Unequal Nitrogen Futures:
Linking Nitrogen Forms, Epistemologies, and Ontologies in Sustainable Development Science and Policy

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The increasing use of nitrogen fertilizer remains central to the process of agricultural change known as the Green Revolution and is one of the main drivers of present-day global environmental change. Although the "nitrogen challenge" has received limited attention compared to biodiversity loss and climate change, international scientific communities and organizations, including the United Nations Environment Programme, consider nitrogen a leading socio-ecological concern for the 21st century and a central pillar for the advancement of the 17 UN Sustainable Development Goals.

Since the 1960s, nitrogen has rapidly expanded from the domain of agricultural and environmental scientists to become a global governable chemical species. Today, about 80% of nitrogen produced as a nutrient intake for global food production is lost into the environment, causing a cascade of social and ecological effects that transcend traditional disciplinary, geographical, and political boundaries.

Although scientific knowledge on the impacts of nitrogen has increased, this corpus of knowledge has grown in a rather unequal way. Today what we considered nitrogen science combines a set of disciplines and bodies of knowledge where expert communities mostly focus on distinct nitrogen forms (e.g., N_2O, NO, or NH_3) or their effects in specific environmental media (e.g., soil acidification, eutrophication of coastal ecosystems). The chemical—and ontological—malleability of nitrogen across time and space has created a set of highly specialized expert communities. While assessing certain phases of these biochemical processes has been easier for some of these communities, other aspects remain unknown.

Today, *unequal* estimations of nitrogen flows—as an expression of the imbalanced scientific knowledge about the tradeoffs between different nitrogen forms and linked biogeochemical cycles—are considered critical for both the further advancements of nitrogen science and the place of nitrogen in the global governance arena. Major legal frameworks addressing nitrogen pollution have indeed followed the epistemic divisions embedded in nitrogen sciences. At a global level, this challenge becomes even more extensive. The UN Environment Programme is currently working with international scientific organizations to establish the "Inter-convention Nitrogen Co-ordination Mechanism" (INCOM), allowing for further coordination between countries, expert communities, conventions, and multilateral environmental agreements. However, relevant instruments to address nitrogen pollution are still divided into many regulatory bodies and intergovernmental organizations.

International scientific networks and organizations have been effective in institutionalizing nitrogen in the governance arena and the global sustainable development agenda since the early 1970s. However, uneven nitrogen flows and impacts, scientific assessments, and policy frameworks have remained across nitrogen governance research and practice. Examining epistemological and ontological inequalities in nitrogen management, science, and policy, this project highlights that official debates in global nitrogen governance and sustainable development policy have omitted additional questions about the inequality of international scientific and policy assessments. Unequal research capacity and priorities across national borders have entered the policy processes and reproduced existing power disparities among international agents and organizations. As in other environmental issues, the inequalities of nitrogen are today embedded in complex interactions of governance, biochemical systems, socio-cultural and farming practices, and competing economic and political pressures to allocate resources at both local and international scales.

Studying the imbalanced governance of global nitrogen flows offers an advantaged platform to expand discussions about the place of inequalities in earth systems governance and long-lasting power disparities among agents, including international scientific communities, farmers, policy frameworks, and chemical species. The biochemical variability of nitrogen, and its centrality for the functioning of modern agricultural markets and economies, make nitrogen a significant challenge for the future of governance systems at the intersection of the food-biodiversity-climate nexus. Nitrogen thus raises several questions about the "polycentric" nature of governance, the barriers to change of "non-governance" systems, and the role of ontological and epistemological multiplicity in addressing justice and agency issues in future human-earth governance systems.