Re-appraisal of the global climatic role of natural forests for improved climate projections and policies

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Along with the accumulation of atmospheric greenhouse gases, particularly carbon dioxide, the loss of primary forests and other natural ecosystems is a major disruption of the Earth’s system and is causing global concern. Quantifying planetary warming from carbon emissions, global climate models highlight natural forests’ high carbon storage potential supporting conservation policies. However, some model outcomes effectively deprioritize conservation of boreal and temperate forests by suggesting that increased albedo upon deforestation could cool the planet. A potential conflict of global cooling vs. regional forest conservation could harm environmental policies. Here we present theoretical and observational evidence to demonstrate that, compared to the carbon-related warming, modeling skills for assessing climatic impacts of deforestation is low. We argue that estimates for deforestation-induced global cooling result from the models’ limited capacity to account for the global effect of cooling from evapotranspiration of intact forests. Specifically, transpiration of trees can change the greenhouse effect via small modifications of the vertical temperature profile. However, due to their convective parameterization (which postulates a certain critical temperature profile), global climate models do not properly capture this effect. This may lead to an underestimation of warming from the loss of forest evapotranspiration in both high and low latitudes. As a result, conclusions about deforestation-induced global cooling are not robust and could result in action that immediately worsened global warming. To avoid deepening the environmental crisis, these conclusions should not inform policies of vegetation cover management, especially as studies from multiple fields are accumulating that better quantify the stabilizing impact of natural ecosystems evolved to maintain environmental homeostasis. Given the critical state and our limited understanding of both climate and ecosystems, an optimal policy with immediate benefits would be a global moratorium on the exploitation of all natural forests.

KEYWORDS
ecosystem stability, climate stability, primary forests, precipitation, evapotranspiration, convective parameterization
1. Introduction

The Earth is suffering from climate destabilization and ecosystem degradation (Figure 1), and humanity seeks to stop both (IPBES, 2019; IPCC, 2021). Policies for global climate stabilization focus on decarbonization and are informed by the outcomes of global climate models that formalize our evolving understanding of the Earth’s system—currently, by the model simulations from the 6th Coupled Model Intercomparison (CMIP6) for the 6th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2021). With the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) formed 24 years later than IPCC, the ecosystem preservation narrative is less formally developed (Wilhere, 2021). Proponents of ecosystem preservation often borrow from the decarbonization argument and invoke the carbon storage potential of natural forests as a major illustration of their climatic importance. For example, the ground-breaking proforestation initiative in the United States emphasizes how much carbon unexploited natural forests can remove from the atmosphere if allowed to develop to their full ecological potential (Moomaw et al., 2019; Faison et al., 2023).

At the same time, the carbon-storage argument for temperate and boreal forests is undermined by the fact that global climate models suggest that deforestation in these regions could cool the planet. Based on these models, increased albedo is estimated to overcome the warming caused by deforestation-induced carbon emissions (Jia et al., 2022, Figure 2.17) even if the latter can be underestimated (Schepaschenko et al., 2021). These model outcomes have been known for quite a while (e.g., Snyder et al., 2004), but recently these ideas clearly gained prominence and are even approaching implementation. A recent Science commentary warned that regrowing boreal forests would not make the Earth cooler (Pearce, 2022), a conclusion that is derived purely from global climate model simulations (e.g., De Hertog et al., 2022). The World Resources Institute’s report “Not just carbon” noted that the increased albedo from deforestation would cool the Earth and emphasized that the positive climate role of boreal forests is only a local effect (Seymour et al., 2022a,b). Aligned with these modeling studies, a recent study in Nature Ecology and Evolution did not include primary boreal forests into Nature’s critical assets (Chaplin-Kramer, 2023). One of the criteria for an ecoregion to be classified as a critical asset was its proximity to people—and primary boreal forests are often distant from any human settlements (which is a major reason for why they are still primary). Together, these models and mainstream messages not only de-emphasize the preservation of natural boreal and, to a lesser degree, temperate forests, but they implicitly prescribe and incentivize their destruction.

In this Perspective, we would like to ring an alarm bell by showing that this potentially biased picture of the role of natural forests, in particular boreal forests, for stabilizing Earth’s climate is based on a few model assumptions that rule out important evapotranspiration feedbacks and can result in policies deepening rather than mitigating the climate crisis. We also outline a clear and possible path forward.

2. Global cooling from plant transpiration

2.1. Local vs. global cooling

We argue that the conclusion of a cooler Earth upon the loss of boreal forests rests from the limited capacity of global climate models to quantify another forest-related effect acting in the opposite direction: global cooling from forest transpiration. The ability of transpiring plants to provide local cooling is well-known (e.g., Alkama and Cescatti, 2016; Hurny and Pokorný, 2016; Bright et al., 2017; Ellison et al., 2017; Hesslerová et al., 2018, and see Figure 2). Instead of converting to heat, some of the absorbed solar energy is spent on breaking the intermolecular (hydrogen) bonds between the water molecules during evapotranspiration. As a result, the evaporating surface cools.

When more sunlight is reflected back to space, the planet receives less energy and it is intuitively clear that it must cool. In comparison, evaporation cools locally, but the captured energy does not disappear: it is released upon condensation elsewhere in the Earth’s system. The methodology of explaining why the planet warms with increasing CO₂ is well-developed (e.g., Benestad, 2017, and references therein). In contrast, how and whether loss of plant transpiration could warm or cool the planet remains conceptually unclear. While the IPCC reports recognize that global cooling from plant transpiration exists (Jia et al., 2022, Figure 2.17), its physical mechanism is not to be found in literature. Nevertheless, the environmental science is inherently transdisciplinary, and understanding this effect is important for the broader community of ecosystem researchers and conservationists, as it will enable a
critical assessment of model outputs offered to guide large-scale vegetation management.

2.2. Methods

To illustrate the global thermal effect of transpiration, we will use a simple model of energy transfer (Figure 3). The greenhouse substances are represented by discrete layers that absorb all incoming thermal radiation and radiate all absorbed energy equally up and down. All the imaginary planets shown in Figure 3 are in a steady state: none is warming or cooling. In the absence of absorbers, the Earth’s surface emits as much thermal radiation as it absorbs solar radiation (Figure 3A). Each layer of the greenhouse substances redirects part of the thermal radiation back to the Earth’s surface. As a result, the planetary surface is warmer according to the greater the amount of absorbers (cf. Figures 3B, C).

When a certain part of the incoming solar radiation is absorbed in the upper atmosphere (for example, by aerosols or clouds), it escapes interaction with the absorbers beneath. Accordingly, in such a case the planetary surface is colder by an amount by which the absorbers would multiply this escaping part if it dissipated to thermal radiation at the surface (cf. Figures 3C, D). Figures 3C, D show that, with unchanged amount of greenhouse gases (e.g., carbon dioxide) and unchanged total flux $q$ of absorbed solar energy, the planetary surface temperature depends on where solar energy dissipates to thermal radiation.

Similarly, in the presence of the non-radiative fluxes of sensible and latent heat, the amount of solar energy converted to thermal radiation at the surface diminishes—and so does the amount of thermal radiation redirected by the absorbers back to the surface. Thus, surface thermal radiation and temperature are smaller (cf. Figures 3D–F). The non-radiative fluxes “hide” a certain part of absorbed solar energy from the greenhouse substances easing its ultimate release to space. Convection, condensation and precipitation “deposit the latent heat removed from the surface above the level of the main water vapor absorbers, whence it is radiated to space” (Bates, 2003). This energy escaping partially from interaction with the absorbers is the physical mechanism behind global cooling from plant transpiration.

A related process is the atmospheric transport of heat from the equator to higher latitudes, where the water vapor concentration in the colder atmosphere is smaller. This transport likewise “hides” a certain part of solar energy absorbed at the equator from the abundant greenhouse substances (water vapor) in the warm tropical atmosphere. As a result, despite the amount of absorbers does not change, the globally averaged greenhouse effect diminishes and the planetary surface cools (Bates, 1999; Caballero, 2001). The potential of this effect was illustrated by Marvel et al. (2013), who modeled an idealized atmosphere with two strong circulation cells connecting the equator and the poles. With such a circulation, the Earth’s surface became eleven degrees Kelvin cooler than the modern Earth (Marvel et al., 2013, their Figure 1e and Figure 3 bottom).

An increase in the non-radiative flux $F_L$ (from $F_L = 0$ in Figure 3D to $F_L \simeq 0.4q > 0$ in Figures 3E, F) decreases surface thermal radiation $F_1$ by a magnitude proportional to the flux change $\Delta F_L$ and to the number $\Delta \tau$ of absorbing layers beneath the height where this flux dissipates to thermal radiation ($\Delta \tau = 1$ in Figure 3E and $\Delta \tau = 2$ in Figure 3F). Historical deforestation affected about 13% of land area $S_L = 1.5 \times 10^8$ km$^2$ (or 3.8% of planetary surface $S_F = 5.1 \times 10^8$ km$^2$) (Figure 1). With the global mean latent flux of $F_L = 80$ W m$^{-2}$, if deforestation has reduced this flux by thirty per cent ($\Delta F_L \sim -0.3F_L$), this could increase the surface radiation by $-0.038\Delta F_L\Delta \tau \sim 0.9$ W m$^{-2}$ (cf. Figures 3D, E, $\Delta \tau = 1$) or twice that number (cf. Figures 3D, F, $\Delta \tau = 2$), Table 1. Given an equilibrium climate sensitivity $f \sim 1$ K/(W m$^{-2}$) (Zelinka et al., 2020), the latter case corresponds to a warming of about two degrees Kelvin (Table 1). If the optical thickness of the atmosphere,
and, accordingly, the magnitude of $\Delta \tau$, is greater, the cooling can be proportionally larger.

In a steady state with the unchanged amount of greenhouse substances, temperature $T_s$ and height $z_e$ of the upper radiative layer remain constant (e.g., Figures 3C–F). Therefore, surface warming caused by loss of plant transpiration should be manifested as an increase in the temperature difference between the surface and the upper radiative layer, i.e., the mean temperature lapse rate $\Gamma = (T_e - T_s)/z_e$ should grow (see discussion and Figure 5 in Section 2.4).

2.3. Dependence of global transpirational cooling on atmospheric circulation

The higher up in the air column that convection transports heat, the more pronounced global cooling it exerts. This is because the energy is radiated more directly to space from the upper atmospheric layer (cf. Figures 3E, F). In addition to the altitude, it matters how rapidly the cooled air descends. When the air rises and increases its potential energy in the gravitational field, its internal energy accordingly declines, and it cools. While evaporation cools the evaporating surface, the release of latent heat during condensation in the rising air partially offsets this decline of the internal energy of air molecules, making the rising air warmer than it would be without condensation. Radiating this extra thermal energy to space takes time. The more time spent by the air warmed thereby radiating energy to space (Figure 4). If, on the contrary, the

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1. Temperature lapse rate $\Gamma$ is the absolute magnitude of the vertical temperature gradient, $\Gamma = -\partial T/\partial z$. 

Figure 3

Scheme to illustrate the dependence of the planetary surface temperature on the amount of greenhouse substances (A–C) and on the magnitude and spatial distribution of the non-radiative energy fluxes (D–F). Thickness of each layer of the greenhouse substances corresponds to unit optical depth $\tau = 1$ (one free path of thermal photons—the mean distance between two consecutive acts of absorption and re-emission by the absorber molecules); $\tau_e$ is the total number of layers: $\tau_e = 0$ in (A), 1 in (B), and 2 in (C–F). A “gray” atmosphere is assumed, where absorption of thermal radiation is the same for all wavelengths (Ramanathan and Coakley, 1978; Makarieva and Gorshkov, 2001; Gorshkov et al., 2002). Thermal radiation of the planetary surface $F_s = \sigma T_s^4$ [W m$^{-2}$] and of the upper radiative layer to space $F_e = \sigma T_e^4$ are related to surface temperature $T_s$ and temperature of the upper radiative layer $T_e$ by Stefan–Boltzmann law, where $\sigma = 5.7 \times 10^{-8}$ W m$^{-2}$ K$^{-4}$ is the Stefan–Boltzmann constant. All energy fluxes are shown in the units of absorbed solar radiation $q$, which is in the steady state equal to thermal radiation emitted by the planet $F_s = q_e$; in (D–F), $q_e = 0.3q$ is solar energy absorbed by the atmosphere (not to be confused with the reflected solar radiation (albedo), which is assumed to be constant and not shown); in (E, F), $F_a$ is the non-radiative heat flux accounting for both sensible and latent heat. Thermal radiation is emitted to space from mean height $z_a$, with temperature $T_a$; $z_a = 0$ in (A), $z_a = z_1 > 0$ in (B), and $z_a = z_2 > z_1$ in (C–F).
TABLE 1 Estimates of global warming from the loss of tree transpiration associated with deforestation; \( \Delta F \) is the local reduction of latent heat on the deforested area, \( \Delta S \) is the change of global surface temperature upon deforestation.

<table>
<thead>
<tr>
<th>References</th>
<th>Area affected</th>
<th>( \Delta S ) (%)</th>
<th>( \Delta F ) (%)</th>
<th>( \Delta T ) (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snyder et al. (2004)</td>
<td>Tropical*</td>
<td>16</td>
<td>-30</td>
<td>0.24</td>
</tr>
<tr>
<td>Davin and de Noblet-Ducoudré (2010)</td>
<td>Global**</td>
<td>90</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>This work (Figures 3D, F)</td>
<td>Historical***</td>
<td>13</td>
<td>-30</td>
<td>2</td>
</tr>
</tbody>
</table>

* Tropical forests replaced by deserts in a coupled atmosphere-biosphere model.
** Estimated as \( \Delta T \sim -\frac{\Delta S}{S_{0}}/\Delta F \) taking into account the change in roughness and change in evapotranspiration efficiency as shown in Table 1 of Davin and de Noblet-Ducoudré (2010).
*** Estimated as \( \Delta T \sim -\frac{\Delta S}{S_{0}}/\Delta F \) assuming that deforestation reduces latent heat flux by 30% of \( F_{t} = 80 \text{ W m}^{-2} \) (Trenberth et al., 2009) on area \( \Delta S \sim 13\% \) of land (the area affected by historical deforestation (Figure 1), \( S_{0}/S_{e} = 0.29 \) is the relative global land area with \( \Delta T = \tau / 2 \) as optical depth of the atmosphere (Figures 3D, F), \( \epsilon = 1 \text{ K W}^{-1} \text{ m}^{-2} \) is the assumed equilibrium climate sensitivity to radiative forcing. Note that with \( q = 239 \text{ W m}^{-2} \), the idealized planet with \( \tau = 2 \) shown in Figure 3F approximately corresponds to the modern Earth with \( q_{0} = 78 \text{ W m}^{-2} \sim 0.4q \), \( F_{t} = 390 \text{ W m}^{-2} \sim 1.6q \).

warmed air descends rapidly and locally, then most heat is brought back to the surface before it is radiated, and the global power of the net cooling effect can be nullified. Therefore, disruptions in the long-distance moisture transport (e.g., by deforestation) and violent local rains should warm the Earth. In smaller convective clouds up to a quarter of ascending air descends locally at a relatively high vertical velocity (Heus and Jonker, 2008; Katzwinkel et al., 2014). These effects are not taken into account when assessing the temperature effects of land cover changes (e.g., Bright et al., 2017).

Current global climate models do not correctly reproduce either the long-distance ocean-to-land moisture transport or the moisture transport over the ocean (Sohal et al., 2022). For example, the Amazon streamflow is underestimated by up to 50% (Marengo, 2006; Hagemann et al., 2011, their Figure 5). This corresponds to a 10% error in the global continental streamflow, the latter being of the same order as global continental evaporation. Similarly, global climate models do not correctly reproduce how the local diurnal cycle of convection changes upon deforestation by producing extreme low and high temperatures (Lejeune et al., 2017, their Figure 7). These are indirect indications of the models’ limited capacity to reproduce global transpiration cooling. We will now discuss the cause of this limited capacity.

2.4. Global transpiration cooling in global climate models

We have seen that, for a given amount of absorbers, surface temperature is determined by the vertical distribution of the non-radiative heat fluxes (Figures 3D–F). But these fluxes themselves depend on the vertical temperature gradient: if the air temperature declines with height faster than a certain critical lapse rate of air temperature, the atmosphere is unstable to convection. The non-radiative heat fluxes originate proportional to the difference between the actual and the critical temperature lapse rates (Ramanathan and Coakley, 1978).

Therefore, strictly speaking, it is not justified to freely vary where and how the non-radiative heat fluxes dissipate to thermal radiation, not paying attention to whether the resulting vertical temperature profile is physically consistent with the convective fluxes specified a priori. However, since the non-radiative (convective) and net radiative energy fluxes in the Earth’s atmosphere are of the same order of magnitude (100 and 60 W m\(^{-2}\)), respectively, Trenberth et al., 2009), a rough estimate of global transpiration cooling can be obtained from considering the radiative transfer alone as done in Figures 3D–F. (This would not be possible if the convective fluxes were an order of magnitude higher than the radiative flux). We emphasize that our goal here is not to obtain an accurate estimate of global transpiration cooling, but simply to present plausible arguments showing that it is overlooked and it can be large.

An exact estimate of what happens when the evapotranspiration and the latent heat flux are suppressed on a certain part of land area requires solving the problem simultaneously for the radiative-convective transfer and the temperature profile. This problem is too complicated for modern global climate models to address, therefore they apply the so-called convective parameterization. Convective parameterization in climate models postulates the (generally unknown) value of a critical temperature lapse rate instead of solving for it. While the numerical simulation is run, “whenever the radiative equilibrium lapse rate is greater than the critical lapse rate, the lapse rate is set equal to the critical lapse rate” (Ramanathan and Coakley, 1978).
Therefore, by construction, global climate models cannot provide any independent information about the climatic effect of evaporational cooling—that should be manifested as the change in the global mean lapse rate—besides what was fed into them a priori via convective parameterization.

The reason for this artificial constraint on the impact of evaporational cooling is that global climate models have been built with a major goal of assessing radiative forcing from changing carbon dioxide concentrations. Accordingly, they do have this capacity: this forcing can be approximately estimated assuming an unchanged atmospheric temperature profile. It is under this assumption that Arhenius (1896) obtained the first ever estimate of global warming from CO$_2$ doubling. But radiative forcing caused by the suppression of evapotranspiration is a conceptually different problem for which convective parameterization precludes a solution that would be non-zero in the first order. Therefore, in the models, global warming resulting from the loss of transpirational cooling is, for the same deforested area, at least one order of magnitude smaller than our estimate (Table 1). For example, according to global climate models, tropical deforestation on 16% of land area would produce a global warming of 0.2 K (Snyder et al., 2004), while converting about 90% of global land area from forest to grassland (with unchanged albedo) would warm the Earth by about half a degree Kelvin (Davin and de Noblet-Ducoudré, 2010), see Table 1.

As a further illustration of the lack of conceptual clarity with regard to global transpirational cooling, one can refer to the conclusion of Davin and de Noblet-Ducoudré (2010, their Table 1) that modeled global warming due to the loss of evapotranspiration is a “non-radiative” forcing. This conclusion is reached by noting that loss of evapotranspiration practically does not change the temperature difference between the surface and the upper radiative layer (Figure 3). The reason for this artificial constraint on the impact of evaporational cooling is that global climate models do indicate that the regional loss of forest evapotranspiration leads to global warming. Although the global effect is small (Table 1), it is of the opposite sign compared to the albedo-related cooling from deforestation that is invoked to argue that certain forests (boreal in particular) are not globally beneficial in the climate change context. Despite this obvious importance for policy-relevant model outcomes, a conceptual description of how evapotranspiration cools the Earth, and how its loss would lead to global warming, is absent from the meteorological literature. If and when conceptual understanding is lacking, how can one independently assess whether the models get the effect right?

Second, we have discussed that, from the first principles, we can expect global warming resulting from the loss of evapotranspiration to manifest itself as an increase in the vertical lapse rate of air temperature. Due to the convective parameterization, global climate models keep this lapse rate roughly constant as the planet warms (Held and Soden, 2006; Jeevanjee et al., 2022). However, this model feature does not agree with observations that accommodate a considerable increase in the temperature difference between the surface and the upper radiative layer (Figure 5).

Land and energy policies based on the model outcomes that we have criticized are being shaped right now and an evaluation/reevaluation that avoids harm is paramount. While the above arguments continue to percolate in the meteorological literature, readers from all disciplines should be interested in evaluating and discussing these concerns and can approach their colleagues in the field of meteorology to see how they respond to the above two challenges, thus getting an indirect confirmation (or disproval) of our argumentation.

At the most basic level, our results highlight the importance of a valid concept at the core of a model. The assumption of an a priori specified critical lapse rate in the convective parameterization yields a negligible global transpirational cooling, which translates into de-emphasizing the preservation of boreal forests. Concepts are powerful; incorrect concepts can be destructive. This brings us to the question, is there a concept that ecology could offer to put at the core of a global climate model, to adequately represent the biosphere?

From our perspective, it is the concept of environmental homeostasis, which is the capacity of natural ecosystems to compensate for environmental disturbances and stabilize a favorable for life environment and climate (Lovelock and Margulis, 1974; Gorshkov, 1995). Recent studies discuss how biotic control can be evident in the observed dynamics of the Earth’s temperature (Leggett and Ball, 2020, 2021; Arnscheidt and Rothman, 2022).

3. Discussion and conclusions

Recognizing that for the ecological audience it could be difficult to assess the credibility of our quantitative estimates, we would like to emphasize two of the more unequivocal points. First, global climate models do indicate that the regional loss of forest evapotranspiration leads to global warming. Although the global effect is small (Table 1), it is of the opposite sign compared to the albedo-related cooling from deforestation that is invoked to argue that certain forests (boreal in particular) are not globally beneficial in the climate change context. Despite this obvious importance for policy-relevant model outcomes, a conceptual description of how evapotranspiration cools the Earth, and how its loss would lead to global warming, is absent from the meteorological literature. If and when conceptual understanding is lacking, how can one independently assess whether the models get the effect right?

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When the information about how the natural ecosystem influences environment is lacking, the best guess could be to assume that they provide a stabilizing feedback to the disturbance.

There was already a predicament in climate science that could have been facilitated by such an approach. It was the missing sink problem: when the rates of carbon accumulation in the atmosphere are predicted that the undisturbed ecosystems should perform a compensatory response to rising atmospheric CO\(_2\) (Hampicke, 1980; Amthor, 1995). However, based on the premises of the biotic regulation concept (Gorshkov, 1995; Gorshkov et al., 2000), and long before the missing sink was assigned to the terrestrial biota, Gorshkov (1986, p. 946) predicted that the undisturbed ecosystems should perform a compensatory response to rising atmospheric CO\(_2\) by elevating synthesis of carbohydrates.

Today, climate science faces a new challenge. Global climate models with an improved representation of clouds display a higher sensitivity of the Earth’s climate to CO\(_2\) doubling than models with a poorer representation of clouds (Zelinka et al., 2020; Kuma et al., 2023). This implies more dire projections for future climate

3 This represents what can be called Odum’s paradox, who thought that ecological succession culminates in ecosystem's maximum control of the environment (Odum, 1969). But if the ecosystem functions on the basis of closed matter cycles, its environmental impact (and, hence, environmental control) is zero by definition. The biotic regulation concept introduced the notion of directed openness of the matter cycles to compensate for environmental disturbances (Gorshkov, 1995).
change, but also poses the problem of how to account for the past temperature changes that are not affected by the model improvements and have been satisfactorily explained assuming a lower climate sensitivity. The concept of the environmental homeostasis and the biotic regulation of the environment provide a possible solution: the climate sensitivity may have been increasing with time—reflecting the decline of natural ecosystems and their global stabilizing impact (Figure 1).

Currently, climate model uncertainties are assessed by comparing outputs from models developed by different research centers (Zelinka et al., 2020). This provides a minimal uncertainty estimate, as the model development may follow universal principles sharing both progress and errors. A distinct approach would be to attempt building a model that departs significantly from the others in its core concept and see if such a model can be plausibly tuned to competitively describe observations. Success of such a model would force the range of model uncertainties to be extended. As global climate models are currently being used to elaborate strategies for the survival of humanity as a whole, such a stress test on their performance would not be superficial.

Such an endeavor requires a plausible alternative concept, and we propose that a global climate model built around the stabilizing impact of natural ecosystems can become such an alternative. This will require an interdisciplinary effort and an account of global transpirational cooling, the role of natural ecosystems in the long-distance moisture transport (Makarieva and Gorshkov, 2007; van der Ent et al., 2010; Ellison et al., 2012; Poveda et al., 2014; Molina et al., 2019; Makarieva et al., 2023) and water cycle stabilization (Zemp et al., 2017; Baudena et al., 2021; O’Connor et al., 2021) and the distinct impact of ecosystems at different stages of ecological succession on the surface temperature and fire regime (e.g., Alénikov, 2019; Baker and Spracklen, 2019; Lindenmayer et al., 2022) and the cloud cover (Cerasoli et al., 2021; Duveiller et al., 2021). Living systems function on the basis of solar energy that under terrestrial conditions can be converted to useful work with a near 100% efficiency. What processes are enacted with use of this energy, is determined by the genetic programs of all the organisms composing the ecological community. Randomly changing the species composition and morphological status of living organisms in the community—for example, by converting to developed land (removing natural elements altogether), replacing natural forest with a plantation, clearing large expanses for farmland, or forcing areas of forest to remain in an early successional or degraded state—disturbs the flow of environmental information and disrupts the ecosystem’s capacity to respond to environmental disturbances (Makarieva et al., 2020; Kellett et al., 2023). We need a better understanding of this fundamental regulation and its tipping points.

While fundamental science is being advanced, the precautionary principle should be strictly applied. Any control system increases its feedback as the perturbation grows. Therefore, as the climate destabilization deepens, the remaining natural ecosystems should be exerting an ever increasing compensatory impact per unit area. In other words, the global climate price of losing a hectare of natural forest grows as the climate situation worsens. We call for an urgent global moratorium on the exploitation of the remaining natural ecosystems and a broad application of the proforestation strategy to allow them to restore to their full ecological and climate-regulating potential.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

AM wrote the first draft of the manuscript. All authors contributed to conception and design of the study. All authors contributed to manuscript revision, read, and approved the submitted version.

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