

# CATALYZING SUSTAINABLE DEVELOPMENT: LEVERAGING RESEARCH AND INNOVATION TO COMBAT CLIMATE CHANGE- PATHWAYS FOR ACHIEVING SUSTAINABLE DEVELOPMENT GOALS



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## Abstract

“Earth provides enough to satisfy every man’s need,  
But not every man’s greed”

–Mahatma Gandhi

*Climate change has become a global emergency, rapidly affecting human well-being and the sustainability of all life forms. The Paris Agreement aims to limit global warming to 1.5°C to avoid the most catastrophic impacts of climate change. As of 2022, the world has already seen an increase in global average temperature of approximately 1.15°C above pre-industrial levels (0.2°C increase per decade). The main driver of climate change is the greenhouse effect, primarily caused by increased CO<sub>2</sub> levels in the atmosphere. The Keeling curve which illustrates atmospheric carbon in parts per million (ppm), has reached a concerning state of 420.99 ppm in 2022.*

*These data emphasize the urgent need for ambitious and collective action to combat the otherwise irreversible consequences. Certain technological innovations, such as Artificial Intelligence, Geospatial Analytics, Tree-Planting Drones, Agrivoltaics, etc., can play a crucial role in achieving the United Nations’ Sustainable Development Goals (SDGs) especially SDG 13, which addresses climate change. This paper explores how technology can contribute to meeting the ambitious climate change control*



*objectives and the need for strong support from the legal system to backup these initiatives.*

### **Keywords**

*Sustainable Development Goals, SDG, Climate Change, Research and Innovation in Climate Control, Artificial Intelligence, Geospatial Analytics, Tree-Planting Drones, Agrivoltaics*

## **1. Introduction**

Climate change is one of the most alarming global challenges of our time, causing significant threats to ecosystems, economies, and societies. India, as a developing nation with a population of over 1.3 billion, is highly vulnerable to the adverse effects of climate change. Extreme weather conditions, increasing temperatures and rising sea-levels are affecting various regions of our country, exacerbating already existing vulnerabilities and threatening sustainable development. This paper provides an in-depth analysis of how the application of cutting-edge technologies and the support of proper legal systems play a critical role in addressing the multidimensional challenges posed by climate change.

This paper also examines the critical role of legal systems in climate control in India and highlights the urgent need for comprehensive and effective climate action. It explores how the Indian legal landscape aligns with international climate agreements and outlines the specific measures adopted to tackle climate change within the country.

Artificial Intelligence (AI), Geospatial Analytics, Tree-Planting Drones, Agrivoltaics and others, in combating climate change are discussed in this paper. These technologies provide unprecedented strategies to address climate deterioration, including carbon sequestration, renewable energy generation, optimum land and water usage etc.

Challenges in realizing these technologies and enforcing the laws are also discussed in this paper, along with some notable case laws and how they have helped in shaping up the legal landscape in India.

## **2. Legal Provisions Related to Climate Change in India**

In the fight against climate change, legal systems play a critical role in shaping policies, regulations, and enforcement mechanisms to mitigate greenhouse gas emissions, promote sustainable practices, and ensure climate resilience. The legal framework in India, backed by national and international commitments, seeks to address the multidimensional challenges posed by climate change.



The legal foundation for climate control in India begins with its commitment to the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement established in 1992 and 2015 respectively. Kyoto Protocol which operationalizes the UNFCCC was adopted in 1997. As a signatory to these international agreements, India has pledged to take ambitious steps to limit global warming and enhance climate adaptation and resilience.

At the domestic level, India has enacted various laws and policies to address climate change challenges. The National Action Plan on Climate Change (NAPCC) outlines eight missions focusing - renewable energy, sustainable practices, energy efficiency, water, sustainable agriculture, and others. The Green India Mission aims to increase forest cover and biodiversity conservation, contributing to carbon sequestration. Additionally, initiatives like the Smart Cities Mission emphasize climate-resilient urban development.

Article 21 of Indian Constitution which provides protection of life and personal liberty, Article 48A which provides that the State shall endeavour to protect and improve the environment, Article 51A(g) which casts a duty on every Indian citizen to protect and improve the natural environment, Article 32 which enables Indian citizens to approach Supreme Court for fundamental rights, Article 226 which enables High Courts to enforce fundamental rights, Article 253 which deals with the law to give effect to international agreements, etc are some of the constitutional provisions in Indian legal system to protect the environment and quality of life.

**Other major laws related to climate change in India are:**

- The Wildlife Protection Act, 1972: This protects the wildlife in the country which includes endangered species, and the habitats of them.
- The Water (Prevention and Control of Pollution) Act, 1974: Control and prevention of water pollution is included in this act.
- The Forest (Conservation) Act, 1980: This act regulates forest conservation and ecological balance. This also controls use of forest land for non-forest usage.
- The Air (Prevention and Control of Pollution) Act, 1981: This deals with air pollution and emission control from various sources.
- The Environment (Protection) Act, 1986: Central government is enabled though this Act to protect and improve the environment quality and prevent pollution.
- The Energy Conservation Act, 2001: Efficient energy usage and conservation of energy is covered in this act.



### 3. Climate Change related Legal Cases

As climate change in mainly anthropogenic (induced by human activities), it should be controlled by appropriate laws. Following Legal cases highlight the human negligence/irresponsible act and how it was penalized/ handled by Indian legal system to ensure a safe/clean environment for all.

*M.C Mehta vs. Union of India (The Oleum Gas Leak Case) (1987)*<sup>1</sup>: Supreme Court ruled that a company is liable for the gas leakage. This is a milestone case in the history of Indian jurisprudence and law.

*M.C Mehta vs. Union of India (Ganga Pollution Case) (1987)*<sup>2</sup>: This case deals with pollution in Ganges River and required control mechanisms for cleaning the river, thereby ensuring protection of its ecosystem.

*Subhash Kumar vs. State of Bihar (1991)*<sup>3</sup>: Unauthorized construction in environmentally sensitive land and its impacts was addressed in this case.

*Vellore Citizens Welfare Forum vs. Union of India (1996)*<sup>4</sup>: Pollution control of Vellore region in Tamil Nadu is addressed by Supreme Court in this case.

*M.C Mehta vs. Union of India (Vehicular Pollution Case – CNG Conversion case)*<sup>5</sup>(2002): In this case Supreme Court ensured that sustainable development plays important role in environmental law. Polluter-pays principle and precautionary principle are considered as important features of sustainable development.

*Goa Foundation vs. Union of India (2014)*<sup>6</sup>: Supreme Court banned mining activities in Goa region to prevent mining practices that damaged the environment.

All these cases played important role in making policies and actions to control climate change and protect the environment in the country. The above list is only indicative. There are many other legal cases and petitions related to climate change and environmental protection.

<sup>1</sup>*M.C.Mehta v. Union of India*, 1987 AIR 1086 1987 SCR (1) 819 1987 SCC (1) 395 JT 1987 (1) 1 1986 Scale (2)1188

<sup>2</sup>*MC Mehta v. Union of India*, AIR 1988 SC 1037;(1987) 4 SCC 463

<sup>3</sup>*Subhash Kumar v. State of Bihar*, 1991 AIR 420 1991 SCR (1) 5 1991 SCC (1) 598 JT 1991 (1) 77 1991 Scale (1)8

<sup>4</sup>*Vellore Citizens Welfare Forum v. Union of India*, 1996 5 SCR 241, ILDC 443 (IN 1996), 1996 5 SCC 647, 1996 AIR 2715, JT 1996, 375

<sup>5</sup>*M.C.Mehta v. Union of India*, WRIT PETITION (CIVIL) 13029 of 1985

<sup>6</sup>*Goa Foundation v. Union of India*, (2014) 6 SCC 590



## 4. Role of Research and Innovation in Climate Control

### 4.1 Artificial Intelligence in Climate Change Control<sup>7</sup>

Artificial Intelligence (AI) plays an important role in combatting climate change. Use of Data Analytics, Machine Learning, Predictions, etc. can help in development of efficient climate control solutions. Following is some of the key areas where AI can effectively help.

- **Carbon Sequestration:** AI helps in development and optimization of carbon capture and sequestration. It also helps in predicting the behavior of CO<sub>2</sub> capture systems and storage sites to reduce greenhouse gas emissions.
- **Climate Monitoring and Analysis:** AI helps to process data related to temperature patterns, atmospheric conditions, ocean currents, and GHG emissions. AI programs develop climate models for future trends and help to prepare for potential climate changes.
- **Energy Saving and Renewable Energy Integration:** AI can help in analyzing energy usage patterns in different infrastructure elements and predict the usage based on the historical patterns. This analysis can help in implementing energy saving measures which will help in carbon emission reduction. AI systems can be designed to efficiently use clean energy by matching the demand vs. production. This is implemented by integration of various renewable energy sources into the energy grid and controlling the production and distribution based on the demand and supply.
- **High Precision Agriculture:** AI combined with different sensors (IoT based) deployed on the field can help farmers in taking informed decision. This can help the farmers throughout the process (identifying the plant, planting, irrigation, pest control, harvesting, etc.)
- **Climate Modelling and defining Adaptation Strategies:** AI systems process data related to temperature patterns, atmospheric conditions, ocean currents, GHG emissions, develop climate models for future trends and create Climate adaptation strategies for vulnerable regions. It also assists in designing strategies to protect communities, ecosystem and infrastructure from climate changes and extreme weather conditions.

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<sup>7</sup>Climate Change Performance Index (2023), CCPI 2023: Ranking and Results. German Watch, New Climate Institute and Climate Action Network International. <https://ccpi.org/>



## 4.2 Geospatial Analytics for Climate Change Mitigation

Geospatial Analytics is based on AI techniques which helps in analyzing data from satellites, remote sensors, and geographic information systems (GIS). This analysis can help in identifying land/forest cover, carbon rich areas, appropriate location for various green energy projects and taking decisions on deforestation/ reforestation, urbanization impact, land usage etc. Following is some of the key areas where Geospatial Analytics can play a vital role.

- **Monitoring forestation and Carbon Sequestration Potential:** Geospatial Analytics plays an important role in maintaining existing forest areas and monitoring effectiveness of the reforestation and afforestation efforts. Geospatial Analytics can also help in identifying regions for carbon sequestration which can help in conservation and afforestation initiatives.
- **Renewable Energy Location Selection:** Geospatial data (wind speed, solar radiation, terrain condition, etc) can help in identifying right locations for installing green energy projects like solar, wind, etc. This data combined with performance of the green energy projects can help in taking better decisions in the future projects.
- **Emission Sources Identification and Land Use Planning:** Greenhouse gas emission from industrial area, power plants, residential area, etc. can be monitored using Geospatial analytics. This analysis helps in planning the land usage based on eco-friendly development practices.
- **Vulnerability Assessment and climate planning:** Risk assessment of climate change impact on a specific area can be done using Geospatial analytics. Based on the historical data from various sources, prediction for the future vulnerabilities and design of more resilient infrastructures can be built using recommendations from Geospatial analytics.
- **Policy Making based on Environmental Impact Analysis:** Geospatial analysis can be effectively used to monitor the impact of various projects/ initiatives. Detection of early impact can help in doing proper course correction, planning for any new projects and identifying better sustainable alternatives.
- **Tracking Progress and Reporting:** Another useful application of data analytics and dashboarding is to help monitor the effectiveness



of various initiatives related to climate control and provide real-time update on the progress to various stakeholders.

### 4.3 Tree-Planting Drones

Deforestation is a major reason for climate change because of its impact on biodiversity and carbon dioxide content in the air. Drones can be used effectively in reforestation and afforestation initiatives. As these are unmanned aerial vehicles, this can reach areas which are hard to reach and plant trees in large scale. Apart from planting trees, drones can also be used effectively in monitoring the progress and take corrective actions when required. Challenges related to choosing appropriate native trees, potential ecosystem impact, monitoring and maintenance, etc. should be considered while planning tree planting projects using Drones.

- **Precision Planting and Rapid Deployment:** Drones can help in reaching the hard-to-reach areas as well as planting the right seed at the right location. Precision planting is required for optimizing the density and growth patterns of the trees during reforestation and afforestation activities. Also scaling up of tree planting efforts can be done quickly by adding more drones to the project, thereby achieving large volume in short time. This will help in restoring the forests quickly after any natural disaster.
- **Monitoring Plant Growth:** After implementing reforestation projects, drones can help in monitoring the growth of the trees by capturing and analyzing arial data. This can help in taking any corrective actions if the effectiveness of the project is low.
- **Reforestation/Afforestation and Biodiversity preservation:** Traditional techniques used in reforestation and afforestation are less effective compared to Drones. As drones can be more effective in reaching hard-to-reach areas, plant large volume of trees in short time, monitor the progress of the growth, etc., it is used as reactive and proactive measure to promote bio-diversity and support wildlife. Also, the ability to choose the right seed (based on the native vegetation in ecosystems) can benefit the wildlife habitats.
- **Financial Efficiency:** Drones are more cost effective and fast compared to manual efforts. This can help in achieving more with less resource/cost. As technology improves, this will become more affordable and accessible.



#### 4.4 Agrivoltaics: Integrating Solar Panels and Farming

Agrivoltaics/solar farming, involves the integration of solar panels into agricultural lands. This innovation can utilize the same land for generating renewable energy while maintaining agricultural productivity. Agrivoltaics is very effective in optimizing the water usage by reducing the evaporation in the field, making it suitable for arid regions.

- **Land Use Efficiency and Water Conservation:** Agrivoltaics is effective in optimizing the land usage and maximizing the water usage. As the solar panels are installed above the crops, it helps in reducing the water evaporation and thus aid in water conservation in arid or semi-arid regions.
- **Renewable Energy Generation:** While providing water conservation, Agrivoltaics can help farmers to generate green energy (solar) with the help of installed solar panels. This can generate additional income for the farmers with added benefits of renewable energy generation with reduced greenhouse gas emission.
- **Accelerated Crop Yield, Economic Benefits and Sustainable Agricultural Practices:** Installation of solar panels can create microclimate by reducing the temperature fluctuations in the field. This will be beneficial for some crops under certain climate conditions. Increased crop yield along with electricity generated by the solar panels can benefit the farmers economically also. Also, it helps in sustainable agricultural practices like organic farming, crop diversification/rotation, etc. While implementing Agrivoltaics, it is important to take following into consideration – solar panel design, water management system, crop selection, suitability of the land, etc. Data Analytics along with AI techniques can help in making these decisions and fine-tune it over a period.

#### 4.5 Other Innovations for Climate Change Control

Apart from the above-mentioned innovative approaches, there are few other techniques which can be considered while making the technology selection. Following are some examples - sustainable materials and construction techniques, carbon capture/utilization methods, efficient storage/connectivity of renewable energy sources, optimization of smart grids for energy distribution, etc.





## 4.6 Integrating Innovations for Comprehensive Climate Change Control

To improve the efficiency of the Climate Control solution, it is important that we understand how various techniques mentioned above can effectively be combined/integrated to provide a complete solution. Following are some examples – Integration of agrivoltaics with smart grid technologies for better energy distribution, Integration of AI with geospatial data for better decision making/ generating alerts, Integration of tree-planting drones with carbon capture for better carbon sequestration, etc.

## 5. Findings/ Market Analysis

As per Global Climate Risk Index 2021, India is the 7<sup>th</sup> most affected nation due to climate change. Because of the growing awareness and national/state level policies, India is rapidly improving on the performance of Climate Change action plans. This is reflected in the Climate Change Performance Index (CCPI) of 2023, which ranks India in 8<sup>th</sup> position and the best among G20 countries<sup>8</sup>.

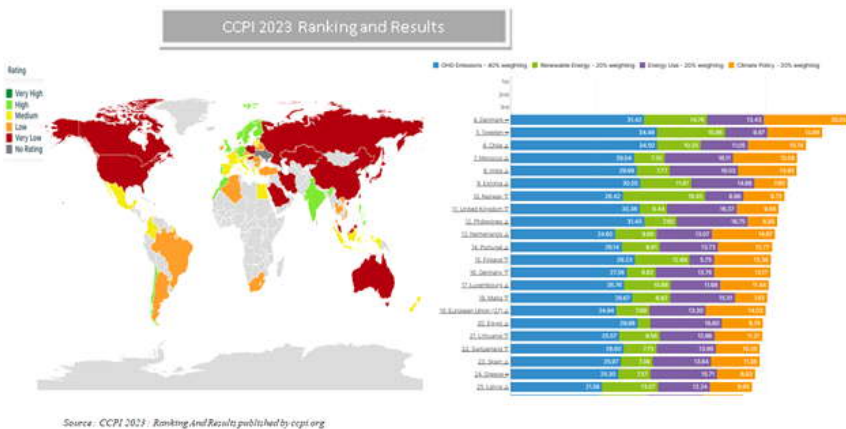
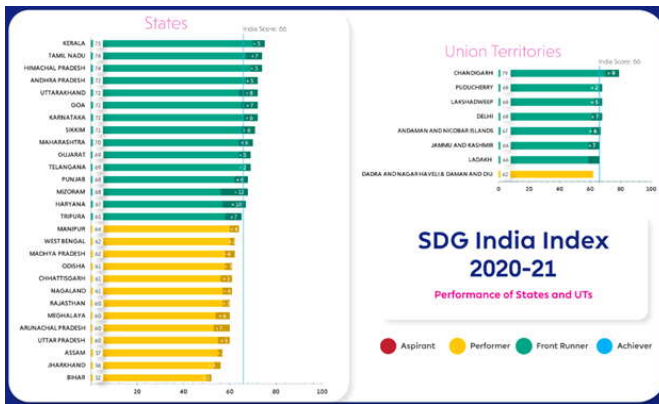


Figure-1: CCPI Ranking and Results

NITI Aayog of India publishes SDG India Index and Dashboard to cover progress made by States and Union Territories towards achieving the Sustainable Development Goals [8]. Overall SDG score in 2020-21 is 66 (from 60 in 2019) while performance score on SDG 13 is 54 (from 60 in 2019). This score is calculated based on the 5 targets and 8 indicators defined by United Nations (UN).

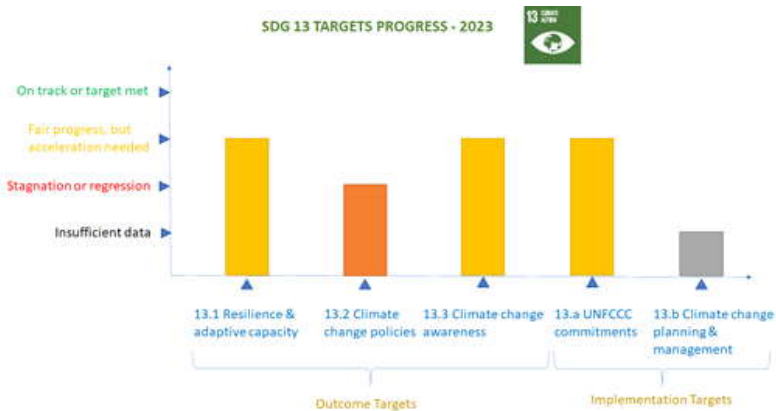
<sup>8</sup>“Climate Change Performance Index” German Watch, NewClimate Institute and Climate Action Network International (2023).



Source: NITI Aayog – Reports on SDG – SDG India Index 2020-21

Figure-2: SDG India Index

As per the global progress chart 2023, published by UN<sup>9</sup>, around 60% of the SDG 13 indicators are in “Fair progress, but acceleration needed” state while 40% of the indicators are in “Stagnation or regression” which requires serious attention.



Source: UN Sustainable Development Goals – Progress Chart 2023

Figure-3: UN Report on SDG 13 Target Progress

In India, some of the renowned schemes to support SDG 13 goal implementation are as given below. Also, some of the Indian and Global companies which are working on solutions for Climate control leveraging different technologies / Research and Development (R&D) are also included in the below list.

<sup>9</sup>“Sustainable Development Goals – Progress Chart 2023.” United Nations(2023).



- India's PM-KUSUM scheme supports the implementation of agrivoltaics projects. There are around 20 projects in states like Gujarat, Uttar Pradesh, Rajasthan, Telangana, Haryana, Maharashtra, and Kerala which are mainly in Pilot phase. The present status of these projects can be seen in the interactive map provided by The National Solar Energy Federation of India (NSEFI) and the Indo-German Energy Forum (IGEF)<sup>10</sup>. The central government provides 30% subsidy, while the state government also provides another 30% subsidy for farmers to install solar panels in farmlands as part of this scheme.
- Cumulative agrivoltaics installation globally stands around 14 gigawatts in 2021 (as compared to 2.2 gigawatts in 2018). China, North America and Europe share the world's major agrivoltaic installation capacity.
- 'Hara Bhara' is a campaign launched by Marut Drones to grow 50 lakh trees in 12,000 hectares in Telangana with the help of their "Seedcopter drone". This aims at planting 1 billion trees by 2030 in the country to accelerate reforestation. Marut has partnered with Uttar Pradesh Government under the 'Vriksharopan Jan Abhiyan 2023' and has launched drone seeding initiatives in Agra and Firozabad districts. Also in the Aravali Mountain range, the Indian government has initiated a drone-based pilot project for reforestation. Drone seeding initiatives mainly use native tree species like Neem, Chilbil, Jamun, Babool, Aru, Seesham, Mahua, Indian Tulip, Custard apple, White teak, and Bamboo.
- Other notable drone seeding firms across the globe are Mast Reforestation – USA, AirSeed Technologies - Australia, Dendra Systems – UK, World Vision Kenya – Africa, Flash Forest – Canada, etc.
- Ministry of Science and Technology has come up with National Geospatial Policy in 2022 <sup>11</sup>to strengthen geospatial sector in India. This policy provides guidelines for the next 13 years to promote India's Geospatial data collection and setting up a framework to use the data effectively to address various citizen services including climate control. As of 2022, Union and State governments collectively spent around 300 Cr INR on Geospatial related programs.

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<sup>10</sup>"Agrivoltaics Map. NSEFI, IGEF." National Solar Energy Federation of India (2023).

<sup>11</sup>"National Geospatial Policy. Department of Science and Technology." Ministry of Science and Technology (2022).



- The Indian Space Research Organization (ISRO) has developed an array of satellites and related technologies to support various geospatial use cases. ISRO's - The Indian Remote Sensing (IRS) satellite series, Cartosat, Resourcesat, and Oceansat and their geospatial platform - Bhuvan helps in geospatial data collection and sharing. National Spatial Data Infrastructure (NSDI) helps in sharing geospatial data among different agencies (citizens, society, private enterprise, and government) based on common conventions and technical agreements, standards, metadata definitions, network, and access protocols.
- United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) is a platform for space related technologies provided by UN for disaster and emergency management. Non-profit organizations like "The Earth Archive" are trying to create 3D digital twins of the earth by collecting baseline data. There are other private companies like Fugro, Skymet Weather, GalaxEye Space, Flotanomers R and D, AccionLAND, Hydenmet and others are actively working on this domain.
- Artificial Intelligence and Machine Learning (AI/ ML) is a concept which can cut across all the projects mentioned above and finds its usefulness in varied manner. There are many governments funded startups (Under different schemes like Startup India initiative by The Department for Promotion of Industry and Internal Trade (DPIIT), New Generation Innovation and Entrepreneurship Development Centre (NewGen IEDC), Technology Development Program, etc.) effectively use AI/ML to provide improvements/effectiveness to the existing process in climate control.
- Few companies which are effectively using AI/ML for building solutions for climate control in India are - Iowaaska Technologies, NatureDots, BrahmWorks, etc. Other AI/ML technology companies across the globe which are contributing in Climate Control related solutions are Immersion4, Sipremo, Kettle, Mortar IO, The Ocean Cleanup, One Concern, Refiberd, Pachama, AgroScout, Watershed, Eugenie.ai, Hummingbird Technologies, NCX, Raptor Maps, FarmWise, etc.

## 6. Discussion on Challenges and Limitations

Innovative techniques discussed in this paper can play a vital role in implementing effective climate control system. But there are few challenges and limitations one should be aware of. Policy gaps can negatively affect the widespread



adoption of these solutions. Also cost barriers related to the selected technology and technology limitations should be considered during the concept stage itself to prevent severe impact at later stages. Ethical concerns related to the use of AI systems and the related data privacy issues need to be addressed based on the local policies. Inclusion of marginalized communities in the solution to make it more compatible and effective under different conditions/ regions is also one important factor that needs to be considered while selecting the solution.

Though India is well positioned to take advantage of the technology/ innovation, there are other challenges for climate control system implementation like, awareness, inadequate enforcement, insufficient financial support, etc. Complementing climate friendly laws with strict enforcement and better stakeholder collaboration is the key for effective implementation in Indian environment.

## **Conclusion**

Innovative techniques and solutions discussed in this paper (AI/ML, Geospatial Analytics, Tree-Planting Drones, Agrivoltaics and others) will play a crucial role in achieving UN's SDG 13 goals. With proper integration/collaboration of various techniques, these innovative solutions can be more effective than the traditional practices in combating climate change and controlling greenhouse gas emissions. These technologies need to be practically supported by Government schemes and large business houses, while being available to the common man. Only by the appreciation and acceptance of the potential benefits of these innovative practices at a larger extent, we can ensure sustainable development for the present as well as the future generations.

Role of the legal systems in India is also very crucial in creating the roadmap and enforcement of the climate control policies. The need of the hour is serious enforcement of a strong legal framework for combating climate change and advanced collaborations with the world forums to protect the environment and the planet.