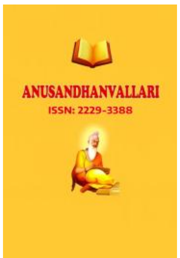

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Environmental Economic Accounting: Bridging Modern Statistical Frameworks, Ancient Indian Statecraft, and Contemporary Governance

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Abstract: This paper presents a rigorous theoretical and philosophical appraisal of environmental-economic accounting frameworks, explicitly bridging contemporary macroeconomic metrics with classical Indian ecological ethics. We dissect the systemic limitations of traditional macroeconomic indicators, mapping the evolution of the United Nations System of National Accounts (SNA) toward the contemporary System of Environmental-Economic Accounting (SEEA) Ecosystem Accounting standard. Moving beyond purely mechanical critiques, we demonstrate how modern market failures and ecological decoupling stem from a worldview that separates human industry from the biophysical matrix.

To resolve this, we explore how integrating traditional Indian knowledge systems (IKS) specifically Kautilya's institutional resource auditing and the holistic *Pancha Mahabhuta* paradigm provides a philosophical foundation for modern strong sustainability. We conceptually evaluate intertemporal optimization, capital accumulation dynamics, and Green Net National Product (GNNP) through descriptive welfare paradigms, eliminating the abstractions of rigid mathematical modelling. Finally, these frameworks are contextualized using global empirical assessments of water tariff volatilities alongside a critical macro-evaluation of India's Environmental Impact Assessment (EIA) regulatory evolution, highlighting the institutional disconnect between national data reporting and localized environmental governance.

Keywords: Environmental Accounting, SEEA, Indian Knowledge Systems, Kautilya's Arthashastra, Environmental Impact Assessment, Sustainable Macroeconomics.

1. Macro Welfare Framework

Traditional macroeconomic paradigms have historically decoupled the industrial engine from its ecological matrix. Sustainable accounting rectifies this structural omission by formalizing the feedback loops between aggregate income generation and the depletion or degradation of biophysical capital stocks. In the absence of an integrated environmental economic calculus, standard indicators of national performance yield distorted signals, conflating the liquidation of natural assets with sustainable economic growth.

To establish a micro-founded, intertemporal social welfare framework, economic theory relies on a continuous social welfare function where aggregate well-being is determined by both market consumption and the overall qualitative stock of environmental amenities. This welfare path is discounted over time by a positive pure rate of social time preference, balancing current industrial utility against intergenerational equity. Within this framework, aggregate production is constrained by available inputs: manufactured physical capital, labor, technological efficiency, and the extraction flow of natural resources.

The long term trajectory of the economy is governed by the concurrent dynamics of physical and natural capital accumulation. While physical capital expands through industrial investment and contracts via structural depreciation and defensive expenditures aimed at mitigating degradation, the natural resource stock evolves based on its inherent biological regeneration rates balanced against human extraction. When extraction continuously outpaces biological regeneration, the underlying asset base contracts, rendering short-term consumption expansions inherently unsustainable.

2. Traditional SNA Formulations

The standard macroeconomic accounts established under the conventional System of National Accounts (SNA) compute aggregate output through a restricted market-transaction lens. Under this classical approach:

- **Gross Domestic Product (GDP)** is calculated strictly as the market value of final goods and services produced within a nation, driven by consumption, investment, government spending, and net exports.
- **Net Domestic Product (NDP)** is derived by deducting the physical depreciation of manufactured capital from GDP.
- **National Income** is further adjusted to account for net factor income from abroad.

Three Systemic Shortfalls of Conventional SNA

1. **The Institutional Market Boundary:** Standard accounts capture output transactions if and only if they command an easily observed market price. Non-marketed environmental amenities, biodiversity balances, and subsistence-level resource extractions are excluded.
2. **Unpriced Environmental Input Flows:** The deployment of crucial ecosystem services, such as carbon sequestration and hydrological regulation, enters industrial production functions as zero-priced intermediate inputs, artificially inflating corporate surplus and aggregate GDP.
3. **Asymmetric Capital Depreciation:** While manufactured assets are subject to continuous capital consumption allowances via depreciation deductions, no corresponding balance sheet adjustments are made for the depletion of finite resources or the qualitative degradation of natural ecosystems.

3. Paradigm Shifts in the SNA (1953 to 2024)

The historical trajectory of the United Nations SNA highlights a gradual transition from strict market-centric accounts to integrated institutional balance sheets that better reflect ecological realities.

SNA Iteration	Core Structural Focus	Treatment of Natural Capital
1953 SNA	Post-WWII macroeconomic reconstruction; foundational Keynesian identities.	Entirely omitted; natural resources treated as infinite, free endowments.
1993 SNA	Post-Soviet global integration; harmonization with international financial frameworks.	Introduction of satellite asset accounts; expansion of asset boundaries to include software and mineral exploration.
2008 SNA	Comprehensive balance-sheet accounting; institutional sector mapping.	Formal recognition of commercial natural assets (land, timber, subsoil minerals) with enforceable ownership rights.
SNA 2024	Full institutionalization of	Direct harmonization with SEEA

	environmental accounting and holistic well-being.	guidelines; comprehensive recording of natural capital as formal capital assets, expanding boundary definitions to trace ecological depletion directly within core accounts.

4. Philosophical Foundations

Modern environmental-economic frameworks often struggle with the conceptual division between humans and nature, treating the environment strictly as an external asset pool to be liquidated or maintained based on utility. To build a truly comprehensive accounting structure, contemporary economics can integrate the deep ecological insights embedded within traditional Indian knowledge systems.

Classical Indian thought addresses economic sustainability through the foundational paradigm of the **Pancha Mahabhutas**: the five primordial elements consisting of Earth (*Prithvi*), Water (*Apas*), Fire (*Tejas*), Air (*Vayu*), and Space (*Akasha*). Rather than classifying these components as unpriced externalities or separate economic sectors, traditional Indian cosmology views human systems as intrinsically nested within this biophysical matrix. Welfare is defined not by linear asset accumulation, but by maintaining cosmic and ecological order (*Rta*), implying that the disruption of any single elemental block destabilizes the entire social fabric.

Furthermore, historical Indian statecraft demonstrates early, functional models of institutional resource accounting. In Kautilya's *Arthashastra*, natural capital preservation is treated as a core pillar of state treasury management and long-term state survival. Kautilya established a structural regulatory framework for resource auditing, appointing specific superintendents over forests and water bodies. These officials were tasked with calculating resource regeneration rates against extraction flows, enforcing strict penalties for ecological degradation, and treating public commons as assets held in state trust.

Integrating this IKS-derived perspective into modern macroeconomic theory shifts the foundational paradigm of natural resources from "infinite consumer assets" to a model of sacred, finite stewardship, offering profound historical validation to the principles of strong sustainability.

5. Capital Substitution Foundations

The representation of ecological sustainability divides into two competing conceptual frameworks based on the elasticity of substitution between manufactured capital and natural capital.

Weak Sustainability

Weak sustainability assumes that the total capital stock the sum of physical, human, and natural capital is the primary determinant of intertemporal welfare. It operates on the premise that technical progress can engineer synthetic substitutes for depleted ecosystem services, implying an infinite elasticity of substitution. Under this paradigm, a declining natural capital stock is ethically and economically permissible, provided there is a compensatory, value-equivalent expansion in physical infrastructure or intellectual capital.

Strong Sustainability

Strong sustainability posits that natural capital provides unique, non-substitutable biophysical functions, such as climate stability and life-support systems, that exhibit critical thresholds and tipping points. It implies a near-zero elasticity of substitution, mandating that the physical integrity of critical natural capital stocks must be preserved intact across generations.

The Critical Threshold Hypothesis: Beyond a specific ecological boundary, the marginal social cost of environmental liquidation approaches infinity, rendering further substitution impossible. Recent frameworks formalize these ecosystems as **Systemically Important Natural Systems (SINS)** macro-critical infrastructure whose destabilization poses existential systemic risk to financial and economic systems.

6. Intertemporal Micro-foundations

The translation of sustainability principles into accounting metrics stems from the Hicksian conception of income: the maximum value an economy can consume during a period while remaining on a trajectory to consume an identical amount in the subsequent period. This guarantees that current consumption patterns do not compromise the welfare of future generations.

For an economy heavily reliant on the extraction of an exhaustible resource, a literal application of non-substitution would require subtracting the gross value of resource extractions from national income.

To operationalize this under a weak sustainability framework, the **Hartwick Rule** dictates that a constant consumption path can be maintained perpetually if the entire scarcity rent derived from resource extraction is systematically reinvested into reproducible physical capital. This scarcity rent, often referred to as Hotelling rent, represents the competitive market price of the resource minus its marginal extraction cost. By maintaining the total capital value constant through active reinvestment, the economy converts a wasting asset into a permanent productive annuity.

7. Forest Dynamics

Forest ecosystems present severe non-linear accounting challenges due to their dual identity as both a macro-economic flow variable (timber output) and an ecological stock variable (carbon sinks, biodiversity protection, and soil stabilization).

Four Primary Accounting Vulnerabilities

1. **Divergence Between Depreciation and Depletion:** Standard linear depreciation models fail to capture the ecological degradation of forests, where canopy fragmentation and topsoil loss disrupt ecosystem resilience non-linearly.
2. **Asymmetric Biomass Growth Tracking:** Biomass accumulation happens via two disparate mechanisms: natural regeneration and anthropogenic silvicultural plantation. Distinguishing these requires high-resolution spatial auditing to avoid misclassifying monoculture expansions as ecological recovery.
3. **Informal Resource Extraction Flows:** In developing economies, a substantial fraction of forest product extraction occurs via informal, non-marketed channels, such as artisanal fuelwood collection, creating massive data gaps in national input-output tables.
4. **Stochastic Natural Disturbances:** Episodic shocks such as forest fires, pest infestations, and climate-induced landslides alter the asset balance sheet unpredictably, requiring complex actuarial tracking under national accounting frameworks.

8. Specification of Green Net National Product (GNNP)

To capture these dynamics within a comprehensive accounting framework without relying on mathematical abstractions, we define **Green Net National Product (GNNP)** conceptually as an adjusted measure of true national welfare.

GNNP modifies standard macroeconomic accounts by taking the sum of private and public consumption aggregates and adding net investments in manufactured capital stocks. It then applies critical ecological corrections:

- It scales net changes in the natural capital stock accounting for natural and anthropogenic biomass growth minus raw resource extraction and stochastic environmental shocks by their estimated shadow prices.
- It adds the imputed value of unpriced utility flows derived directly by citizens from environmental amenities.
- Crucially, it **deducts** all defensive capital expenditures, such as the deployment of water purification systems and air filtration networks, to avoid the systemic distortion of double-counting intermediate mitigation costs as final welfare consumption.

9. Valuing Non-Market Environmental Assets

When market clearing prices are missing for ecological services, environmental economists deploy microeconometrically grounded non-market valuation techniques to determine shadow prices.

Revealed Preference Methods

Revealed preference models deduce the shadow price of environmental goods by observing consumer choices in parallel, interrelated market structures.

- **The Hedonic Pricing Model:** Isolates the environmental amenity premium embedded within property values by evaluating housing prices against a vector of structural attributes and local environmental quality indicators, such as localized air quality indices.
- **The Travel Cost Method:** Uses the opportunity cost of travel time and direct expenditures incurred by visitors to map out consumer surplus and derive a demand curve for recreational ecosystems.

Stated Preference Methods

When non-use values, such as existence value and bequest value, dominate an ecosystem, economists construct hypothetical markets via stated preference frameworks.

- **Contingent Valuation Method (CVM):** Employs structured bidding games or open-ended surveys to directly solicit an individual's Willingness to Pay for environmental preservation or Willingness to Accept environmental degradation.

Methodological Warning: Stated preference methods are highly prone to systematic cognitive biases, including strategic maneuvering, hypothetical bias, and embedding effects, requiring strict statistical validation controls before integration into national accounts.

10. The SEEA Framework

The **System of Environmental-Economic Accounting (SEEA)** bridges environmental statistics and the core SNA framework. Consolidating updates from the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA), the framework splits into two complementary standards:

1. **The SEEA Central Framework (SEEA CF):** Takes a resource-based approach to measure the physical and monetary flows of energy, water, and materials between the environment and the economy.
2. **The SEEA Ecosystem Accounting (SEEA EA):** Formally adopted as an international statistical standard, it uses a spatially explicit approach to measure ecosystem extent, environmental condition, and the physical and monetary flow of ecosystem services across defined landscapes.

Core Policy Alignment

- **Global Biodiversity Monitoring:** Provides the empirical baseline for compiling indicator matrices under the Kunming-Montreal Global Biodiversity Framework.
- **Climate Change Tracking:** Directly aligns greenhouse gas emission footprints with industrial sector classifications via Environmentally Extended Input-Output models, matching carbon output to specific components of final demand.
- **Embedded Sustainability Integration:** Empowers national-level policy-makers to embed long-term sustainability considerations into national accounting rather than leaving environmental variables to disconnected satellite records.

11. Global Resource Pricing Dynamics

Data from global urban infrastructure surveys reveals a profound market distortion at the heart of resource economics: an inverse relationship often exists between localized water scarcity and municipal water pricing.

The Water Pricing Paradox

In regions facing acute physical scarcity, water tariffs are frequently heavily subsidized due to institutional constraints and political economy considerations. These under-priced assets lead to severe fiscal stress for utilities, preventing necessary capital reinvestment into wastewater management and distribution networks, which accelerates localized depletion.

Conversely, metropolitan areas with higher GDP per capita and lower baseline water stress often feature higher, cost-reflective water and wastewater tariffs. This revenue generation supports advanced recycling, efficient desalination, and robust climate-resilient infrastructure.

Macroeconomic Transmission Channels of Scarcity

- **Supply Shocks:** Acute water shortages hit rain-fed and irrigated agricultural systems directly, triggering upward pressure on primary food prices and importing inflation into secondary processing industries.
- **The Wastewater Asymmetry:** Wastewater treatment requires higher capital and operational expenditure per cubic meter than primary drinking water purification. When macroeconomic shocks hit urban budgets, wastewater infrastructure tariffs are often compressed, leading to a breakdown in treatment protocols and a rise in waterborne disease externalities.

12. India's EIA Regulatory Evolution

At the micro-project level, structural accounting tools interface directly with environmental law via the **Environmental Impact Assessment (EIA)** process. Originally governed by the landmark 2006 Notification under the Environment (Protection) Act, 1986, India's environmental clearance architecture has undergone significant structural transformations through recent regulatory amendments.

Key Regulatory Shifts and Contemporary Criticisms

- **The PARIVESH 2.0 Architecture:** Transitioned the entire regulatory workflow including Screening, Scoping, Appraisal, and Clearance issuance onto a centralized digital platform to improve transparency and standardize compliance tracking. However, critics argue this automated efficiency serves to fast-track approvals at the expense of comprehensive, on-site ecological appraisal.

- **Climate Change and Carbon Footprint Integration:** Contemporary EIA regulations mandate projects to model their long-term carbon emissions profile and evaluate climate resilience capabilities, aligning project clearances with national net-zero commitments. Nonetheless, actual implementation often remains shallow, excluding key downstream Scope 3 emissions.
- **The "B2" Exemption and Threshold Loopholes:** A structural dilution within contemporary Indian environmental law is the systematic expansion of the "B2" project classification, which entirely exempts a wide array of industrial actions from scoping and public hearings. By relying on rigid capacity thresholds rather than regional ecological vulnerability, major infrastructural projects are permitted to expand without localized stakeholder consensus or rigorous judicial risk vetting.
- **Urban Hydrological Failures:** Systematic evaluations of high-profile urban developments—such as those surrounding New Delhi and the Yamuna floodplain—demonstrate that while individual projects technically secure clear environmental checkpoints via automated portals, the absolute absence of strategic and cumulative baseline assessments leaves long-term regional river water quality and topsoil tables completely degraded.

13. Conclusion

The transition from traditional national accounting systems to integrated environmental-economic accounting is a structural necessity for sustainable macroeconomic policy. By adjusting the System of National Accounts via the modern SEEA standard and formalizing natural capital depreciation, green accounting fundamentally redefines how we measure economic progress. These modern frameworks achieve greater conceptual completeness when anchored in traditional Indian knowledge systems, which replace the view of nature as an exploitable externality with an ethos of holistic stewardship based on the *Pancha Mahabhutas*.

At the macro level, correcting resource pricing distortions—such as the water tariff scarcity paradox—is essential to prevent total asset depletion. At the micro level, integrating carbon accounting and ecosystem tracking into regulatory tools like the updated EIA framework ensures that capital formation does not come at the expense of long-term ecological stability. Resolving the institutional gap between Ministry of Statistics and Programme Implementation (MoSPI) data reporting and Ministry of Environment, Forest and Climate Change (MoEF&CC) field-level clearances is paramount to ensuring that national asset generation converts resource depletion into intertemporal wealth preservation.

Comprehensive Analytical Matrix of Accounting Adjustments

To operationalize the theoretical principles established across this paper, the following matrix outlines the required accounting corrections to transform standard macroeconomic indicators into sustainable, ecologically adjusted metrics:

National Account Target	Nature of Ecological Distortion	Required Conceptual / Statistical Correction	Resulting Target Metric
Gross Domestic Product (GDP)	Treats unpriced ecosystem asset liquidations as net positive output; completely omits non-market welfare flows.	Add imputed shadow values of non-market environmental services and resource self-consumption. Deduct intermediate defensive expenditures.	**Adjusted Gross Output**

Net Domestic Product (NDP)	Isolates capital consumption allowances strictly to physical, man-made infrastructure.	Subtract the monetary value of natural capital depletion and qualitative environmental degradation.	**Environmentally Adjusted NDP (EDP)**
Capital Balance Sheets	Overstates net national wealth variations by ignoring the depletion of subsoil and biotic assets.	Integrate physical and monetary natural resource accounts using SEEA Central Framework asset boundaries.	**Comprehensive Wealth Index**
Sectoral Gross Value Added (GVA)	Obscures the carbon and resource intensity profiles of distinct industrial classifications.	Divide sectoral GVA by total physical resource throughput and greenhouse gas emissions to calculate micro-targeted efficiency metrics.	**Green Sectoral Efficiency Ratios**

References

[1.] Beutel, J. (2025). Environmentally extended input-output tables for Germany. *AIMS Environmental Science*, *12*(2), 180–205.

[2.] Bhattacharya, R. N. (2001). *Environmental Economics: An Indian Perspective*. New Delhi: Oxford University Press.

[3.] Blanchard, O. (2017). *Macroeconomics*. Pearson.

[4.] Bradeen, E., et al. (2026). *Integrating climate considerations into environmental impact assessments: A global comparative review*. Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

[5.] Devarhubli, G., & Shrivastava, A. (2024). The advancement of environmental procedural rights in India: an analysis of issues, problems and prospects. *Cogent Social Sciences*, *10*(1), 1–18. https://doi.org/10.1080/23311886.2024.2312949

[6.] Edens, B., Maes, J., Hein, L., Obst, C., Siikamaki, J., Schenau, S., Javorsek, M., Chow, J., Chan, J. Y., Steurer, A., & Alfieri, A. (2022). Establishing the SEEA Ecosystem Accounting as a global standard. *Ecosystem Services*, *54*, 101413. https://doi.org/10.1016/j.ecoser.2022.101413

[7.] Global Water Intelligence (GWI). (2020). *Global Water Tariff Survey 2020*. Market Research Report.

[8.] Hicks, N. (1979). Indicators of Development: The Search for a Basic Needs Yardstick. *World Bank Reprint Series*.

[9.] Jha-Thakur, U. (2023). Three decades of EIA reforms in India: reflections on the complexities of simplifications. *Impact Assessment and Project Appraisal*, *41*(4), 244–248. https://doi.org/10.1080/14615517.2023.2208397

[10.] Khataniar, A. B., & Barua, B. (2016). Strong or weak sustainability: A case study of emerging Asia. *Asia-*

Pacific Development Journal.

[11.] Kritika, K., & Kumar, R. (2026). Review of Environmental Impact Assessment Applications in New Delhi's Urban Development: A Systematic PRISMA Review. *Integrated Environmental Assessment and Management*, vjag041. https://doi.org/10.1093/inteam/vjag041

[12.] Mayer, B. (2025). Climate Effects in Environmental Impact Assessment. *Transnational Environmental Law*, 1–23. https://doi.org/10.1017/s2047102524000402

[13.] Ministry of Environment, Forest and Climate Change (MoEF&CC). (2025). *EIA Notification 2006 and Subsequent Amendments up to 2025*. Government of India.

[14.] Ministry of Statistics and Programme Implementation (MoSPI). (2026). *EnviStats India: Frequently Asked Questions (FAQ) 2026*. Government of India.

[15.] Mohapatra, S. (2025). *The water paradox in India: Managing abundance amid growing scarcity* (NCAER Working Paper No. 182). National Council of Applied Economic Research.

[16.] Mukhopadhyay, P. (2026). Nature and human well-being: Theory, policy and practice. *Ecology, Economy and Society*, *9*(1), 101–115. https://doi.org/10.37773/ees.v9i1.1926

[17.] Nxumalo, P. N. (2026). Evaluating the Effectiveness of Environmental Impact Assessment in Flood-Prone Areas: A Systematic Review of Methodologies, Hydrological Integration, and Policy Evolution. *MDPI Sustainability*, *18*(2), 768.

[18.] Ranger, N., Philip, T., Tayler, T., & O'Donnell, E. (2026). *Too big to fail: Critical natural systems as macro-critical infrastructure*. Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science.

[19.] Shrivastava, A., & Gurpur, S. (2024). Critical evaluation of EIA Notification 2020 in India w.r.t Sustainable Development Goals and European Union best practices in climate change policy. *E3S Web of Conferences*, *491*(01008), 1–12. https://doi.org/10.1051/e3sconf/202449101008

[20.] United Nations. (2025). *System of National Accounts 2025*. United Nations Department of Economic and Social Affairs, Statistical Division.

[21.] United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA). (2025). *Global Assessment of Environmental-Economic Accounting 2025*. United Nations Statistics Division.

[22.] United Nations Statistics Division. (2012). *System of Environmental-Economic Accounting 2012: Central Framework*. New York: United Nations.

[23.] United Nations Statistics Division. (2021). *System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA)*. New York: United Nations.

[24.] Waylen, K., Patil, I., & Carmen, E. (2026). Can natural capital help national-level policy-makers to embed sustainability considerations? Insights from Scotland. *Ecological Economics*, *240*, 108150. https://doi.org/10.1016/j.ecolecon.2026.108150