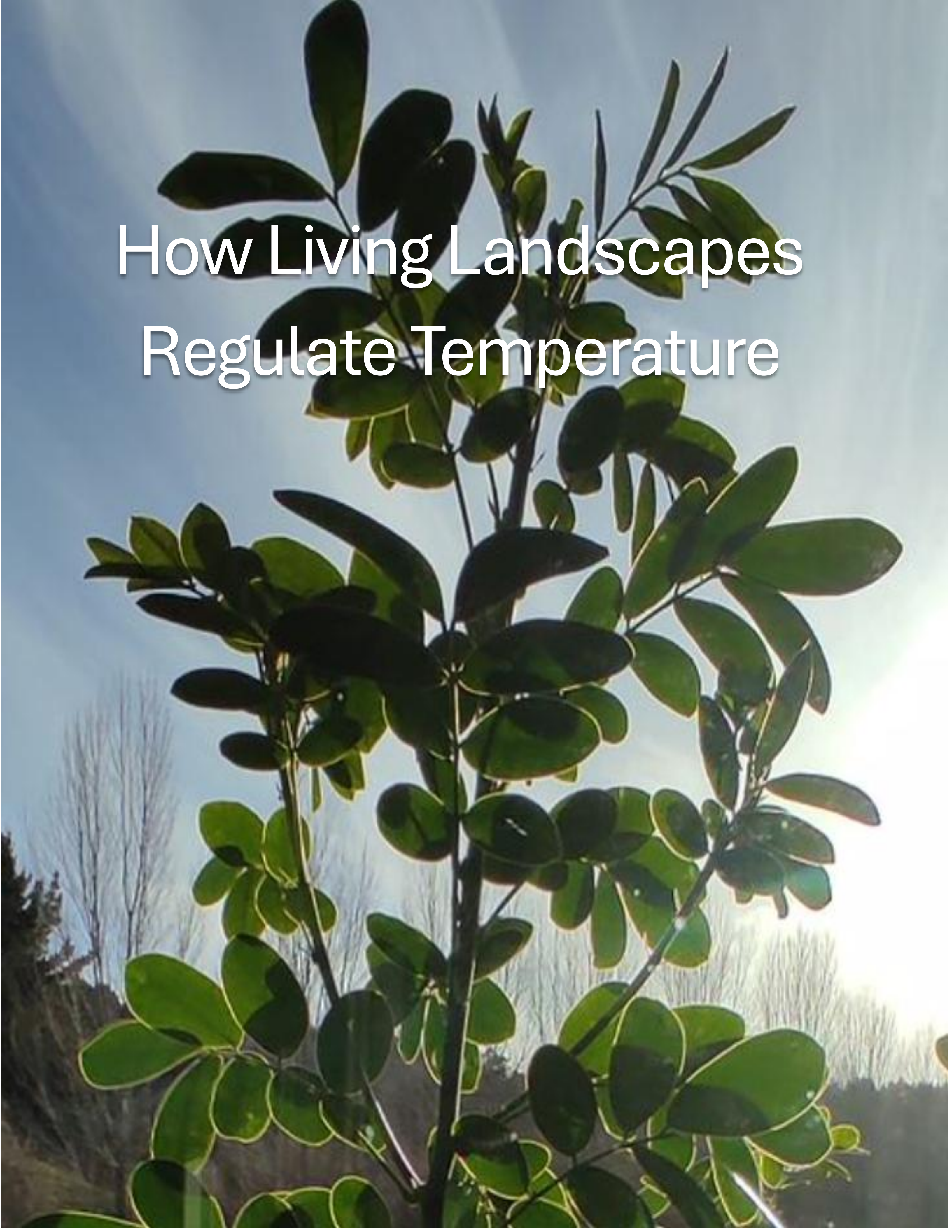
How Living Landscapes Regulate Temperature



How Living Landscapes Regulate Temperature

Primary production, water, and the climate we experience

Peter Bruce-Iri, January 2026

1. A framing problem in climate discourse

The dominant public framing of climate change is built almost entirely around greenhouse gas emissions, particularly carbon dioxide. While essential, this framing is incomplete. It treats the Earth's living systems as **passive victims** of climate change rather than as **active regulators of climate itself**. Yet the difference between incoming and outgoing radiation driving global warming is less than one percent[1], meaning that climate stability depends on extraordinarily subtle shifts in energy dynamics. (See appendix one for more on the tension between climate science and policy).

Living systems – vegetation, soils, and the hydrological cycles they sustain – play a central role in determining how solar energy is processed at the land surface.[2],

> Nature regulates climate at global and regional scales through multiple pathways, including greenhouse gas fluxes, surface albedo, evapotranspiration, and the regulation of energy and water exchanges between the land surface and the atmosphere. (IPBES secretariat, 2019)[3]

2. What vegetation does to heat

Vegetation cools landscapes primarily by diverting energy from sensible heat, which raises surface and air temperature, to latent heat through evapotranspiration. When water evaporates from soil or is transpired through plant leaves, it absorbs large quantities of energy that are no longer available to heat the land surface.[4, 5, 6]

At midday under clear conditions, thermal imaging routinely shows temperature differences of 20 °C or more between vegetated and non-vegetated surfaces. These differences are not marginal; they are the primary signal from which microclimate and atmospheric effects emerge.

3. From surface temperature to lived climate

Surface temperature differences do not translate one-to-one into air temperature differences, but they shape the thermal character of the lower atmosphere. Near the surface, vegetation reduces radiant heat stress dramatically.[7] At greater heights, aggregated land cover influences boundary-layer depth (see appendix two), humidity, and convection. Landscapes dominated by vegetation tend to produce shallower, cooler boundary layers, while degraded landscapes generate deep, hot boundary layers that amplify heat extremes. [8]

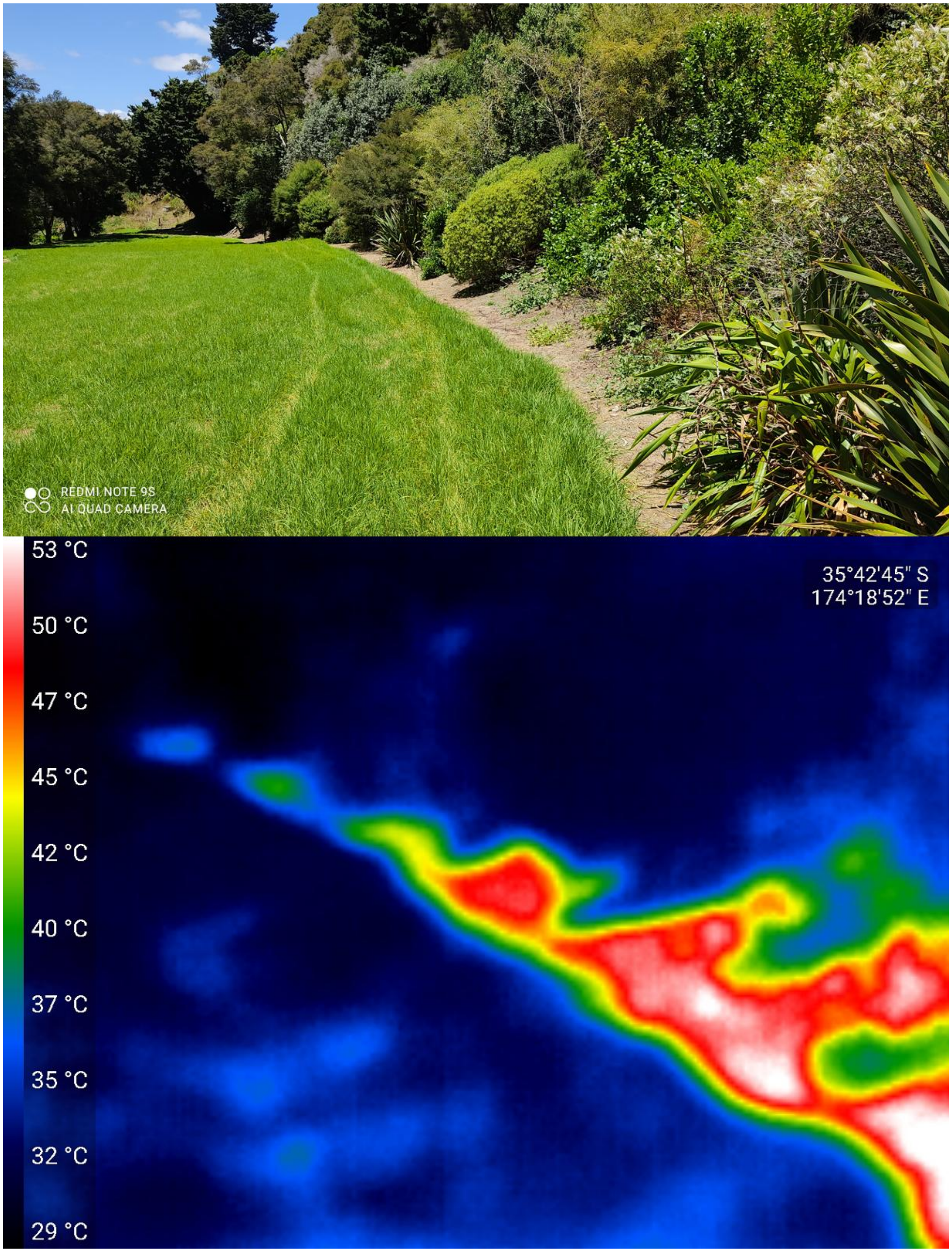


Figure 1: : Coronation reserve in Whangārei. The bottom image is a thermal image of the same site, with a slightly different perspective, mainly caused by different camera lenses. Note that the grass and the bush have similar heat signatures. Temperatures range from 29 to 37 °C. while the dividing herbicide strip is up to 53 °C.

4. Primary production as a climate variable

Primary production (photosynthesis) integrates water availability, vegetation health, soil function, and energy partitioning (see appendix two). Because photosynthesis and transpiration are inseparable, high primary production implies high evapotranspiration and therefore strong cooling capacity.

Modern satellite data now allow primary production to be mapped at high resolution, revealing a consistent inverse relationship between primary production and land surface temperature.

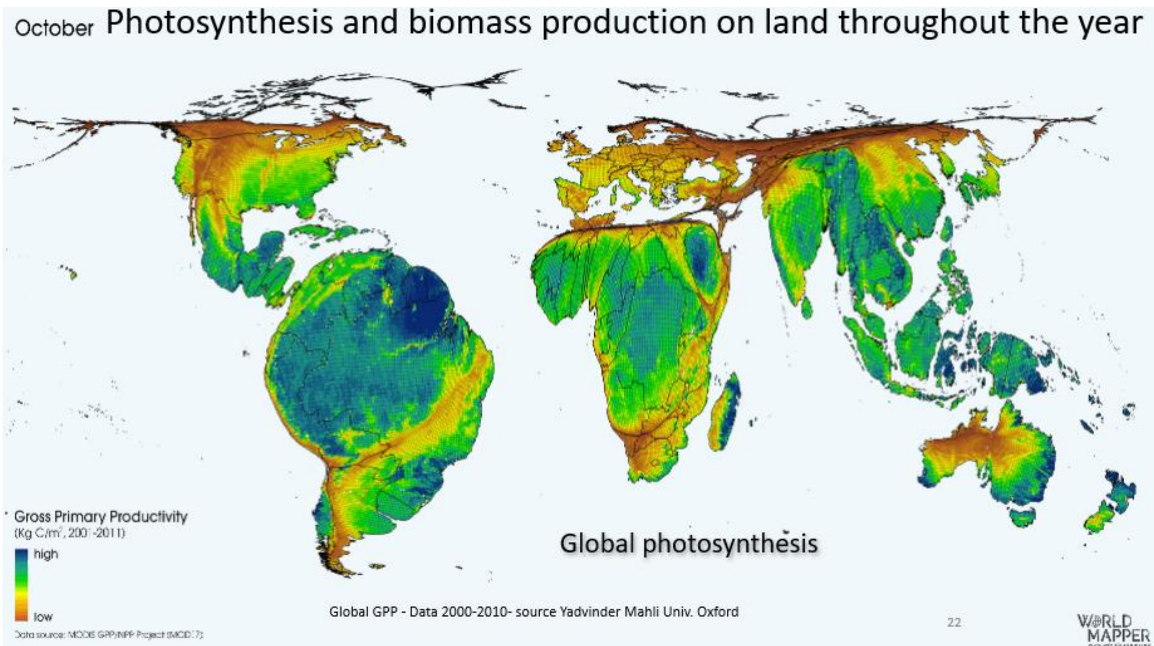


Figure 2: This image shows global terrestrial gross primary production (GPP) for the month of October, based on satellite-derived data. Colours indicate relative rates of photosynthesis and biomass production, with higher productivity shown in green and lower productivity in yellow–brown tones. This is a single frame from an annual animation; the full seasonal cycle highlights the dynamic movement of photosynthetic activity through the year. (Source: MODIS GPP dataset; after Malhi et al)

5. The Amazon–desert contrast

At equatorial latitudes, the Amazon Basin experiences significantly lower temperatures and smaller thermal extremes than desert regions at similar or higher latitudes. This difference cannot be explained by latitude alone.

The Amazon remains cooler because high primary production routes solar energy into latent heat, cloud formation, and vertical heat transport. Desert landscapes, stripped of vegetation and moisture, convert nearly all incoming energy into sensible heat.[9]

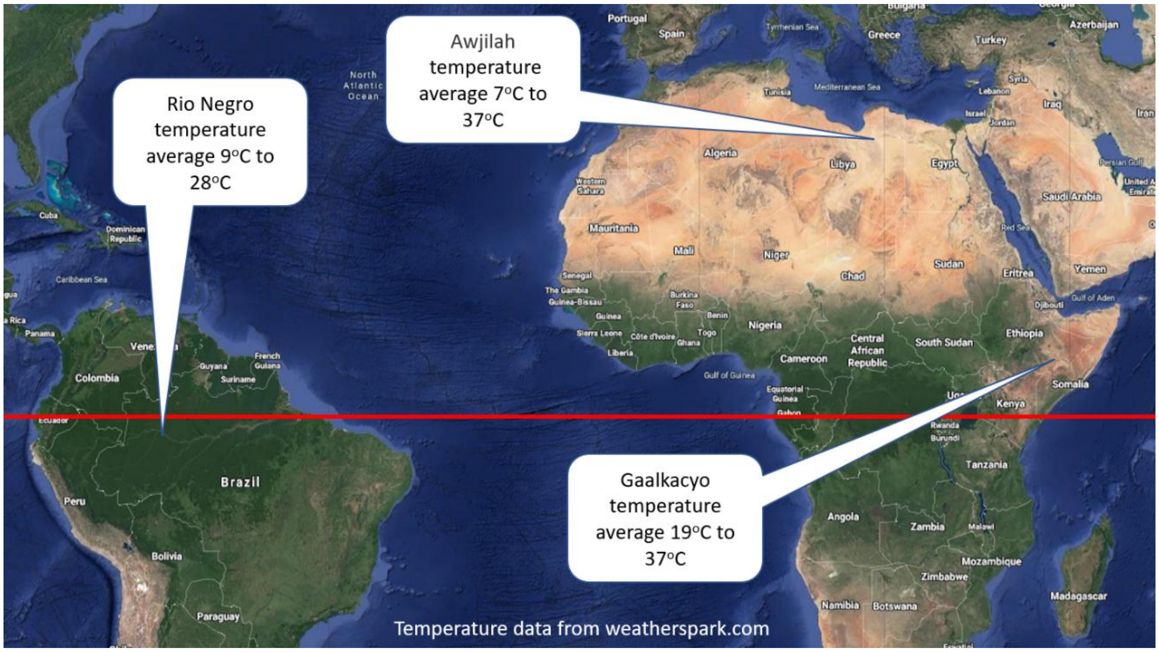


Figure 3: Note the difference in temperature between Rio Negro in the Amazon and the two African sites. Rio Negro is closer to the Equator. Awjilah is in the subtropical zone, equivalent to North Florida.

6. Heat relocation, not heat elimination

Evapotranspiration does not destroy heat; it relocates it. Heat absorbed at the surface is transported upward in water vapour and released during condensation higher in the atmosphere, where it is far less effective at warming surfaces and people.[10, 11] A review of temperature trends over a century attributed a cooling impact from widespread reforestation in the eastern United States.[12]

This vertical redistribution of heat is one of the most important – and least appreciated – mechanisms of climate regulation.

7. Revegetation and climate repair

Across the world, revegetation and rehydration projects consistently demonstrate strong reductions in surface temperature and improved resilience to heat extremes. While systematic air-temperature monitoring is often lacking, the underlying mechanisms are well established. Examples include the work reviving rivers and aquifers in Rajasthan[13] and increases in recorded temperatures subsequent to deforestation in the Mau Forest complex in East Africa.[14]

Regeneration should therefore be understood not only as a biodiversity or carbon strategy, but as **direct climate repair**.

8. Conclusion

Climate is not determined solely by the composition of the atmosphere. It is shaped by how sunlight interacts with land. Living landscapes regulate temperature by routing energy into water, biology, and vertical transport rather than surface heating.

Regeneration of natural and managed landscapes restores this function. In doing so, it offers one of the most immediate and powerful pathways for stabilising the climate.

As climate writer Judith D. Schwartz has observed:

> When we hear about climate, the story we get is that it's all about greenhouse gas emissions and fossil fuels. But in its most basic sense, the story of climate is the story of what happens when sunlight hits the ground: whether the solar energy is incorporated into life forms or becomes sensible heat. What determines the fate of sunlight is natural cycles—the carbon, water, nutrient and energy cycles—which are driven by the activity of plants, animals and microbes. In other words, by life.

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Appendix one: The IPCC Misalignment: Science, Policy, and the Cost of Negotiating the Narrative

A recurring tension runs through contemporary climate governance: the difference between what climate science *knows* about how the Earth system works, and what climate policy frameworks feel able to *say plainly*.

This tension is especially visible in the contrast between the IPCC Working Group I Summary for Policymakers (SPM) and the underlying technical chapters, as well as the broader IPCC Working Group II and IPBES assessments.

What the science shows clearly

Across the technical literature, including IPCC Working Group I chapters on the energy budget, the water cycle, and regional climate, there is no serious doubt that:

- Land surfaces are **active regulators of climate**, not passive backdrops.
- Vegetation, soils, and water cycles strongly influence:
    - surface and near-surface temperature,
    - the partitioning of energy between sensible and latent heat,
    - boundary-layer development,
    - the intensity and persistence of heat extremes.
- Degradation of land and loss of vegetation **amplify warming and climate extremes**, while restoration and rehydration **reduce risk**, even under the same atmospheric greenhouse forcing.

In the technical chapters, these processes are discussed explicitly in terms of **evapotranspiration, soil moisture feedbacks, surface energy balance, and land–atmosphere coupling**. In Working Group II and IPBES reports, ecosystems are described unambiguously as providing **climate regulation through biophysical pathways**, not merely as victims of climate change.

In short: **the science treats land, water, and life as part of the climate system itself.**

What the Summary for Policymakers emphasises instead

By contrast, the IPCC Working Group I SPM presents climate change almost entirely through the lens of:

- greenhouse gas emissions,
- fossil fuel combustion,
- radiative forcing,
- and global mean temperature change.

Land-surface processes are not denied, but they are:

- compressed into the language of “feedbacks,”
- treated as secondary modifiers rather than co-determinants,
- and largely detached from questions of agency and responsibility.

This produces a narrative in which climate appears to be driven primarily by what happens **in the atmosphere**, rather than by the coupled system of atmosphere, land, water, and life.

Why this misalignment exists

This divergence is **not** the result of scientific uncertainty. It is a consequence of **institutional and political constraints**.

The SPM is negotiated line-by-line with governments and is designed to support:

- clear attribution of responsibility,
- accountability for emissions,
- and policy instruments that can be quantified, regulated, and enforced.

Fossil fuel emissions meet these criteria. Land systems do not – at least not neatly.

There is a well-founded concern within climate diplomacy that broadening the narrative beyond fossil fuels could:

- allow laggards to deflect responsibility,
- encourage substitution of land-based actions for emissions reductions,
- revive offsetting logics that delay decarbonisation.

As a result, the SPM maintains **narrative discipline**: it keeps the causal story tight in order to keep pressure on the atmospheric drivers of global warming.

The unintended consequence

This strategic narrowing has an unintended cost.

By under-communicating the role of land, water, and ecosystems in regulating climate:

- land degradation is implicitly framed as a side issue,
- restoration is cast as optional or supplementary,
- and societies are left poorly equipped to understand why climate impacts are already intensifying even where emissions stabilise.

In effect, the SPM protects **emissions accountability**, but at the expense of **system understanding**.

The false choice and how to resolve it

The perceived trade-off – that recognising land and ecosystem regulation might “let laggards off the hook” – rests on a false choice.

Acknowledging the climate-regulating role of living landscapes does **not** weaken the case for rapid fossil fuel phase-out. It strengthens it by showing that:

- emissions reductions are necessary to limit long-term forcing,
- but land stewardship determines how that forcing is experienced as heat, drought, floods, and extremes,
- and continued land degradation will amplify climate risk even under ambitious mitigation pathways.

This is not a substitute responsibility; it is **additional responsibility**.

Why this matters now

As climate impacts accelerate, the gap between atmospheric metrics and lived experience is widening. The misalignment between the SPM narrative and the full Earth-system science makes it harder for policymakers and the public to grasp why:

- restoring soils, vegetation, and water cycles matters immediately,
- regeneration reduces risk regardless of emissions trajectories,
- and climate stabilisation is as much about **how sunlight is processed at the surface** as about what gases are in the sky.

A broader of climate solutions comes into play. Solutions regenerating natural and managed ecosystems extend agency to many more humans who may not have the resources to implement costly technical solutions.

Appendix two: The boundary layer and energy partitioning

The **atmospheric boundary layer** is the lowest part of the atmosphere, extending from the Earth's surface to roughly a few hundred metres at night and up to one to four kilometres during the day. It is the zone where land and air interact directly, responding within hours to changes in surface temperature, vegetation, soil moisture, and land cover.

Land surfaces strongly influence the boundary layer through **energy partitioning**. Vegetated and well-hydrated landscapes convert a large share of incoming solar energy into **latent heat** via evapotranspiration, resulting in cooler surfaces, higher humidity, and a **shallower, cooler boundary layer**. Degraded, dry, or sealed surfaces convert most incoming energy into **sensible heat**, producing very hot surfaces and a **deeper, hotter boundary layer**.

Boundary layer characteristics are critical because most heat stress, air pollution, fire weather, and extreme temperature events occur within this zone. A deep, dry boundary layer amplifies daytime heat, suppresses night-time cooling, and increases the persistence and severity of heatwaves. Conversely, restoring vegetation and soil moisture reduces **boundary layer risk** by enhancing evaporative cooling and lifting heat upward, where it is more readily dispersed.

Energy partitioning at the land surface

When solar radiation reaches the Earth's surface, it is **partitioned** into different energy pathways. The most important of these for climate and heat risk are **sensible heat** and **latent heat**.

Sensible heat is the portion of energy that directly raises the temperature of the land surface and the air above it. Surfaces with little vegetation or moisture, such as bare soil, asphalt, concrete, or dry ground, convert most incoming energy into sensible heat, leading to high surface temperatures and a hotter near-surface atmosphere.

Latent heat is the portion of energy used to evaporate water from soils and to transpire water through plant leaves. This process absorbs large amounts of energy without raising temperature, effectively cooling the surface. The absorbed heat is transported upward with water vapour and released during condensation higher in the atmosphere, where it is more readily dispersed.

Vegetation and soil moisture strongly influence how energy is partitioned. Landscapes with healthy vegetation and adequate water shift energy away from sensible heating and toward latent heat flux, resulting in cooler surfaces, higher humidity, and reduced heat accumulation in the atmospheric boundary layer. Degraded or sealed landscapes shift energy in the opposite direction, increasing heat extremes and climate risk.

An Earth without vegetation would not simply be warmer on average; it would be far more thermally extreme, with land surfaces behaving as persistent heat amplifiers rather than regulated components of the climate system.

Together, energy partitioning at the land surface and the structure of the atmospheric boundary layer determine whether solar energy is dissipated safely through biological and hydrological processes, or concentrated as heat in the air that people and ecosystems experience.

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[2] IPCC, *Climate Change 2021: The Physical Science Basis* (Cambridge University Press, 2021), https://www.ipcc.ch/report/ar6/wg1/. See Chapter 7 *Author's note: the IPCC Working Group I Summary for Policymakers emphasises greenhouse gas forcing because it is designed to support global mitigation accounting and intergovernmental negotiation. The underlying assessment chapters, and especially the Working Group II reports, are more explicit that land cover, water cycles, and ecosystem function actively regulate regional climate through biogeophysical processes, including energy partitioning and moisture fluxes*.

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