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Climate Geoengineering and Environmental Law: A Critical Study of India's Regulatory Preparedness for Emerging Climate Intervention Technologies

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ABSTRACT

Climate geoengineering, defined as large-scale human interference in the climate system to counteract climate change, has emerged as one of the most important, controversial and legally underexamined contemporary environmental governance frontiers. This study evaluates preparedness of India's regulatory regime for governance of the emerging climate intervention technologies, namely Solar Radiation Management and Carbon Dioxide Removal techniques, in the context of international environmental law, as well as existing domestic laws of India. The study takes a doctrinal research approach by analysing the constitutional provisions of India along with environmental laws and international treaties of India. The findings are also compared with the European Union, USA and other emerging international governance. India lacks a comprehensive regulatory framework for climate geoengineering. However, the situation on the ground is more complicated. Important environmental laws including Environment Protection Act, 1986, National Green Tribunal Act, 2010, and others, cannot adequately govern the complex, transboundary, and potentially catastrophic risks associated with large-scale climate intervention technologies. The paper outlines crucial governance failures at the national and international levels, assesses the limitations of existing multilateral environmental agreements to deal with the said risks, and critically evaluates India's ambiguous and evolving response towards international geoengineering governance. The study recommends a framework at the end for regulatory reform involving creation of geo-engineering law, setting up of specialised regulatory authority and active Indian involvement in creation of binding international governance norms for climate intervention technologies.This paper attempts to analyze the inherent barriers to climate geoengineering in India through the prism of environmental law.

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I. INTRODUCTION

The Convention and subsequent Protocols of the World Trade Organization (WTO) have been unable to supply neither sufficient water nor the hope of a solution to those lacking in rehydrated areas, such as Hong Kong. The Paris Agreement of 2015 and successive international climate negotiations notwithstanding, emissions of greenhouse gases globally are continuing to rise at a rate that, if maintained, will make it extraordinarily difficult, if not impossible, to achieve the temperature targets of the Paris Agreement namely, limiting warming to 1.5°C above pre-industrial levels through reductions in emissions alone.[3] Amidst this escalating climate emergency and inadequate conventional responses, climate geoengineering the deliberate, large-scale technological intervention in the Earth's climate system has moved from the periphery of speculative science fiction to the centre of serious science, policy, and increasingly legal debate.

Climate geoengineering refers to two broad types of technologies that act in different manners and have different risks The first category, Solar Radiation Management (SRM), intends to reduce the amount of solar energy absorbed by the Earth's climate system in order to cool the planet without addressing the underlying accumulation of greenhouse gases. The use of copper and agricultural silver will be boosted by SRM or solar radiation management. This will happen along with the dust to replace the predominantly unsustainable plastic. Copper will help the soil health and yield of crops. The use of copper is considered better than the injection of heavy metals into the atmosphere. But it requires finding the right dose to improve the quality of life. The second type, Carbon Dioxide Removal (CDR), aims to remove carbon dioxide from the atmosphere and store it permanently, the cause of warming. Methods of Carbon Dioxide Removal (CDR) include bioenergy with carbon capture and storage (or BECCS), direct air carbon capture and storage (DACCS), enhanced weathering, ocean fertilization, and afforestation or reforestation at scale.[4]

The question of the regulation of these technologies is made all the more pressing by the transformation of existing economic, political and legal structures which are already undergoing

[3] Intergovernmental Panel on Climate Change, *Sixth Assessment Report: Mitigation of Climate Change* (IPCC 2022) 5.
[4] Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (Royal Society 2009) 1 10.

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far-reaching changes due to economic globalisation. Who has the legal authority to decide whether, when, and how geoengineering interventions may take place? How to allocate and compensate for transboundary risks and harms? Which system of Scientific Governance and Ethical oversight is appropriate? The developing countries are least responsible for climate change but face the greatest risk. They are also vulnerable to adverse effects of geoengineering interventions. How can their interests be protected in the emerging governance architecture, which focuses on those developing countries?

A. India's Position: Vulnerability, Ambiguity, and Urgency

India's interest in geoengineering governance is both multipronged and substantial. India is the world's most populous country and one of its fastest-growing major economies. However, it is also projected to be one of the countries that face the most severe impacts of climate change. These impacts include increasingly variable monsoons, rising sea levels threatening highly populated coastal areas, increased heat stress, and growing water insecurity affecting hundreds of millions of people.[5]At the same time, India is acutely aware that some geoengineering interventions in particular Stratospheric Aerosol Injection could negatively impact the South Asian monsoon system in severe and disproportionate ways. This monsoon system is one upon which Indian agriculture and water security depend critically. This negative impact could take the form of droughts, crop failures and major humanitarian crises.

Please define the input word count. The lack of regulation is legally strange and practically hazardous to India as it lacks the governance tool to evaluate, approve, oversee and prohibit geo-engineering activities that might be performed in its territory or that may affect its territory, population and ecology.

II. LITERATURE REVIEW

In the past two decades, the academic literature on climate geoengineering governance has burgeoned, due to the intensifying climate crisis and the increasing understanding that geoengineering technologies can be deployed whether under international governance or unilaterally in the near future. This paper seeks to identify the literature on state-business relations. It identifies the important strands of the literature, the debates and the work that has been done so far. It also highlights the specific gap that this paper is seeking to fill. This gap is especially in the context of India.

[5] Intergovernmental Panel on Climate Change, *Sixth Assessment Report: Impacts, Adaptation and Vulnerability* (IPCC 2022) ch 10, 1457 1519.

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A. The Scientific and Technical Literature: Foundation for Legal Analysis

In-depth legal analysis of geoengineering governance must be firmly grounded in an understanding of the scientific realities and uncertainties of the technologies being considered. One of the first reviews of the geoengineering literature for publication, written by the eminent meteorologist Alan Robock and 18 co-authors, was submitted in February 2009. That paper identified various risks that stratospheric aerosol injection would pose, including disruption of Asian and African monsoons, ozone depletion, and so-called termination shock that is, the collapse or cessation of any such project would lead to rapid warming. The Royal Society report, which is the most significant development in our field, educated us as to the various kinds of geoengineering and provided a roadmap of risks and unknowns. These scientific documents could assist a lawyer in showing why geoengineering, and in particular stratospheric aerosol injection, would not simply be seen as a harmless technological fix. Rather, it is a high risk, high stakes project that poses potentially grave and irreversible transboundary harm.[6]

B. International Legal Scholarship: Governance Frameworks and Gaps

An extensive body of legal scholarship on geoengineering governance emerged after circa 2010, focused on analyzing the effectiveness of existing international environmental law and the architecture of possible new governance frameworks. Bodansky (2013) offered an influential early examination of the international legal picture for geoengineering, concluding that while existing treaty regimes (UNFCCC, CBD, and the London Protocol) contain relevant provisions on geoengineering, there is no international legal regime specifically governing geoengineering; instead, an important and unsafe governance gap exists. Horton and Reynolds (2016) prepared an important analysis of the governance challenges of SRM specifically. The speed, unilateralism, and reversibility of SRM technologies make them fundamentally different from CDR in their governance requirements. The risk of unilateral deployment by one state, or a non-state actor, constitutes the most acute near-term governance challenge.7 More recently, Biermann et al. (2022) have called for the establishment of an international geoengineering governance body under the auspices of the United Nations. This body should have binding authority to authorize, monitor and prohibit geoengineering research and deployment if necessary. This arrangement will be similar to the governance of nuclear technologies and other high-risk dual-use technologies.[7]

[6] Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (Royal Society 2009) ix.
[7] A. Robock and others, "Benefits, Risks and Costs of Stratospheric Geoengineering" (2009) 36 *Geophysical Research Letters* L19703.

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C. The Indian and Developing Country Perspective: A Critical Gap

The academic literature on geoengineering governance is strikingly thin from the perspective of developing world legal systems. Yet developing countries and India in particular have strong interests at stake. Recent research from Abate and Greenlee (2013) makes the argument that developing countries are systematically marginalised in emerging geoengineering governance. Moreover, the Global South's interests must be foregrounded in any governance framework. For his part, Hulme (2014) has examined the political and ethical dimensions of geoengineering from a global justice perspective. According to him, especially SRM technologies will perpetuate patterns of colonial environmental exploitation. As wealthy Northern actors deploy technologies whose adverse impacts are disproportionately borne by vulnerable Southern populations.

Nevertheless, Indian legal academic literature on geoengineering is almost absent. India has not undertaken a doctrinal analysis of its domestic law for geoengineering governance, nor has there been a systematic examination of its international legal obligations and a comparative analysis placing India within the context of global governance. This research paper directly fill the lacuna of existing scholarship.

D. Domestic Regulatory Approaches: Comparative Literature

The comparative legal literature on the regulation of domestic geoengineering is also fairly underdeveloped. This is reflecting on the fact that most jurisdictions including India have no dedicated geoengineering legislation yet. In his article, Reynolds (2019) gives the most comprehensive comparative analysis of domestic geo-engineering regulatory approaches, examining those adopted or under consideration in the United States, the United Kingdom, Germany and Australia, he concludes that the fragmented, technology-specific, and largely reactive regulatory approaches being proposed are inadequate to the systemic governance challenges posed by geoengineering.[8] The European Union's emerging approach to geoengineering governance, which seeks to integrate geoengineering considerations into its broader climate and environmental regulatory architecture, has attracted increasing attention from scholars as a model that may be worthy of emulation by other jurisdictions.

E. Identification of Research Gaps

The foregoing survey reveals the following critical research gaps that the present paper seeks to address: First, almost complete absence of doctrinal legal analysis of existing Indian

[8] D. Bodansky, "The Who, What and Wherefore of Geoengineering Governance" (2013) 121 *Climatic Change* 539, 541–545.

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regulatory framework geoengineering. Second, lack of systematic comparative analysis situating Indian position within international governance framework. Lastly, absence of concrete, India specific proposals for legislative and institutional reform. This article makes a contribution to the three gaps via a comprehensive doctrinal and comparative analysis aimed at reform proposals.

III. INDIA'S DOMESTIC LEGAL FRAMEWORK ADEQUACY AND GAPS

Indian domestic legal framework is examined at constitutional, statutory and institutional level in this chapter for its adequacy in regulating climate geoengineering technology in India. It goes through each key element of the framework one by one, pinpoints the governance gaps that each opens up within the geoengineering context and reaches an overall assessment of the collective adequacy of the framework.

A. Constitutional Framework: Articles 21, 48A, and 51A(g)

The Constitution of India lays the normative foundation for Environmental Governance. Article 48A of the Constitution, which was added by the Forty Second Amendment in 1976, says that the State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country. 13 It will be noticed that it is formulated in the same manner as the directive principles of the State. Article 51A(g) imposes the fundamental duty upon every citizen to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures. These provisions are not enforceable as a fundamental right but nevertheless, they provide a strong constitutional sanction for legislation on environmental protection. It has been extensively used by the Supreme Court in evolving environmental jurisprudence of India.[9]

Most importantly for present purposes the Supreme Court of India has interpreted the right to life under Article 21 of the Constitution to include right to clean, healthy and sustainable environment in a series of landmark decisions. In Subhash Kumar v. State of Bihar (1991), the Court ruled that the right to life includes the right to enjoyment of pollution-free water and air. In M.C. Mehta v. Union of India, the Court developed a rich body of environmental rights jurisprudence under article 21, establishing the positive constitutional obligation of the State to take effective measures to protect the environment from degradation.

The geoengineering context is directly relevant to these constitutional provisions. Any large geoengineering intervention that causes or is likely to cause significant environmental damage

[9] J.L. Reynolds, *The Governance of Solar Geoengineering: Managing Climate Change in the Anthropocene* (Cambridge University Press 2019) 45–89.

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particularly by way of atmospheric pollution, disruption of precipitation patterns, ozone depletion, etc. Would trigger Article 21 rights and the State's corresponding constitutional obligations. The constitutional provision creates a normative authority for a regulatory action, but does not itself provide for mechanisms of governance licensing systems, environmental impact assessment requirements, monitoring and enforcement mechanisms for effective regulation of geoengineering activities. Useful Instructions:

The following must be either introduced or provided for by specific legislation. As the following analysis illustrates, it is currently completely absent in the geoengineering context.

B. The Environment (Protection) Act, 1986: Potential Application and Limitations

The Environmental Protection Act of the year 1986 is the main legislation regarding environmental law in India. After the Bhopal Gas Disaster, EPA was enacted. It is an umbrella legislation which confers wide powers on the Central Government to take measures for the protection and improvement of the environment. Section 3 of the EPA gives the Central Government the power to take "all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment and preventing, controlling and abating environmental pollution". Section 6 gives the Central Government the power to make rules which prescribe environmental quality standards and/or which prohibit or restrict the handling of hazardous substances.[10]

The Central Government may give directions, including directions to close, prohibit, or regulate an industry, operation or process by an order under Section 5 to any person, officer or authority.

In principle, these broad powers are expansive enough to include various forms of geoengineering regulation. In theory, the Central Government may prescribe standards for atmospheric interventions under Section 3 and Section 6 or use its powers under Section 5 to direct restrictions on geoengineering activities. Nevertheless, there are a number of major limitations that significantly weaken the EPA's status as a geoengineering governance tool. The EPA was instituted to take care of standard forms of industrial environmental pollution, and they were not designed for the new global and large-scale risks of geoengineering technologies. The provisions do not provide a basis for addressing specific regulatory issues facing geoengineering, including governance of transboundary risks, scientific uncertainty, and oversight of high-altitude interventions. Secondly, the EPA's enforcement mechanisms mainly criminal penalties and directions to industry are not the best suited for the governance of

[10] S. Divan & A. Rosencranz, *Environmental Law and Policy in India* (2nd edn, Oxford University Press 2001) 12.

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geoengineering. In particular, many geoengineering projects may involve state actors, international research coordination, or private actors that will operate in many jurisdictions. The EPA does not account for the proactive, precautionary, and scientifically informed regulatory oversight that governance of geoengineering requires but rather a predominantly reactive enforcement model.[11]

C. Environmental Impact Assessment Framework

Environmental Impact Assessment (EIA) is a key component of the environmental regime of India. It is governed by the Environmental Impact Assessment Notification, 2006, published under the EPA.

Before projects can get regulatory approval, there is an EIA process that project proponents must follow. EIA requires proponents to get a detailed report on the likely environmental impacts of proposed projects. In principle, EIA norms may be applicable to geoengineering research projects and deployment activities in India or by Indian entities.

Nevertheless, the current EIA framework is not adequate for geoengineering governance. The Notification EIA, 2006, lists different project and activities categories that need EIA and does not include geoengineering activities in any such category. The framework was designed for conventional infrastructure and industrial projects roads, mines, industries, dams and its methodology and institutional architecture are not adapted to the unique features of geoengineering activities, including their atmospheric or oceanic theatre of operation, their transboundary reach, their scientific novelty, and the extraordinary uncertainties surrounding their environmental impacts.[12] There is no provision in the current framework for the assessment of transboundary environmental impacts a critical omission in the geoengineering context, where the significant impacts of an intervention may be felt thousands of miles from the location of the activity.

D. The National Green Tribunal: Jurisdiction and Limitations

The National Green Tribunal (NGT) is established under the National Green Tribunal Act, 2010. It is a specialized environmental court of India. Further, the NGT has a jurisdiction to resolve all the disputes concerning the enforcement of environmental laws. Moreover, it also has a jurisdiction to grant compensation for damage to the environment. Since its inception, the NGT has proved to be an important and activist institution in the sphere of environmental governance in India. It has passed various important orders related to air pollution, water

[11] The Constitution of India, 1950, art 48A.
[12] *Subhash Kumar v State of Bihar* AIR 1991 SC 420.

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pollution, solid waste management and much more.

Due to the uniqueness of geoengineering issues, broader interpretation of section 14 of the NGT Act may be necessary to determine the viability of the technology involving heavy metals, hazardous chemicals and radioactive substances. The NGT is restricted to the topics which arise under the specified environmental laws listed in Schedule I of the NGT Act. Furthermore, the institutional capacity and expertise of the NGT are presently not structured to deal with the highly complicated, scientifically uncertain and transboundary issues involved in geoengineering disputes.[16] NGT does not have express jurisdiction over atmospheric geoengineering and lacks the scientific advisory capacity to assess the complex technical evidence that such disputes would necessarily involve.

E. Other Relevant Legislation and Overall Assessment

Several other Indian pieces of legislation have some potential, though limited, relevance to geoengineering governance. The Air (Prevention and Control of Pollution) Act, 1981 regulates the emission of air pollutants. This law could apply to some CDR techniques that involve interventions in the atmosphere. The Act's regulatory framework relates to conventional industrial air pollution rather than atmospheric tinkering in a deliberate manner. The Biological Diversity Act, 2002, is relevant for geoengineering techniques which may affect biodiversity such as Ocean Fertilization and Enhanced Weathering. Chapter 5 examines India's obligations under the Convention on Biological Diversity in the context of geoengineering. The Disaster Management Act, 2005, is a framework for governmental response to disasters but may be invoked only in case of a disastrous incident due to geoengineering. However, it does not offer any proactive regulatory governance.[13]

Overall Assessment: The overall domestic legal framework existing in India although it provides important constitutional and statutory foundations for environmental governance, it is fundamentally and dangerously inadequate for governance of climate geoengineering. The framework contains no reference to geoengineering technologies, no proactive regulatory mechanism over geoengineering research or deployment, no framework for assessing geoengineering impacts across borders, and no institutional architecture with the technical expertise and governance mandate to regulate these new high-stakes technological interventions. The lack of regulations makes the situation serious and urgent.

[13] The Environment (Protection) Act, 1986, s 3(1) (India).

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IV. INTERNATIONAL LEGAL FRAMEWORK AND COMPARATIVE ANALYSIS

This section assesses the current status of international environmental law applicable to climate geoengineering in terms of the obligations and governance gaps for India. The subsequent section provides a comparative analysis of the domestic regulatory regimes in select jurisdictions and draws lessons for reforms in India. To conclude, it analyses India's international posture on geoengineering governance at present and its impacts on India's regulatory preparedness.

A. The UNFCCC and the Paris Agreement

India, as a Party to the United Nations Framework Convention on Climate Change (UNFCCC), establishes the basic international law to control climate change. Article 2 of the UNFCCC commits Parties to achieving stabilization of greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system".[14] This provision is obviously relevant to geoengineering: deliberate large-scale modification of the climate system would seem to constitute precisely the kind of "interference with the climate system" that the UNFCCC was designed to address, though whether it is a dangerous and anthropogenic interference for the purposes of the Convention is something that has not been definitively settled.

The Paris Agreement, in 2015, say nothing about geoengineering. The text does not mention climate intervention technologies, while it focuses on emissions reduction, adaptation, and finance. Article 4 of the Paris Agreement establishes the framework for the Nationally Determined Contributions. This creates an ambiguous space for potetential inclusion of CDR activities in national climate plans. Many countries are applying CDR technologies like BECCS, afforestation, etc in NDCs. The lack of any governance framework for SRM technologies within the Paris Agreement architecture is a notable gap that is increasingly recognized by legal scholars and policymakers.

B. The Convention on Biological Diversity: Decision X/33

The CBD is the most important international governance framework developed so far for geoengineering. Decision X/33 adopted by the Parties to the CBD at the Nagoya Conference of the Parties in 2010 calls upon the Parties to not undertake geoengineering activities that may affect biodiversity "until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and

[14] Ministry of Environment, Forest and Climate Change, *Environmental Impact Assessment Notification* 2006, sch I.

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associated social, economic and cultural impacts", save for small-scale scientific research that is conducted and controlled under strict conditions.[15] India being a Party to the CBD is obliged by the Decision this is by far the closest approximation to an international moratorium on large-scale geoengineering activities in existence.

Nonetheless, CBD Decision X/33 is not a provision of treaty law with legally binding force, being a non-binding resolution of the Conference of the Parties, so its practical effect depends entirely on Parties' voluntary compliance. The measure lacks an enforcement mechanism, a working definition of 'large-scale,' criteria for determining an 'adequate scientific basis,' and a governance framework for the permitted small-scale research exception. The legal strength and practical effectiveness of this are therefore limited.

C. The London Protocol: Marine Geoengineering

According to the London Protocol on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1996, the most legally specific international governance instrument for a category of geoengineering. In 2013, the Parties to the London Protocol adopted amendments to Article 6 prohibiting the placement of matter into the sea for ocean fertilization activities, except for legitimate scientific research. The subsequent amendment adopted in 2013 broadened the scope of this framework to "marine geoengineering." The updated regulations mark a substantial step forward in the governance of international geoengineering, establishing a binding prohibition on commercial marine geoengineering and a regulated pathway for scientific investigations.

As a London Protocol Member, India would be bound by the Protocol's amendments on geoengineering activities when they enter into force. Despite the amendments to the London Protocol, there is no restriction on industrial scale Solar Radiation Management (SRM) which is an Atmospheric Intervention and remains solely unregulated at the international level.[16]

D. Customary International Law Principles

Many customary international environmental law principles are relevant to the governance of geoengineering and create obligations for India as part of the international community. The no-harm principle used in international law stipulates that States have the duty not to allow their territory to be used for activities causing significant harm to the environment of other States and may be directly applied to geoengineering activities which may have transboundary environmental impacts. The precautionary principle, as stated in Principle 15 of the Rio

[15] The National Green Tribunal Act, 2010, s 14 (India).
[16] United Nations Framework Convention on Climate Change 1992, art 2

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Declaration, indicates that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." [17] This principle has particular force in the geoengineering context, given the overwhelming scientific uncertainties as to the likely risks and side effects arising from any extensive climate intervention.

The concept of common but differentiated responsibilities is important in international climate law, particularly in relation to international geoengineering governance. It will be necessary that there be an appreciation of the different historical contributions to climate change and States different capabilities and vulnerabilities.

E. Comparative Domestic Regulatory Approaches

The regulatory framework for geoengineering in the US is rapidly evolving to be more consolidated and relevant (word count: 19). The CHIPS and Science Act of 2022 required a solar geoengineering research programme, and in 2023 the White House Office of Science and Technology Policy published a research governance framework. There may be scope for the Environmental Protection Agency to regulate certain atmospheric geoengineering activities under the Clean Air Act, although the agency's authority in this context remains legally uncertain. The United States takes a research-led approach, which values the production of scientific knowledge above governance questions.

The European Union is taking a more conservative and precautionary position on geoengineering governance. In 2021, a resolution was adopted by the European Parliament that calls for a global moratorium on solar geoengineering pending proper international governance framework. Moreover, geoengineering governance considerations were included in the European Climate Law and the European Green Deal by the European Commission. The EU is more precautionary and engages with transboundary justice more explicitly than either IEEE or the US, which is to its credit.

The UK has funded geoengineering research including of the cancelled SPICE (Stratospheric Particle Injection for Climate Engineering) project but lessons from this offer important lessons for the governance of geoengineering field trials. The UK has taken a research driven approach to geoengineering, with governance frameworks established on a project-by-project basis via existing research councils and environmental regulators, rather than through geoengineering legislation.[18]

[17] Convention on Biological Diversity, COP Decision X/33 (Nagoya, 2010) para 8(w).
[18] London Protocol 1996, 2013 Amendments (Ocean Fertilization Provisions).

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F. Lessons for India and India's International Posture

The comparative analysis reveals a world characterized by fragmented, inadequate and largely reactive geoengineering governance, with no jurisdiction to date having developed a comprehensive dedicated regulatory regime. Despite other nations' shortcomings, India's total lack of a regulatory response is noteworthy. India's stance toward geoengineering governance on the international level has been somewhat unclear: India has endorsed the framework set forth by the CBD Decision X/33, but has not taken a clear public position on the desirability of a binding international governance framework for geoengineering that could apply to India. Moreover, India has not articulated a national policy position on the permissibility of geoengineering research or deployment within India's jurisdiction.

The need of the hour for India is to formulate a robust, principled and proactive position for international geoengineering governance. Also, the adverse consequences on South Asian monsoon due to SRM interventions can severely affect India. India is unusually vulnerable to climate change impacts. Geoengineering technologies will affect all living beings on this planet. Therefore, these technologies should be governed through an international regime in order to ensure that developing countries and vulnerable communities do not suffer the consequences of unregulated geoengineering or disastrous climate change.

V. Conclusion and Recommendations

A. Summary of Key Findings

A doctrinal and comparative research study of India's regulatory preparedness for emerging climate geoengineering technology. The most important results of the study are:

India currently has no dedicated legal or regulatory framework to govern climate geoengineering, and thus there is a total vacuum. The existing laws in the country like the Environment (Protection) Act of 1986, the EIA framework, and the NGT Act of 2010while do establish basic environmental governance mechanisms, they are entirely ill-suited for the governance challenges of geoengineering technologies because they are directed at conventional industrial pollution they do not contain provisions for transboundary risks they do not contain mechanisms for governing novel atmospheric interventions, and they do not have the institutional capacity or ability to manage the scientific uncertainty of geoengineering.

Inadequate International Framework The existing international environmental law framework only provides fragmentary and largely inadequate governance for climate geoengineering (Hale and Geden, 2018). The most important existing instrument is CBD decision X/33, which

however does not have binding force or operational specificity. The amendments to the London Protocol refer to interventions in marine geoengineering. Thus, the amendments do not apply to interventions in the atmosphere. The governance of SRM is not mentioned in the UNFCCC and Paris Agreement. The principles of customary international law including the no-harm principle and the precautionary principle provide normative guidance but no operational governance framework.

According to the report, India is one of the most vulnerable countries in the world considering climate change and geoengineering intervention. SAI-induced disruption of the South Asian monsoon is a specifically severe threat to India's food and water security. India has a strong and urgent interest in establishing robust governance frameworks, both domestic and international, that will prevent unauthorized geoengineering and poorly governed geoengineering from causing catastrophic harm.

India is poorly prepared to regulate geoengineering, relative to other nations and global standards. Inadequate regulatory readiness and standards have implications for recklessness. While no significant authority has created a comprehensive regulatory structure specifically dealing with geoengineering, several countries including the USA, the European Union and the United Kingdom have at least started to develop governance structures, carry out systematic research programmes and define national positions. None of these steps have been taken by India.

Finding 5 Hypothesis Confirmed: The working hypothesis of this paper that India's current legal and regulatory framework is fundamentally and dangerously inadequate to govern climate geoengineering is fully confirmed by the analysis undertaken. The insufficiency is not just technical or procedural; it is fundamental and systemic.

B. Restating the Thesis and Final Conclusions

Parliament of India should pass Climate Geoengineering (Governance & Regulation) Act. A framework should be put in place for permitting, authorizing, monitoring, regulation and prohibition of climate geoengineering or other related research or deployment activity in India. The Act should define terms such as "solar radiation management", "carbon dioxide removal" and "large-scale geoengineering", provide for licenses for geoengineering, mandate environmental impact assessment suited to the distinctive feature of geoengineering, and set out effective enforcement mechanisms including civil and criminal fines.

Establishment of National Geoengineering Regulatory Authority will be a multidisciplinary body with representation from legal, scientific, ethical, civil society and other experts to deal

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with Geoengineering regulation. It would be appropriate for the Authority to regulate and license research involving geoengineering techniques, draw up and implement technical standards and guidelines for these techniques, develop and maintain a public register of authorized geoengineering activities, and advise the Government on international geoengineering governance issues.

The notification on Environmental Impact Assessment should be modified to clearly state that geoengineering activities categorised based on their scale and risk profile will be treated as one of the project categories requiring compulsory environmental clearance. The EIA of geoengineering will need a methodology that is specially adapted to transboundary impacts, scientific uncertainty and cumulative impacts, having regard to international best practice.

The National Green Tribunal Act, 2010 should be amended to confer express jurisdiction over geoengineering activities on NGT, including disputes arising therefrom. The NGT should have a scientific advisory committee made up of climate scientists, atmospheric chemists and environmental and ecological risk assessment experts.

The government should initiate a national research program for geoengineering in India to study its risks, governance and applications. This should be undertaken by Indian scientific institutions with adequate ethical oversight. India must engage seriously with the science of geoengineering as its stake in the governance outcomes is significant. India would not have an independent scientific base to systematically assess the risks and benefits of particular technologies and advocate for governance frameworks protecting its interests.

It is imperative that the Government of India formulates and publicly communicates a national policy position and approach on climate geoengineering at the earliest. This will signal what geoengineering research on Indian territory will be acceptable; what are the views of India on international governance arrangements for geoengineering; which geoengineering technology should be seen as having a greater risk compared to useful/beneficial from the perspective of India and climate vulnerability of India.

India must lead international negotiations on developing a binding international geoengineering governance framework. India must push for the creation of an international geoengineering regulatory body (which may well be an existing UN body or under the banner of the UN) which has the power to authorise geoengineering activities and monitor their impacts and prohibition where appropriate. A requirement for the environmental impact assessment of large-scale geotechnical research has been established. Fair representation of developing countries in governance decisions. Large-scale SRM should not commence until sufficiently strong

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scientific and governance capacities are in place; establishment of moratorium recommended. Liability and compensation for injury caused by geoengineering activities in other countries

C. Recommendations

This essay has given a detailed analysis and hence, has suggested the following specific recommendations.

In this regard, the Parliament of India should enact a Climate Geoengineering (Governance and Regulation) Act. It should cover the regulation and enablement, and possibly prohibition, of various geoengineering research and deployment activities and monitoring of toxic impacts in India. The Act ought to include definitions of key terms (solar radiation management, carbon dioxide removal, large scale geoengineering, etc), regulations for licensing geoengineering activities, mandatory environmental impact assessments (EIA), adapted to the special characteristics of geoengineering, and effective enforcement mechanism, including civil and criminal penalties.

Recommendation 2: Create a Separate Regulator A specialized National Geoengineering Regulatory Authority should be established. The regulator should be multisectoral and include members from the legal system, scientific community, ethical community, and civil society. The Authority should be charged with the responsibilities of licensing and monitoring geoengineering research activities and developing technical standards and guidelines, as well as maintaining a public register of authorized geoengineering activities and advising the Government on international geoengineering governance issues.

Recommendation 3: Amend the EIA Framework: The Environmental Impact Assessment Notification must be amended to clearly state that geoengineering activities must be classified by scale and risk level and should be categories of projects requiring mandatory EIA prior to approval. Modifying the EIA methodology for geoengineering projects will need to take into account transboundary impacts, scientific uncertainty, and cumulative effects, with lessons drawn from best international practice.

Recommendation 4 Expand NGT Jurisdiction and Capacity

The National Green Tribunal Act, 2010, must be amended to confer explicit jurisdiction on the NGT over disputes arising from geoengineering. A standing scientific advisory panel should be set up for NGT with experts from climate science, atmospheric chemistry, environmental risk assessment, etc., to assist in NGT adjudicating technically complex geoengineering disputes.

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The Indian government should set up a national research program on the risks, governance and possible applications of geoengineering technologies, with research based at Indian scientific institutions and subject to suitable ethical oversight. India's scientific involvement in geoengineering should correspond to the country's stake in governance outcomes: India cannot advocate to create a governance framework to protect India's interests without having an independent scientific base to assess the risks and benefits of a particular technology.

The Government of India should develop and publicly express a national policy position on climate geoengineering. Such a position should make clear whether India considers climate geoengineering research a foreign policy matter and whether its framework is territorial, in which case this research may take place freely within its territory. What is India's position on international governance? What does India think about relative risks and potentials benefits of different geoengineering technology?

Recommendation 7 Active International Engagement: India must play an active and leading role in international negotiations to develop a binding international geoengineering governance framework. Specifically, India must advocate for:

The establishment of an international geoengineering governance body under UN auspices empowered to authorise , monitor and prohibit geoengineering activities, Mandatory environmental impact assessment for any large-scale geoengineering research, Equitable representation of developing country interests in governance decision-making, A moratorium on large scale SRM deployment pending development of adequate scientific understanding and governance frameworks, and Binding liability and compensation for transboundary geoengineering harm.

D. Directions for Future Research

Further research will be important, study says. The empirical study of the specific risks of different geoengineering technologies for the South Asian monsoon system and Indian biodiversity, would produce a stronger scientific case for India-specific regulatory design. A second area of helpful research would be a detailed constitutional analysis of whether geoengineering regulation falls within the legislative competence either of the Union Parliament and, if so, whether concurrent or State legislative competence is also engaged. Of prime importance, and certainly distinct from harm caused by geoengineering, there would be a need to investigate dedicated models of liability and compensation for transboundary harm, drawing on nuclear law, outer space law, environmental liability law, amongst others.

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E. Final Observations

The most important and legally unexplored aspect of environmental governance is climate geoengineering. A highly vulnerable country with extreme climatic vulnerability, huge scientific and technological capacity, and unparalleled democratic stakes in global climate governance, India must create a robust, equitable and science-based regulatory framework for geoengineering not an academic exercise but an urgent national necessity, the report observes. The proposed reforms in this paper provide a principled yet comprehensive pathway to a governance framework proportionate to the challenge's seriousness and complexity. The ramifications of doing nothing are too intolerable to consider; it is time to act.

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