fail to finish due to their vulnerability to the increasing aridification and drought stresses.

Whatever the rainfall, options exist for all farmers to improve the productivity, resilience and drought avoidance capacity of their crops and pastures by simply regenerating the structure, water holding and buffering capacity of their soils as functional deep additional 'in soil reservoirs'.

3.The use of deep rooted perennial plants to aid their access to soil water and drought survival.

For plants to survive they need not just soils that hold water but roots that can access that water. This is particularly critical for plants in arid regions and in droughts when water may be limited and only available from deep subsoils. As such the extent and depth of the plant's root system and the volume of soil it can access is often critical to the plant's ability to take up water and nutrients, particularly in dry times and its capacity to avoid, buffer and survive aridification and 'droughts'

Just as we can enhance the 'in soil reservoir' capacity of degraded soils by regenerating their carbon content and structure, this can also improve the aeration and shear strength of soils to foster root proliferation to depth and the resilience of those plants to aridification and drought stresses. This is often critical for plants colonizing seasonally arid regions that depend on high root/shoot ratios and deep sinker roots that can penetrate tens of meters into arid soils to access deep moist soil strata.

For example America's tall perennial prairie grasses often have root/shoot ratios of 10/1 to access soil water in seasonally dry and arid regions. This root biomass not only sustains photosynthesis by these grasslands but enables them to sequester large quantities of carbon into these soils to aid root proliferation, access to water and the productivity of this bio-system, despite drought stresses. Indeed these roots, by bio-sequestering carbon into these soils, helped convert the compacted waterlogged mineral outwash tills as the former ice sheet retreated into the highly productive well structured up to 6 metres deep organic soils that dominated these prairies.

The natural mycorrhizal soil-plant interfaces formed under these conditions can also often extend the uptake of water and nutrients from soil surfaces and films at water tensions well beyond those possible by just root hairs. This can assist mycorrhizal plants to build more extensive soil-plant interfaces and survive much better under drought conditions than non-mycorrhizal plants.

Innovative farmers are using combinations of ecological grazing, pasture cropping and mixed species cover cropping strategies to similarly optimize the colonization of soils by roots so as to form such extensive soil-microbial-root interfaces to depth to optimize water uptake and drought resilience.

This contrasts with many of our industrial crop plants that are selected based on their often very low root shoot ratios of 1/10 to maximize shoot yields but are thus highly dependent on irrigation and fertilizer inputs and extremely vulnerable to drought stresses if these inputs are not available.

Leading case studies confirm the effectiveness and potential of such root regeneration strategies.

For example the extension of ecological grazing strategies to restore the structure, hydrology and root proliferation in soils to depth over half of Australia's rural and semi arid rangelands would help to extend the longevity of green growth, resilience, productivity and further natural regeneration of these soils and bio-systems and their capacity to avoid, buffer and survive drought stresses.

Clearly the natural vegetation that has survived for millions of years in arid, drought prone regions, such as Australia inland has done so by evolving very efficient systems to maximize their access to and use of the often limited supplies of water. By understanding the processes that have evolved to do this and using them wisely we should be able to regenerate drought resilient bio-systems that can help meet our future food and resource needs and help restore their hydrology and climate.

4.Can we enhance the longevity of green growth and transpiration by regenerating plants?

After 50 years of warning the reality that we have locked in global warming and increased dangerous climate extremes, including the aridification and droughts in many regions is now inescapable. To limit their impacts we may need to urgently;

1. Maximize the resilience of residual bio-systems to survive such aridification and extremes.
2. Regenerate drought resilient bio-systems to help buffer and secure our essential needs.
3. Regenerate the natural processes that can offset this warming and limit climate extremes.

Given that these climate extremes are all governed by or impact via hydrological processes, priority needs to be given to restoring the key processes that we may have impaired to help avoid, buffer, adapt to and mitigate these extremes and help re-secure our former more stable safe climate.

Fortunately, as in nature, we should be able to address each of these urgent imperatives by simply extending **the longevity of green growth** within the Earth's residual vegetation. As detailed above this should enable the Earth's landscape and atmospheric hydrology that governs 95% of the heat dynamics and climate of the blue plant to re-balance itself to help cool and re-stabilize the climate.

To restore this longevity of green growth we need to ensure that the plants have access to adequate water and nutrients which, as in nature we can do by **regenerating the Earth's soil carbon sponge**.

Leading case studies all demonstrate how practical land management action can help plants to draw down more carbon from the air back into soils to help regenerate soil structures and via that their; rainfall infiltration, its retention in in soil reservoirs, the proliferation of root growth to depth, the increased availability of water from that soil and thereby the longevity of green plant growth.

The increased longevity of green growth can In turn; enhance the resilience of bio-systems to buffer and survive droughts and increase transpiration and thus the hydrological cooling of regions to help offset warming and climate extremes. By transpiring water from the soil into the air green plants transfer vast quantities of heat from the surface into the air and then out to space, to help cool it.

We can enhance this transpiration and the natural hydrological cooling of regions dramatically by simply extending the longevity of green growth of our residual and regenerating new bio-systems. As nature did in creating our cooler balanced climate, we too can do this by regenerating the Earth's soil carbon sponge wherever feasible as now our last chance to secure our safe climate and future.

5.Can we use shelterwoods to limit evaporation and water losses and reduce wind scour effects?

Currently over 90% of the rain that falls on our degraded soils may run off, with over 50% being lost by evaporation, particularly for bare wind exposed soils. Given that we must maximize the longevity of green transpiring plant growth to cool regions and offset our induced global warming and climate extremes, we need to limit this loss of soil water so that it can be used to sustain such transpiration.

The natural scattered shelterwood tree canopies were critical in limiting this loss of soil water via evaporation by greatly reducing the surface wind speeds and scouring that drove this evaporation.

The scattered open tree canopies are also important in shading soils and pastures, limiting water stresses and optimizing the growth of the trees and pastures particularly in drought periods.

The tree canopies and these shaded pastures provide nutritious food for herbivores that aided the cycling of nutrient and the productivity of these shelterwood savannas. Most importantly they also reduced fuel levels and the risk and intensity of wildfires that risked degrading such bio-systems.

Lead case studies confirm how the better hydrated soils under these ecological shelterwood and grazing strategies can improve the productivity of these commercial grazing operations. Pastures under such shelterwoods with reduced evaporation losses and stress retained more soil moisture and were able to sustain growth and cooling transpiration fluxes up to ten times longer than in adjacent exposed degraded sites. Such ecological shelterwood regeneration and grazing strategies in high risk arid rangelands retained more soil water and limited the spread and impacts of wildfires.

As in nature we can readily regenerate such shelterwoods and grazing ecologies across most of Australia’s currently degraded rangelands to limit their loss of water by evaporation, optimize their sustained transpiration, productivity and local cooling effects and reduce their increasing risk of further degradation by extreme wildfires arising from their systemic aridification.

6.Can we harvest water from humid air flows via plants and hygroscopic surfaces?

We currently assess how much water a region receives based on its rainfall, the sum of the water able to be measured in rain gauges at regional locations over time. These data indicate what climate zones, changes, deficiencies, ‘drought’ levels and operational responses may be needed. While often the ‘best available’ at a macro level there can be marked differences in the water may be received and its effectiveness and use at the micro-level that most directly influences plant productivities.

While how much rain a region receives matters, so too is the reality that vast quantities of water may flow over many regions most days as humid hazes, fog, mist and dew that is not recorded and thus not considered. This additional water and may be critical in arid regions or those in drought.

In fact unseen rivers of moisture flow continually over many regions, including deserts, as humid air flows. These may contain up to 5% water by weight but as they are not recorded they are often not considered or harvested as a resource. Despite this many natural arid bio-systems rely on such water to help sustain their resilience, productivity and ability to avoid and survive extreme droughts.

The foliage of many arid zone plants may be very efficient at condensing and harvesting such water. Plants in some extreme deserts may rely exclusively on water they can harvest via such processes. Up to 70% of the water needs of the Earth’s tallest forests in coastal California may be harvested by the specifically evolved redwood foliage from such fogs and mists flowing in from the north Pacific.

By understanding the processes involved we too can harvest additional water from such humid air flows over arid regions to aid their rehydration and regeneration. Leading case studies confirms that shelterwood and cover crops can harvest substantial water from such air flows to help them avoid droughts. Long term field studies confirm that these processes to help and sustain healthy moist rainforest bio-systems in sites that naturally only sustained much dryer xeric vegetation.

Just as nature develops ever better structured soils that can infiltrate and retain more water it has also developed foliage with hygroscopic surface structures and surfaces that can harvest water from humid air flows and thereby reinforce its resilience and productivity and change its micro-climate. As such many micro-climates may not be static and fixed by their geographical climate determinants but can either rehydrate to be more productive or aridify and degrade depending on their biological soil improvement and water harvesting processes, which our management influences significantly.

7.Can we use of vegetative covers to limit heat absorption and its re-radiation from soils?

Global warming to date has resulted in the air retaining on average 3 watts per square metre of extra heat that it had previously been able to naturally re-radiate back out to space. This abnormal increase in the Earth's greenhouse effect has resulted from human induced changes to;

1. The level of infra-red heat being re-radiated by the Earth's warmer soil surfaces.
2. The amount of this re-radiated heat that is being absorbed by greenhouse gases.
3. Changes in the concentration and longevity of these greenhouse gases in the air.

To date most scientific, policy and public focus has been on the fact that atmospheric carbon dioxide (CO_2) levels have risen abnormally by some 30% over the past 250 years and exponentially over the past 70 years linked to our increased CO_2 emissions from burning fossil fuels. As it is a greenhouse gas that at 410 ppm contributes some 20% to the absorption of heat re-radiated from the land surface it has been seen by many as the major cause of the Earth's abnormal greenhouse warming.

While water vapour is by far the dominant greenhouse gas as it can occur at up to 50,000 ppm and can contribute up to 60-70% of the heat absorption by greenhouse gases, unlike CO_2 its level in the atmosphere can varies widely naturally in time and space, with no evidence till recently that it had increased abnormally and thus be potentially responsible for the abnormal global warming.

However given that the greenhouse effect is governed by how much heat re-radiated by the Earth is absorbed by such gases, the amount of heat being re-radiation is also a key driver and determinant. Hence activities that increase the amount this re-radiated can also directly increase the greenhouse effect. Conversely activities that limit the heat re-radiated can decrease the greenhouse effect.

As the amount of heat being re-radiated from the Earth depends on the temperature of its surface factors that increase that temperature will increase this re-radiation of heat and its absorption by greenhouse gases. The Stefan Boltzman Law for all black body radiators dictates that the amount of heat re-radiated increases at the fourth power of the increase in temperature in degrees Kelvin.

This means that any increase in the Earth's surface temperature will result in a marked increase in its re-radiation of heat able to be absorbed by greenhouse gas molecules in the air till fully heated. Conversely cooling the Earth's surface will reduce this in re-radiation and the greenhouse effect, largely independent of the concentration of different greenhouse gas molecules in the air.

Whereas moist shaded soils insulated by vegetation rarely heat up to above 20 oC, similar but cleared bare desiccated soils will absorb most of their incident solar radiation and often heat up to over 60 oC. This bare degraded soil will re-radiate massively more heat than the shaded soil.

The hot bare soil will inevitably induce much higher greenhouse warming from the constant CO_2 molecular concentration but particularly if water vapour concentrations are high and persistent. Where the hot bare soil also emits dust micro-nuclei into the air that induce the formation of humid hazes this can significantly increase the level and persistence of humidity in the air and its dominant sustained greenhouse warming and dangerous humid heat effects. They also aridify such regions.

Our key priority to limit greenhouse warming and the aridification of landscapes is thus to limit the re-radiation of heat from soils as this drives and is the major variable to limit the greenhouse effect. We can do that by keeping soils cool. By covering and insulating soils by plants so as to limit their adsorption of incident solar radiation and thus its re-radiation. By keeping soils hydrated so they can sustain transpiring plants that cool soils via their transfer of latent heat from the soil into the air.

Long term demonstration sites confirm how such litter and plant protection and the hydration of soils can greatly reduce the temperature and avoid the aridification of soils relative to adjacent exposed sites that absorb more incident solar radiation, heat up, re-radiate it, aridify and desertify. Even on hot days soil temperatures in the protected and hydrated sites are often 15 oC below the ambient air temperatures and 30 oC cooler than in the adjacent bare exposed soils. While protected soils sustain moist rainforest habitats, the adjacent exposed site has formed a desert habitat.

Leading farmers confirm how similar soil protection and rehydration strategies can transform former dry sclerophyllous grasslands into cooler mesic shelterwoods habitats able to sustain productive palatable pastures for longer particularly under drought conditions. Only by extending such actions can we now hope to rehydrate, cool and offset the greenhouse warming of our habitats and future.

8.Can we limit wind erosion of soils to reduce aerosol nuclei levels and their humid haze effects?

Bare soils exposed to solar radiation and wind can desiccate and collapse structurally as they lose the extensive networks of fungal hyphae that had aggregated them while plants grew in them. Such degraded bare soils are highly susceptible to wind erosion often producing billions of very small dust particles that can act as micro-nuclei for water to condense and form billions of small charged and thus mutually repulsive humid haze micro-droplets.

These humid haze micro-droplets are far too small and light to fall out of the air under gravity or coalesce and instead stay in the air as persistent suspended hazes. The micro-droplets absorb up to 20% of the incident solar radiation while in the liquid phase as evidenced by global dimming. As they evaporate they further absorb re-radiated infra red heat from the Earth's surface as the principal gas driving the greenhouse effect. As they recondense at night back into hazes the latent heat they release further warms the night time air.

This accords with the data that global warming is due largely to rises in night time temperatures.

These triple warming effects from the increase in humid haze levels over many regions globally contribute not only to global warming and its hydrological climate extremes but also to the systemic aridification of regions via their warming effects and the impairment of former normal rainfalls.

Our widespread exposure and degradation of soils via our past and current industrial agriculture has to date created 5 billion hectares of man-made desert and wasteland across 40% of the land surface. This has resulted in many billions of extra tonnes of dust nuclei being emitted into the air every year.

Together with the particulates and volatiles emitted from our increased wildfires, the burning of fossil fuels and industrial pollution they readily account for the increase in the persistent warming and aridifying humid heat hazes that now blanket whole continents in summers. These pollutant humid heat hazes risk the physiological health of people living under them as they can no longer cool themselves via evaporation or perspiration. Unless addressed they create major urgent health risks.

We need to and can both minimize their abnormal production levels and remove them from the air. We can do the former by simply protecting soils from excessive exposures to sun and by ensuring that their microbial aggregation processes are not impaired.

As discussed below we can also safely and naturally remove them from the air by simply coalescing them first into larger cloud droplets and then even larger raindrops heavy enough to fall out of the air under gravity. In doing this we can naturally convert their triple warming effects into high albedo clouds that reflect incident solar radiation back out to space to cool the planet and minimize their former aridification effects. In doing so we can help restore the Earth's natural balance of juxtaposed heating and cooling processes to help safely restore our stable climate.

Leading case studies confirm that we can protect soils from such desiccation and wind erosion via strategic vegetation covers and wise management practices. These additional hydrological and climate benefits will be critical if we are to secure our safe climate and future in time.

9.Can we enhance the formation of ice and microbial precipitation nuclei to induce more rain?

Our increased emission of haze aerosols above natural levels in the past century has clearly vastly increased the level and persistence of humid hazes in the atmosphere over extensive areas globally.

If not removed these hazes contribute significantly to the dominant water vapour greenhouse gas effect and the warming and aridification of their underlying regions. They now also pose major risks to human health where humid heat levels in summer exceed our physiological cooling capabilities.

While humid hazes have occurr naturally, their warming effects were always offset and balanced by precipitation processes that coalesced millions of haze micro-droplets into larger cloud droplets and dense clouds that reflect incident solar heat out to space to cool regions. As cloud droplets coalesce into raindrops they remove the hazes from the air and rehydrate the former aridified regions.

It is this balance between the greenhouse warming effect of these humid hazes and the processes that transform these hazes into cooling clouds that has regulated the Earth's elevated temperature yet largely stable climate for over the past 3 billion years. Increasingly this natural balance has been regulated by the evolution and production of two types of microbial nuclei. These are;

1. The small **haze nuclei** such as di-metyl sulphide and terpenes produced by biota which along with dust and carbon particulates govern the production of humid hazes and warming, and
2. The larger hygroscopic ice, salt and bacterial **precipitation nuclei** that can overcome charges to coalesce the haze droplets into cloud and then raindrops to remove them from the air.

While the ice and salt precipitation nuclei dominate in nucleating clouds and rain in high latitudes, altitudes and over the oceans, by far the most hygroscopic and effective nuclei are specific bacteria produced in and transpired from the stomatal cavity of some trees. These nucleate much of the cloud and rain over inland and tropical regions that dominate the Earth's heat dynamics and climate.

Our management of the Earth's residual forests directly influences these processes and our rainfall. Given that we have cleared 70% of the Earth's primary forests (UNEP) it is of no surprise that this is consistently associated with the subsequent decline in local rainfall and aridification of those areas and increased persistent humid hazes that intensify greenhouse warming and aridification effects.

Numerous case studies, some centuries old, confirm that we can restore rainfalls and rehydrate aridified regions by regenerating forests producing such microbial precipitation nuclei.

These processes are also directly implicated in many such re-forestation-rainfall associations globally such as the Rabbit proof fence and shelterwood regeneration cases described previously above.

While there is more to know, we can potentially use these processes to again precipitate some of the water in the 'aerial rivers' that still flow over many of the Earth's 5 billion hectares of man-made desert and wasteland to rehydrate and regenerate these areas and safely reduce the dangerous warming humid hazes that now threaten our health, climate and stable future.

10.Can we limit wildfires, the oxidation of plant carbon and its particulate aerosol effects?

As global warming and aridification effects intensify vast formerly 'safe' regions will be impacted by dangerous climate extremes including storms, floods, droughts and wildfires in our residual habitats.

Even now some 300-400 million hectares, or 10% of the Earth's residual forests, burn annually to emit from 20-200 tonnes of carbon per hectare as CO_2 into the air. Globally 2 billion hectares or 30% of our grass and crop lands also burn annually to emit 3-10 tC/ha as extra CO_2. These CO_2 emissions exceed and are additional to our 10 btC/an we emit globally as CO_2 from our burning of fossil fuels. As they are deemed 'natural' nations do not account for their emissions from forest or grass fires.

In addition to their CO_2 emissions these fires also emit vast quantities of carbon particulates, dust and organic volatiles that act as humid haze nuclei to intensify local warming, aridity and pollution.

While wildfires are a natural periodic factor in the ecology of some bio-systems, their increased intensity and impacts far the capacity of most to regenerate fully after them. This risks the accelerated desertification and collapse of many residual bio-systems and regions within the next decades with profound, ecological, climate, economic and social impacts.

It follows that we need to take responsibility for this reality and its consequences in our existential self interest. As in nature we can do this by ensuring that fire fuels and micro-climatic conditions limit rather than intensify these fire risks.

For the past 400 million years every gram of biomass that has been grown on land has either been burnt or oxidized back into the CO_2 and solar energy used to make it or else been bio-sequestered by specific fungi into stable soil carbon. While the former mostly dictates the desertification of those bio-systems; the latter mostly ensures that the soil can infiltrate and retain more rain water and thus sustain a moister more productive, resilient and far less fire prone bio-system.

As in nature we have a choice between 'fire or fungi'; between burning the carbon plants fix or its bio-sequestration into stable stored carbon and solar energy in healthy better hydrated soils.

Leading case studies confirm how regenerative land management practices can ensure that most of the carbon fixed by plants is safely bio-sequestered into stable soil carbon to re-hydrate bio-systems and thereby reduce fuel levels and the risk of and the damage from wildfires.

They confirm how practical ecological grazing practices can bio-convert fuels into high nitrogen excrements that can then aid the in situ carbon bio-sequestration and hydrology of bio-systems to further reduce fire risks.

They demonstrate how such practices have and can help rehydrate and limit fire risks in rangelands and forests despite and in response to the systemic aridification of regions and increased droughts.

11.Can we restore the low pressure corridors that aid humid air inflows and more rainfalls.

As discussed previously vast rivers of water vapour flow continually aerially over most regions, even our deserts most of which were previously hydrated and vegetated prior to our aridification of them. However where these rivers of low pressure air flow and if they can deliver their up to 5% moisture content as rain depends on many factors including if high pressure heat domes block their path.

As we can control whether and where such blocking high pressure heat domes form to some degree we can influence some of these air flows and their precipitation. We can influence these dynamics via our management of the Earth's hydrology, vegetation and their cooling and heating effects.

Whereas, bare exposed soils will absorb and re-radiate massive quantities of heat back into the air to create high pressure heat domes that can block incoming cool moist low pressure air flows; vegetated regions often create 'corridors' of cool low pressure air that allows the inflow of more moist low pressure air, often from the oceans to far inland.

The common observation in inland regions that 'rain follows rain' is often valid as the first seasonal rains create green low pressure 'corridors' for subsequent low pressure air flows and more rain. By contrast as the remaining adjacent dry areas heat up and re-radiate more heat they can form high pressure ridges that funel such inflows and thus rain from them for much of that season.

Observations in SW Western Australia also confirm that more rain may fall over valleys that have remained or been re-forested relative to adjacent cleared and cropped valleys. This is consistent with the increased transpiration and thus cooling of the forested valleys and their lower air pressure relative to the hotter cleared adjacent valleys. Clearing the forests negates this rainfall difference.

As the climate warms globally vastly more water is being evaporated from the oceans that absorb 93% of the additional heat being retained by the Earth. This water will add to these aerial rivers and risk far more intense, dangerous storms, floods, droughts, wildfires and the collapse of bio-systems.

However we can minimize such extremes by harvesting some of this extra water from these aerial rivers and in so doing help rehydrate and regenerate many of our formerly vegetated desert areas. As in nature we can do this by revegetating strategic areas to foster the inflow of such humid air inland and then harvesting some of that extra water via its condensation by plants and fostering the increased production of precipitation nuclei and rain.

Conversely we can accelerate the warming, aridification and desertification of regions by continuing with our current land management practices until their extreme climatic consequences limit us.

12.Can we reverse the aridification of regions by regenerating our former monsoons?

Up to 6000 years ago many of the Earth's current deserts were vegetated as grassy shelterwoods that must have had access to but also sustained higher seasonal rainfalls and soil water resources. For example pollen analyses from sediment cores and paleo-hydrological data confirm that Australia had a more intense monsoon that extended into and was in part nucleated in Central Australia.

The 'storm water dreaming' of Australia's First Nations similarly records how this monsoon forms, how human changes to the management of 'country', its vegetation and hydrology, has contributed to its retreat and what we need to do to help the 'rainbow serpent' the monsoon, restore its health.

Scientifically the question is, can we by understanding, respecting and restoring key processes and the land management practices that regulate them, help to extend the inflows of humid air from one of the Earth's major evaporation basin, the Indian Ocean, and the harvest of water from it by and for its vegetation? Can this understanding and these options help to rehydrate other wider regions?

In the case of Australia the evidence (BOM) is that the NW of Australia is and should get more rain from the stronger seasonal humid air from the Indian Ocean that flows across Australia to the SE. The question is can we induce the moisture in these air flows to precipitate or condense as it used to as recent as 6000 years ago, or let it flow past to help rehydrate the Tasman Sea and New Zealand?

Can we regenerate the natural shelterwoods and soils across northern Australia adequately to cool these regions and create the conditions to increase the harvest and precipitation of water from our aerial rivers to help restore the Australian monsoon and rehydrate these former vegetated regions?

The evidence above, be it from the Rabbit Proof Fence or biotic pump effects indicate that we can. Further evidence from Quilpie in SW Queensland confirms nature is already doing this successfully. Extensive areas of perennial Mitchell grass with Mulga woodland around Quiplie were overgrazed by sheep 120 years ago and so degraded that they were largely abandoned as semi arid wastelands. Despite their loss of topsoils and desiccation these wastelands have since naturally regenerated as thick low Mulga, Acacia aneura, scrublands with little commercial value as pasture.

With their regeneration, these Mulga wastelands have recorded consistent increases of some 80% in the winter rain they are receiving this otherwise dry region. In contrast to periodic unreliable cyclonic rainfalls in summer, this winter rainfall mostly comes from the humid NW air flows from the distant Indian ocean that have been able to be nucleated and precipitated by the new vegetation. No comparable rainfall increases have been recorded for the nearby grazed non forested areas.

While how much additional moisture may be being harvested by the tree canopies to help sustain their growth has not been recorded, other studies confirm that such arid zone shelterwood canopies may harvest from 0.2-2 mm of water per night from such humid air flows over similar arid regions.

Recent rainfall data and models by BOM and CSIRO have recorded 'anomalies', zones of unexplained higher than normal rainfall, over such naturally reforested regions in SW Queensland and NW NSW. While there is more to know to understand this reality and the processes driving it, the evidence indicates that the health of our vegetation and the hydrology of landscapes may directly not just depend on regional rainfalls and climates but directly contribute to creating and enhancing them.

That we may be able to partly restore the Australian monsoon by our regeneration and 'caring for country' so as to reverse our former and current widespread degradation and aridification of it.

That our first nation's insight and message in 'storm water dreaming' are real and relevant to the wellbeing of bio-systems and communities in much of Australia as climate extremes intensify but are relevant globally to help 'Regenerate Earth' to help secure our safe climate and future.