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Commentary – Earth Credits: a science-based framework for sustainable planetary policy beyond carbon

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Abstract

Humanity's global footprint now far exceeds Earth's capacity to renew resources and absorb waste. Recent studies show that several ecological thresholds have been surpassed, some of which experts have deemed critical. Six of the nine safe planetary boundaries, as specified in Steffen et al (2015), have already been breached, leading to unprecedented biodiversity collapse, resource depletion, and increased climate risk. Staying within a "safe operating space" is crucial to prevent an irreversible environmental change (Rockström et al 2009). In practice, however, many large-scale developmental activities go unchecked, while ignoring the enormous stresses on water, soils, nutrients, and species. To address this urgent unmet need, we propose an Earth Credits Framework (ECF): a unified accounting system that quantifies a project's total planetary consumption, integrates the existing carbon credit system, and establishes a limit on the number of Earth Credits that can be justifiably allocated within the nine planetary boundaries. With sufficient data and accepted standards, ECF can offer governments, funders, and agencies a reliable compass for investing in truly sustainable outcomes.

Keywords: Earth Credits Framework; Carbon; Planetary Consumption; Planetary Boundaries; Climate Risk

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1. Planetary Overshoot

Earth system indicators paint a stark picture: climate change, biodiversity loss, land degradation, and water stress are well known (Shemer et al., 2023). Initially introduced by Rockström et al. (2009) and most recently refined by Richardson et al. (2023), the Planetary Boundaries framework defines a quantifiable "safe operating space" for humanity by identifying nine critical Earth-system processes that govern planetary stability: climate change, biosphere integrity, land-system change, freshwater change, biogeochemical flows, novel entities, ocean acidification, atmospheric aerosol loading, and stratospheric ozone depletion. The framework asserts that maintaining human activity within these limits is essential to preserve the Holocene-like conditions under which modern civilization evolved, while exceeding them risks triggering non-linear, potentially irreversible tipping points in the Earth system. Studies indicate that six of nine planetary boundaries (including biodiversity, land, and biogeochemical flows) have already been breached (Richardson et al 2023).

Trends suggest that biodiversity loss will worsen over time (Eastwood et al., 2022). Based on a global assessment of 29,400 terrestrial vertebrate species, Gerardo Ceballos and colleagues (2020) identified 515 species – approximately 1.7% of all evaluated vertebrates – as being on the brink of extinction. Alarmingly, nearly 94% of the populations of 77 critically endangered mammal and bird species have been lost over the past century. Predictions point to a disastrous outcome from the unabated extinction of species unless remedial measures are put in place immediately.

Data suggest that over 4.0 billion people (two-thirds of humanity) experience water scarcity for at least 1 month per year, and 0.5 billion people suffer year-round. Intensifying droughts already threaten global food production and health. Intensive agriculture and deforestation have degraded land, eroding soil fertility, disrupting water cycles, and impacting food systems (Timmis & Ramos 2021).

2. The Earth Credits Concept

The Earth Credits Framework (ECF) extends the accepted format of carbon credits into a more comprehensive planetary ledger. Instead of counting only tonnes of CO_2, ECF aggregates a project's impacts on all major dimensions of the Earth system.

Just as a financial credit score reflects risk based on our economic behaviour, the Earth Credit Score (ECS) would reflect the health and resilience of our planet. The nine planetary boundaries would serve as its core benchmarks. Every time we cross one, the score falls—signalling that humanity is building an unsustainable ecological debt and pushing the Earth closer to systemic environmental failure.

If adopted, each proposal or policy would be assigned an Earth Credit Score (ECS) – a composite metric reflecting resource depletion, emissions, waste generation, and ecological damage relative to scientifically-grounded thresholds. A low ECS means a project operates primarily within Earth's regenerative capacity; a high ECS flags excessive impact.

ECS will be calibrated by normalizing a project's total biophysical impacts against Earth's scientifically defined regenerative limits, weighting them by systemic ecological risk, and integrating them across space and time.

It is essential to set planetary boundaries that account for physical flows in measurable units. Calibration of each parameter would require absolute reference limits that map to the safe operating envelope defining biophysical limits within which humanity can safely operate without destabilizing Earth's life-support systems.

The ECS must be scale-independent (i.e., local, national, regional, or global levels) and universally comparable. Weights will be assigned based on irreversibility, tipping risk (i.e., irreversible collapse of the system), time to recovery, cross-boundary additive effects, and so on. A low ECS would be planetary-compliant, and a high ECS would trigger an ecological risk signal.

ECS must be time-normalized (i.e., real planetary change, not short-term fluctuations), consider natural resource vulnerabilities (robust vs. fragile ecosystems), and remain anchored in ground-level data.

The ECF framework is actionable, as it integrates existing accounting tools into a unified platform, leaving room for further innovation and aligning with planetary thresholds to support more effective decision-making.

In this model, every project would undergo a life cycle analysis (LCA) not only for carbon but also for water use, land use, and materials. Established standards, including the IPCC carbon budgets for greenhouse gases, the IUCN Red List/HCV approach for biodiversity, the Water Footprint Network methodology for water use, and global material flow analysis for resource inputs and waste, would form the basis of the ECS calculator. A brief explanation of these standards is below.

The advantage of these standards is that they are based on a strong scientific foundation, as these collectively define the validated biophysical limits of the Earth system and enable ECS to operate as a globally interoperable, regulatory-grade planetary accounting instrument. These particular standards are chosen because, together, they form the most authoritative, scientifically validated, and globally interoperable measurement system for the Earth's life-support processes. Each one anchors a key planetary dimension of the Earth Credit Score (ECS) in hard biophysical science, rather than market-driven or voluntary metrics.

The IPCC carbon budgets are globally accepted, rooted in climate physics, earth system modeling, and observational data, and align with international climate law and policy. Without IPCC budgets, ECS would lack a credible planetary reference for climate impact. The IPCC does not govern biodiversity loss, material throughput, chemical pollution, planetary limits beyond carbon, and accounting systems required for sustainable Earth-system governance.

The International Union for Conservation of Nature (IUCN) Red List and High Conservation Value (HCV) framework provide the most comprehensive global system for quantifying biodiversity risk, ecosystem fragility, and extinction probability. The IUCN/HCV is a globally harmonized system that links species survival, habitat integrity, and ecosystem services.

Likewise, the Water Footprint Network (WFN) provides a spatially explicit, hydrologically grounded accounting of water use, making ECS hydrologically sensitive rather than just volumetric. Water scarcity is local and basin-specific, not global. This methodology will allow ECS to integrate regional ecological vulnerability into its scoring.

The Material Flow Analysis (MFA) is a comprehensive framework that captures mineral depletion, biomass harvest, construction materials, industrial waste, and tailings i.e., unwanted products generated after mining and mineral processing. The MFA is indispensable, as carbon and water alone do not capture: rare-earth depletion, structural material lock-in, circularity failures. This integration makes ECS multidimensional (not carbon-myopic), threshold-based, real-world, and globally interoperable (comparable across nations and sectors).

These metrics will then be compared against planetary "budgets" or safe limits. For instance, an ECS would penalize deforestation or nitrogen pollution in proportion to how far these pressures exceed sustainable thresholds. By contrast, activities that restore ecosystems (such as reforestation and regenerative agriculture) or utilize waste streams (circular materials) would earn positive credit or lower scores.

Planetary budget benchmarking under the Earth Credit Score will be subject to continuous global and regional recalibration to reflect evolving Earth system science, dynamic ecological risk, and location-specific carrying capacities. The ECS must operate at both international and region-specific scales. This is essential for scientific accuracy, regulatory fairness, and ecological relevance in the real world.

Planetary budgets and safe limits are not static numbers. They evolve as Earth system science improves and as environmental conditions change over time. Without recalibration, ECS would quickly become scientifically obsolete and regulatorily unreliable.

If a planetary boundary is exceeded (e.g., nitrogen loading or forest loss), the remaining safe operating space will obviously contract. ECS must therefore tighten thresholds over time, and increase penalty intensity for high-impact activities.

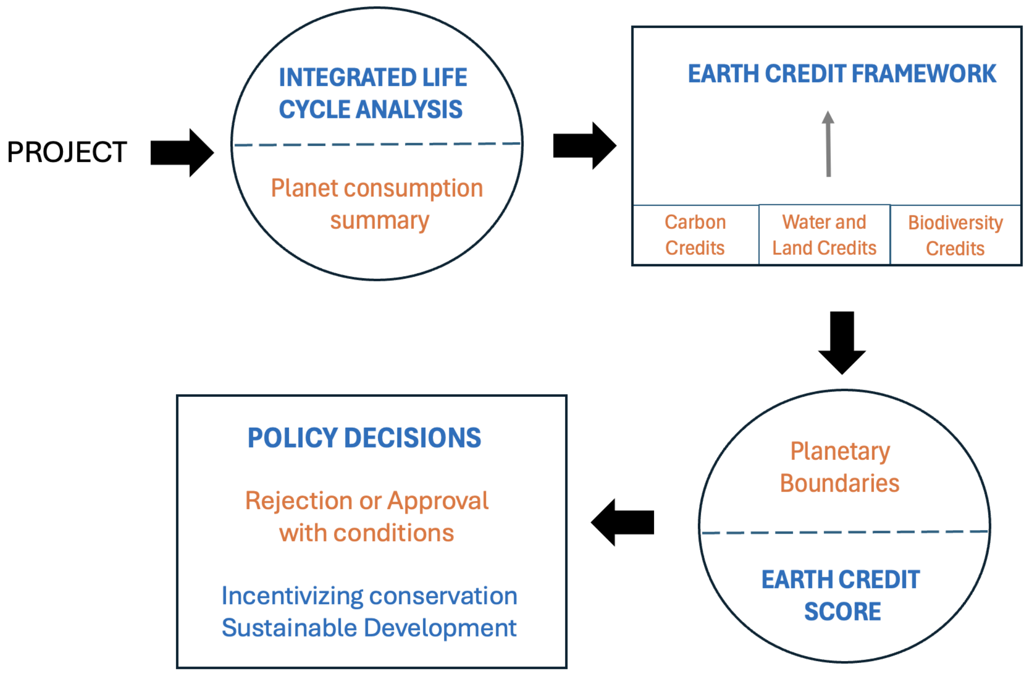
Positive Earth Credit Score weights shall be assigned based on verified ecological gain, benefit permanence, regional vulnerability, and systemic repair value. They shall be periodically recalibrated in line with evolving Earth system science.

Based on such data, funders will evaluate whether the anticipated benefits sufficiently outweigh the costs to warrant investment in each project. This approach is not academic but pragmatic: it stitches together tools already used by experts. The added value is systematizing them in funding decisions. Every grant or infrastructure loan could require an Environmental and Social (E&S) evaluation, making environmental trade-offs explicit upfront.

The intent is not to propose direct financial incentives or subsidies; instead, frame environmental and social (E&S) evaluation as a mandatory screening criterion for funding decisions. Funders will be incentivized to incorporate these assessments because they reduce risk, protect capital, and align with ESG and regulatory requirements. Compliance could become a mandatory condition for grants, loans, or other development financing, ensuring that projects meet sustainability thresholds before funding is disbursed.

While such E&S evaluations could initially be implemented at the national level through domestic regulations and funding protocols, full effectiveness for cross-border projects would require international coordination. Enforcement would rely on conditionality in financing, whereby funding is contingent on compliance, and monitoring could be achieved through third-party verification, audits, and remote sensing, similar to mechanisms used in climate finance and multilateral development programs.

Figure 1: Overview of the Earth Credits Framework



Project impacts on carbon, biodiversity, water, land, and waste are quantified (via LCA, footprint models, and IUCN indicators) and aggregated into an Earth Credit Score. Scores are benchmarked against science-based sustainability thresholds (the planetary boundaries) to guide policy and funding decisions.

Several features distinguish the Earth Credits approach from piecemeal approaches:

- Unlike carbon offsets, Earth Credits track biodiversity loss, soil degradation, water depletion, pollution, and resource use in a **multi-dimensional and unified** way. For example, a mining project's ECS would reflect not only its emissions but also habitat destruction, water withdrawal, tailings waste, and chemical runoff.
- The ECS scores will be calibrated to **science-driven thresholds** aligning with global standards. ECS calibration should integrate global scientific thresholds for planetary consistency and local ecological limits, to ensure scores are both internationally comparable and locally meaningful. Global norms provide absolute planetary ceilings, while local norms provide contextual calibration. For climate, IPCC carbon budgets apply; for biodiversity, limits might derive from "safe operating space" values (e.g., the percentage of species loss); for nutrients, the planetary boundaries or Earth system limits (van Vuuren et al 2025).
- Projects that restore nature earn credit and lead to **regeneration incentives**. For instance, a wetland restoration could yield "negative ECS" by sequestering carbon, filtering water, and providing habitat, effectively offsetting high-impact activities elsewhere.
- Earth Credits would estimate how long ecosystems need to recover from project impacts i.e., **regeneration time**. Projects with rapid reclamation or recyclability get better scores. For example, an innovation that utilizes reclaimed materials and on-site remediation would score much more favourably than one that causes long-term ecosystem destruction.

Several key aspects of the ECF framework need to be mentioned here.

- A development project meeting climate goals might still score high (bad) if it wrecks forests or pollutes rivers.
- Development in biodiversity hotspots (e.g., tropical forests) in return for project funding would secure endangered species and lower the ECS.
- Local scarcity indicators would weight a manufacturing industry's water withdrawals. Activities that convert rainforests or farmlands incur extra credit penalties.
- Life-cycle material use and waste flows (via material flow analysis) would be accounted for and embedded in policy decisions. Conceptually, the ECF translates every activity into "hectares of Earth used per year" or similar lingua franca, making trade-offs transparent.

A case in point is the Belo Monte Hydroelectric Dam in Brazil that illustrates the Earth Credit Score (ECS) framework, where significant local ecological impacts outweigh climate-positive outcomes. Despite low lifecycle greenhouse gas emissions, the project's deforestation of ~4,000 hectares and disruption of endangered species habitats would drive a high ECS, further compounded by regionally weighted water and material use. This example demonstrates that ECS can capture the interplay of global and local thresholds, life-cycle flows, and ecological sensitivity, providing a transparent, integrated metric for evaluating environmental trade-offs.

3. Policy Pathways: From Theory to Action

- Governments would require an ECS assessment for all significant spending. For instance, infrastructure projects (such as roads, dams, and factories) would need to meet an ECS threshold. Those failing would be shelved or redesigned.
- National development banks and ministries could set sectoral ECS targets.
- Private organizations should not be allowed to set Earth Credit Score (ECS) baselines, as doing so could introduce conflicts of interest, bias the evaluation in favor of commercial priorities, and undermine the scientific integrity of the metric.
- Establishing baselines must remain a function of independent, impartial, and science-driven institutions to ensure that ECS reflects genuine planetary limits rather than short-term economic interests.
- An aggregated national "Earth Credits account" could complement GDP in budget planning, tracking how economic growth affects the nation's natural capital.
- Projects that involve field studies, labs, or new products would submit an Earth Credit Impact Statement, analogous to ethical or safety reviews. For example, a biomedical research institute building a new lab would estimate resource use, waste, and habitat disturbance. Funding would favour "green labs" with minimal water and energy waste.
- Over time, Earth Credits could become a discipline – scientists specializing in carbon, water, and biodiversity accounting would produce standardized ECS databases and tools.
- For development agencies and investors, multilateral lenders (such as the World Bank, the Asian Development Bank, and the Green Climate Fund), ECF would enable them to quantify the global footprint.
- Global Donor agencies could integrate ECS into their grant evaluation, aligning foreign aid with planetary sustainability. Private investors could use ECS as an ESG metric; impact investors would screen portfolios for low ECF scores.

4. Data-Driven Support

- Data from IUCN Red List, GBIF species records, and remote sensing can quantify project impacts (Ceballos et al. 2020)
- Global hydrology models yield precise water-stress indices by region and season (Wada et al., 2011). These feed directly into ECS water-use scoring.

- Studies have attempted to quantify safe nitrogen/phosphorus cycles as planetary boundaries (Steffen et al 2015). Soil carbon mapping (E.g., SoilGrids) and land degradation assessments (IPCC report 2023) enable ECS to capture the impacts on soil health.
- The IPCC and EM-DAT databases provide damage functions that link ecosystem loss to climate resilience and disaster risk, which can be internalized in scores.
- Over time, machine-readable databases (such as remote sensing of land change and biodiversity monitoring networks) could automate much of the ECS calculation, just as carbon life-cycle tools are now widely used. Open-source software frameworks for integrated environmental accounting already exist; ECF would extend and unify them.

5. Conclusion

Every innovation extracts a cost from the planet – a ledger of that cost is no longer abstract – it is ecological, measurable. Clearly, we cannot continue to consume the Earth forever! The moment has arrived for a new planetary metric that goes beyond carbon alone, building on its success while accounting for the full spectrum of material, ecological, and biophysical limits. In an age when resources are stretched thin, ecosystems are collapsing, and the climate crisis grows more urgent by the day, one question looms large: How much more can the planet give before it gives out entirely?

Our Earth is finite, but human desires are infinite. Earth Credits bring a fresh perspective and introduce a framework of planetary responsibility that calls for global deliberations, growth calibrations, and consumption standards. By anchoring development in real biophysical data, dynamic life-cycle assessments, and inclusive projections, the Earth Credit System offers a practical architecture for sustainable development. To meet the United Nations Sustainable Development Goals, the need of the hour is to operationalize planetary boundaries into everyday decision-making. The future of growth must be measured not by expansion alone, but by regeneration and conscious consumption.

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