



Governing Intelligent Machines on the Farm Field: Legal and Regulatory Frameworks for Artificial Intelligence in Climate-Smart Agriculture — A Comparative Analysis of India, the European Union and the United States

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Abstract. The deployment of artificial intelligence (AI) is taking place in various arenas and climate-smart agriculture (CSA) is not an exception. AI in agriculture is used to measure precision in irrigation and monitor crops through satellite-based tools, AI-driven carbon sequestration tracking, and algorithmic advisory systems. The present legislative frameworks are inadequate for governing the AI tools and systems. This paper undertakes a systematic comparative analysis of how India, the European Union (EU), and the United States (US) currently regulate, or fail to regulate, AI systems deployed in agricultural contexts for climate adaptation and mitigation. The focus of the paper will be covering five domains which are environmental and climate law, data governance, liability frameworks, intellectual property, and AI-specific governance. European Union's AI Act deals different tiers of AI systems, liabilities and duties of producers, developers and manufacturers. A revised Product Liability Directive (2024/2853), and Farm to Fork Strategy focuses on relationship between AI tools and agriculture. India operates through various policy platforms such as AgriStack, IndiaAI Mission etc., but are backed by limited binding safeguards. Voluntary industry self-regulation is the methodology followed by US such as Agriculture Data Transparent framework with a deregulated federal structure. The three main legal deficiencies are lack of the data governance of non-personal data of agriculture, allocation of liability in case any harm is caused and the inadequate integration of agricultural AI governance with international environmental and intellectual property obligations. The paper proposes an original Risk-Responsive Adaptive Governance Framework (RRAGF) which deals with regulation for AI tools, risk tiered classification of tools, data sovereignty, algorithmic fairness and transparency, open data interoperability, linkage to international environmental obligations, and adaptive governance mechanisms.

Keywords: Artificial Intelligence; climate-smart agriculture; environmental law; data governance; EU AI Act; comparative regulation; product liability; India; precision agriculture; algorithmic governance.

1 Introduction

The integration of Artificial Intelligence into agricultural systems has accelerated sharply over the past decade, catalysed by challenges of food security, climate adaptation and digital transformation. An existential crisis exists where these productive intelligent systems need to be adopted for destabilising climate change. The global CSA market is projected to reach USD 25.4 billion by 2030, with AI-enabled platforms accounting for an increasingly dominant share [1]. As a socialist State, it is the responsibility of the State to look into the best interest of every individual coming from every section of the society. Thus, keeping the best ethical standards for use of AI, it would uplift and add to the growth of the economy at large. The major problem faced is whether the legal frameworks are ready to deal with technological innovations.

The central research question dealt with in the paper is whether the present regulatory frameworks either in India, European Union (EU) and US are able to govern the risks available such as algorithmic bias, data exploitation and diffusion of liability in case of deployment of smart agriculture tools and if not, what theoretical and practical principles should guide a reformed governance architecture? This question needs to be answered for two reasons which are firstly, the risks are context specific such as data asymmetries or any error in the advice given by automated tools. Secondly, the jurisdictions dealt are distinctive and not same for all. Thus, it will help in understanding the limitations of legal transplantation.

As defined by Lipper et al. Climate-smart agriculture (CSA) is an approach which transforms the traditional agriculture systems inclusive of agricultural productivity, climate adaptation, and greenhouse gas mitigation to tackle the emerging aspects of climate change [2]. The objective of the Food and Agriculture Organisation of the United Nations is to promote sustainable agriculture by eradicating hunger and malnutrition [3]. Artificial Intelligence and Remote sensing is revolutionising traditional agriculture by increasing efficiency and sustainability. For example, Blue River Technology's 'See & Spray' technology is used for application of herbicides with precision when needed for separation of weeds from the crop. IBM's Watson Decision Platform for Agriculture is used as a decision-making tool as when to plant, irrigation to be done or crops to be harvested [4]. Predictive Analytics helps in managing pest infestation by predicting weather forecasts [5]. A number of challenges arise even with the adaptation of India's AgriStack, mandated through the EU's Common Agricultural Policy (CAP) Area Monitoring System [6], and commercialised by agritech corporations serving US commodity agriculture about the quality and control of the data, whom to be made liable, what kind of regulatory frameworks will be applied in case any harm is caused or the sharing of benefits [6]. The present frameworks lack the adequacy of dealing with the challenges faced by the inclusion of artificial intelligence in smart agriculture. The paper addresses the governance gap through a systematic comparative analysis of India, the EU and the US that collectively account for a substantial share of global agricultural output, AI governance norm-setting and the deployment of AI-powered CSA tools.

With EU's AI Act [7] dealing with the rules for adoption of binding AI and India's pro-AI approach can be represented by the G20 Ministerial Declaration [8] which was made during India's presidency and also the statement in Parliament in April 2023 [9]. As per the United States, the Fiscal Year 2025–2026 AI Strategy by Department of

Agriculture, AI will be integrated into every field by creating operational efficiencies, enhance real time surveillance for planning of land, expansion of use of predictive analytics and for research in agriculture. The goals and objectives are to provide an AI governance model, ready workforce, AI Infrastructure, Responsible AI and Data Readiness [10].

The paper proceeds as follows. Section 3 establishes the conceptual framework by mapping AI applications across the CSA scale. Section 4 delivers the comparative legal analysis across the three jurisdictions, covering environmental and climate law, data governance, AI-specific regulation, liability, and intellectual property in each. Section 5 identifies the challenges across various jurisdictions. Section 6 proposes the normative framework for governance reform. Section 7 deals with the conclusion with implications and suggestions.

2 Research Methodology

The article has incorporated the comparative methodology wherein the legal systems have been analysed and compared with different systems in a systematic manner to determine its functionality and effectiveness. Adopting this methodology for AI governance is appropriate in agriculture as it addresses how the technological risks are catered in various legal and their respective instruments. These instruments include regulation on ex ante product in EU, ex post liability in USA and in India it is focused on the sectoral fragmentation. The jurisdictions India, EU and USA have been purposely taken for the study to deliberate upon the issue as EU provides detailed legal framework covering the AI regulation, i.e., AI Act (Regulation (EU) 2024/1689). Thus, establishing the global analysis for the other States with no such positive framework dealing with AI regulations. The USA sets a standard across the world through institutions such as ISO and OECD keeping in mind the governance of technology, market needs, tortious liability and constitutional framework. India, developing country, provides a combination of massive reliance on agricultural sector (approx. 85% of farmers population in India hold < 2 hectares) and has laws which are at nascent stage governing the AI governance which include the Digital Personal Data Protection Act 2023, draft National Data Governance Framework and proposed AI governance framework by MEITY). These laws have been made with an objective to ensure distributive justice and actively engage to meet the Global South AI governance agenda as well as to align with the EU and USA standards via iCET process.

The primary sources include statutes, various guidelines, regulations, court decisions as well as treaties in the context. Additionally, secondary sources are inclusive of policy documents, scholarly works and literature available on AI applications specifically in agriculture. The secondary sources are well cited in reputed journals and database for Scopus and Web of Science. The comparative analysis has been made at various stages: (a) scope of AI systems and its applications in agriculture; (b) data rights and its governance; (c) Algorithmic transparency as well as accountability; (d) Redressal mechanism and liability; (e) Powers of Institutions and Enforcement.

3 **AI Applications Across the Climate-Smart Agriculture Sector**

As operationalised in practice, deployment of climate-smart agriculture advances three functional categories firstly Predictive by predicting the weather, crop patterns and soil health, secondly Prescriptive by generating the recommendations given by automated system on the basis of training dataset such as timing to harvest, irrigation schedules and rate of application of fertiliser and lastly, Autonomous System, where the tasks are performed through automation with certain degrees of human oversight depending upon the act performed [11]. Every specific category of automated models generates a different level of risk such as bias, accuracy, informed consent, hallucination and any form of error will specifically impact the small agriculture holders. The large agriculture holders will be able to overcome the losses borne because of wrongful decision making and lack of human oversight. Another sharp question raised is who shall bear the responsibility as to the loss borne or crops damaged, software developer, distributor or the operator.

The agricultural automation is data intensive as models require high volumes of soil, climate, nature of crops and various other forms of data. Somehow, the data collected is about the individual farmers' land. This agricultural data is generated by the farmer and used by the platform providing benefit to the farmers in monetary form. Where the data relates to a specific individual then personal data protection frameworks will be applicable and if relating to environment or land then law relating to indigenous community is affected. This kind of structural asymmetry remains unaddressed by the present legal frameworks.

AI applications can advance crop productivity and environmental sustainability through real-time monitoring, resource optimisation, and precision agriculture techniques [12,13,14,15]. Recurrent neural network (RNN) architectures have demonstrated noteworthy predictive accuracy for agricultural planning [16].

EU Farm to Fork Strategy is an important part of the European Green Deal, which has laid down targets of reduction of 50% of pesticides, loss of nutrients and antimicrobial by 2030 [17]. The emphasis of India-AI Impact Summit 2026 is the vision of 'Welfare for All, Happiness for All' and reinforcing the principle of 'AI for Humanity' by portraying AI as a human-centric [18]. According to Minasny et al. the demonstration of AI multiagent platforms has proven to generate novel soil carbon sequestration strategies by integrating heterogeneous scientific literature, laboratory data, and field observations [19]. Sharm el-Sheikh Joint Work on Implementation of Climate Action on Agriculture and Food Security (2022) joint work on adoption of sustainable tools for agriculture and food security [20].

The legal questions raised by AI-based carbon accounting is about the amount of AI based computation to be determined and leading to an increase in electricity [21].

Mehrabi et al.'s landmark study, published in Nature Sustainability, found that only 24–37% of farms smaller than one hectare benefit from third-generation (3G) or fourth-generation (4G) mobile connectivity, in contrast to coverage rates of 74–80% for holdings exceeding 200 hectares [22]. Any governance framework that disregards this structural asymmetry risks constructing legal protections that serve large-scale commercial operators while denying climate-vulnerable smallholder farmers meaningful legal recourse.

4 Comparative Legal Analysis

4.1 India: Aspirational Digitisation Under Fragmented Governance

India presents a paradoxical regulatory landscape: the world's most ambitious government-led programme for agricultural digitisation operates alongside an AI governance architecture that is almost entirely non-binding. The Indian government has introduced numerous AI-driven initiatives, including Bharat-VISTAAR is a multilingual AI platform designed to provide farmers with integrated access to agricultural resources such as Kisan e-Mitra, the National Pest Surveillance System, an AI-powered forecasting tool for local monsoon onset to inform Kharif sowing decisions, and several other innovations. AgriStack, a flagship product of the Digital Agriculture Mission, is designed to assign every farmer a unique digital identity through a dedicated Farmer Identification number. This identifier is integrated with land records, livestock ownership data, information on crops under cultivation, and records of government benefits accessed, thereby enabling secure identification and streamlined access to agricultural services [23,24].

India's environmental and climate legal framework, while substantively developed, does not address AI. The National Action Plan on Climate Change (NAPCC, 2008) is based on the following guidelines which includes protection of poor and vulnerable sections of society, achieving national growth objectives, cost effective strategies, deployment of appropriate technologies and engineering innovative form of market. Its eight National Missions which are strategies for achieving key goals in achievement of climate change include the National Mission for Sustainable Agriculture (NMSA) where the objective is to identify and develop a number of varieties of crops and Indian agriculture resilient to climate change [25,26].

The Environment Protection Act, 1986 [27] and the Biological Diversity Act, 2002 [28] (amended 2023) govern environmental protection with the objective to protect and improve environment and conservation of biological diversity but contain no provisions governing AI-driven agrobiodiversity databases. Data protection under the Digital Personal Data Protection, Act 2023 (DPDPA) [29] applies exclusively to personal data which relates to data of an identifiable individual but not to non-personal data such as soil composition, crops, weather patterns etc. The NITI Aayog's 2021 Responsible AI for All principles [30] and the November 2025 India AI Governance Guidelines [31] articulate seven principles including safety, accountability, transparency, understandable by design, human oversight and fairness but impose no legal obligations on AI developers or deployers.

Within twenty-four months of its launch, the India AI Mission backed by a budgetary outlay of INR 10,372 crore earmarked for developing the nation's AI ecosystem has succeeded in laying the foundational infrastructure for advanced model development [32]. The proposed Digital India Act, which is intended to supersede the Information Technology Act 2000, remains in pre-legislative consultation and may ultimately address high-risk AI systems; however, its enactment timeline and substantive provisions remain uncertain [33].

India's liability framework for AI-caused agricultural harm is markedly underdeveloped. The Consumer Protection Act, 2019 [34] introduced a product liability regime (Sections 82–87) covering defective products and deficient services under a no-

fault concept, but the definition of 'product' focuses only on tangible goods which further doesn't cover AI software. Till date there hasn't been any case which has addressed agricultural AI liability [35] or any framework dealing with black box problem statutory risk-utility framework analogous to the US Restatement (Third) of Torts [36]. The Protection of Plant Varieties and Farmers' Rights Act, 2001 (PPV&FR Act) [37] interaction with AI-driven digital phenotyping and genomic prediction is legally untested, and not on parallel lines with the growing use of AgriStack data by private AI developers creates tensions with the Act's farmer-protective spirit.

The Indian legal framework is a weak area which needs to be focused upon. The major areas of focus which include a need for a dedicated regulatory authority which are equipped with the legal principles as well as technical support under one head to address the AI related matters. Furthermore, under the DPDP Act, the jurisdiction of the Data Protection Board is limited to personal data and does not cater to the agrarian data which are non-personal in nature. The infrastructural requirements are also pertinent to take into account for upscaling the AI's role in agricultural sector. The growing reliance of farmers upon AI with the help of their smartphones for decision making purposes for taking risks through these advisory applications is alarming as neither Consumer Protection Act, 2019 [34] nor IT Act, 2000 addresses the liability of advises provided by these AI applications. Civil litigation for seeking redressal is always an alternate for such matters, however, such litigation is time consuming. Lastly, the collective interests of farmers should be addressed collectively and the present framework is not adequate for the same.

4.2 **European Union: Architecturally Comprehensive but Sectorally Incomplete**

The EU AI Act (Regulation 2024/1689) establishes a risk-stratified governance architecture that classifies AI systems into four categories: unacceptable risk (subject to prohibition), high-risk (subject to mandatory conformity obligations), limited risk (requiring only transparency disclosures), and minimal risk (eligible for voluntary codes of conduct). Notably, however, agriculture has not been included among the high-risk domains enumerated in Annex III of the Act [7].

Val's analysis in the European Journal of Risk Regulation which is the most rigorous legal examination of the AI Act's application to agrifood to date identifies three critical lacunae's in the Act's agricultural application. Firstly, the AI Act does not classify food production and processing infrastructure which are critical to food security. Secondly, the Act is silent on sustainable environment or protection of biodiversity or animal protection and absent from the AI Act's risk assessment parameters. Third, non-mechanical safety hazards arising from algorithmic agricultural recommendations might not fall within the Machinery Regulation's safety component definition, leaving advisory AI in a regulatory interstice [38]. Another limitation is that the act focuses on industrial or urban area and not agricultural surroundings. GDPR compliance costs for SMEs have been estimated at EUR 50,000–100,000. [64]

The EU's environmental law framework provides normative guidance but limited operational governance for agricultural AI. The Nature Restoration Law (Regulation 2024/1991) [39], a key element of EU Biodiversity Strategy sets targets which are binding to restore degraded systems. The CAP's Area Monitoring System, mandatory

from 2023, uses Copernicus Sentinel satellite imagery and machine learning for automation of area-based payment verification across member states [5].

EU Code of Conduct on Agricultural Data Sharing by Contractual Agreement (EUCC), was introduced for clarification of agricultural data sharing between farmers, agricultural advisors, and ag-tech providers [40]. Atik argues that the term 'data ownership' is ambiguous and linked with 'smart farming' [41]. The proposed AI Liability Directive (COM(2022) 496), which dealt with proposed fault based delegation has now been formally withdrawn by the European Commission [42].

4.3 United States: Voluntary Self-Regulation Under Deregulatory Pressure

The United States' approach to agricultural AI governance is characterised by voluntary industry self-regulation but with no comprehensive federal legislation which governs AI in agriculture. Transformation took place from President Biden's Executive Order 14110 (October 2023) [43]; Trump's Executive Order 14179 (January 23, 2025) reframing AI policy eliminating algorithmic fairness, bias mitigation, and the precautionary governance mechanisms that the prior framework had developed [44]. The USDA's inaugural AI Strategy (FY 2025–2026) establishes technological and cultural infrastructure to AI [45]. And at the state level, California's Automated Decision Systems Accountability Act, Colorado's SB 205 on high-risk AI, and Illinois' Artificial Intelligence Video Interview Act are among the most significant legislations.

The Ag Data Transparent (ADT) certification programme, commits to 11 principles covering data ownership, portability, transparency, and informed consent. However, participation is entirely voluntary, enforcement mechanisms are absent, and there is no independent auditing of compliance [46]. Ferris' laid emphasis on agricultural data being legally non-personal and therefore unregulated [47]. To create liability for manufacturing defects, AI needs to be considered as a product [48]. The Clean Water Act (33 U.S.C. §§ 1251–1389) [49] and National Environmental Policy Act both legislations deal with the application of AI but still vagueness lies as to governance of AI [50].

5 Cross-Cutting Legal Challenges

5.1 The Non-Personal Agricultural Data Governance Gap

The most structurally significant legal deficiency identified across all three jurisdictions is the absence of regulatory frameworks for non-personal agricultural data. Agricultural AI systems are trained on the data which is generally non-personal such as soil composition measurements, aggregate crop yield data, livestock health patterns, satellite imagery, weather station readings, and AI model outputs. And the present legislations lack the requirement of dealing with such kind of data.

Wiseman et al.'s empirical research demonstrated that the absence of legal and regulatory frameworks for collection, sharing or the use of agricultural (non-personal) where farmers bear the risk and receive limited benefit [51]. Ruder and Wittman's recent analysis deals with lack of consensus to adopt methods to adopt achieve data justice [52]. The EU's proposed Common European Agricultural Data Space [53]

facilitates data sharing, processing and analysis whereas the US ADT programme's mandated AI/ML training data disclosure [54]. Nonetheless, India's AgriStack [55], is allocating with minimal non-personal data governance infrastructure which are further creating risks.

5.2 The Liability Allocation Vacuum

The question of who bears liability arises if an agronomic harm is caused due to algorithmic tools in the form of crop failure, environmental damage or financial loss and remains legally unresolved in all three jurisdictions. The EU's revised Product Liability Directive deals with different of products and their liability but AI remains secluded from it [56].

In the US, The Restatement (Third)'s design defect framework offers the most viable pathway for mass-marketed AI, but requires the proof that a reasonable alternative design was available [51]. This is difficult to prove in the case of machine learning systems as they are adaptable to environment and can even learn on the basis of the surroundings. Similarly, in India the gap is wide as The Consumer Protection Act 2019's [34] product liability provisions are untested for AI and tort law's negligence framework is structurally ill-suited to algorithmic causation.

To establish liability is difficult under the grounds of diffuse causation chains [65] in agricultural AI on account of various grounds such as environmental conditions including weather, soil, pest evolution; developers of AI, farmer operators and platforms providing for agriculture. On account of these factors, the doctrines for establishing product liability and negligence have turned out to be insufficient [47].

In addition, it is also important to acknowledge that the AI's behaviour does not result in uniform outcomes as the system upon which the tests were conducted does not certify an identical outcome upon being tested [66]. Moreover, the losses in agricultural sector are not attributed to single reasons but with many others which proofs as inadequacy contributions in the advice of AI. Since the limited source of income in the field acts as a limitation, this further leads to individuals not taking up litigation and seeking remedy for the AI's advice and other related matters [67].

For a better understanding, the following table depicts the different legal framework existing in the three jurisdictions as follows:

Table 1. Comparative study of regulatory frameworks in EU, U.S.A. and India for AI.

Criterion	EU		United States		India	
Scope of agricultural AI	Partial Climate Agriculture is listed under the category of not so high-risk.	wherein Smart is explicitly under the category	The same has been observed in pieces not uniformly, i.e., only in selected sectors.		Neither any legal framework for agricultural AI nor any specific provision of statute dealing with the same.	
Rights for Agrarian Data	Limited under GDPR Act.	as provided and Data	Need for federal framework as the state provisions are weak.		DPDPA deals with personal data whereas data kept	only data kept

Criterion	EU	United States			India		
					collectively unprotected.	remains	
Algorithmic accountability	High for risks as major CSA tools address the gaps.	There exists no obligation binding in nature.			No per se enforcement mechanism, however, the principles are in existence.		
Liability and redressal	Developing in terms of AI Act and product safety.	Covered under Tort Law for causation barriers.			Inadequate as Consumer Protection Act alone cannot address the expertise requirement of AI.		
Capacity of Institutional Body	Highly considering the authorities of strong market surveillance.	Moderate considering the sector such as FTC.			No AI centred authority and DPDPA Board's role is limited, therefore, weak.		

5.3 Intellectual Property, Genetic Resources, and AI

The intersection of agricultural AI with intellectual property law creates governance challenges at both the domestic and international levels. With the DABUS litigation, it was established that AI cannot be named as an inventor under patent law. The USPTO, EPO, and UK IPO all rejected AI inventorship. The rationale behind it is that only human can be considered as an author as defined under Section 6 of Patents Act. requires a human inventor [58]. This has further resulted that the voices of indigenous communities are remaining unheard and rights are given to the companies inventing the agricultural ai tools.

The Convention on Biological Diversity [59] and its Nagoya Protocol [60] collectively establish an international framework for ensuring fair and equitable distribution of the benefits arising from the utilisation of genetic resources. However, a significant regulatory vacuum persists in respect of digital sequence information (DSI), which contributes to the progressive dematerialisation and dispersal of genetic material, facilitating its enclosure through overlapping legal, technological, socio-economic, financial, and logistical mechanisms [61]. The PPV&FR Act 2001 provides for the establishment of a National Gene Fund to enable centralised benefit distribution; however, this mechanism cannot readily be extended to address plants developed or modified through AI-driven processes [38]. The ITPGRFA Multilateral System is designed to enable participating countries to share genetic diversity and associated data from their publicly held gene banks with research communities worldwide. This framework has not, however, been adapted to govern AI-mediated distribution pathways, leaving a material governance gap at the international level.

6 **Toward a Risk-Responsive Adaptive Governance Framework (RRAGF)**

The comparative analysis reveals that there is no existing jurisdiction which has developed a coherent and specific legal regime for AI in climate-smart agriculture. The regulatory patchwork across different fields as environmental law, data protection, AI governance, product liability, and intellectual property creates governance gaps. These limitations are harmful especially for indigenous communities and small farmers. This paper proposes a Risk-Responsive Adaptive Governance Framework (RRAGF) as a seven-element normative model for legislative reform.

Responsive regulation theory, as developed by Ayres and Braithwaite, where the regulatory systems are calibrated towards the behaviour and capacity of the regulated entity. And when applied to AI agricultural governance, the framework takes into account both smallholder and large holder platforms.

The concept of Polycentric governance theory further explained in the Ostrom's work on common pool resource management. It deals with common pool of authorities regulating rather than a single authority with objective of shared norms and credible sanctions. AI tools must have a common sanction and collective choice arrangements which this framework constitutes.

Firstly, adapting Val's analysis [38] and the EU AI Act's general architecture, the RRAGF proposes a three-tier taxonomy of three tiered agricultural AI systems providing both normative justification and practical design criteria. The high-risk agricultural AI (AI-driven pest and disease management which affects food safety and especially the systems which lack human oversight), medium-risk advisory AI (recommendations given to the crops to be grown or when and by which method irrigation to be done or predicting market values to sell crops but final decision-making power must be with farmers), and low-risk monitoring AI (satellite-based area monitoring, soil sensing, and weather prediction). This sector-specific classification addresses the AI Act's Annex III gap for agrifood and provides regulatory certainty for agricultural AI developers and deployers.

Secondly, drawing on Ruder and Wittman's framework [52], RRAGF proposes three data governance tiers: personal agricultural data (disclosure about the farmer through any means such as I-cards, revenue records) governed by existing data protection law; data generated by farmers (soil readings, crop yields, input records) and agricultural intelligence data (AI model outputs). These are subject to benefit-sharing obligations modelled on the ITPGRFA's Multilateral System. This tiered model addresses the different kinds of data and the level of protection subsequently slotted to each of them.

The third element is proportionate liability allocation such as strict liability in cases of high-risk agricultural AI, adoption of reasonability principle for medium-risk advisory AI, with mandatory explainability requirements for algorithmic recommendations. Where any model is adopted lacking human oversight then a no-fault compensation pool is proposed. Mandatory training data diversity audits is promoted for algorithmic fairness adoption of regulatory sandboxes, following the adaptive governance approach of Perboli et al. [62]. Fourthly mandates open data interoperability standards, building on CGIAR's FAIR data principles where the tools must be in alignment with the farmers interests. The data must be able to accurately interpret. Fifthly, explicitly integrates agricultural AI governance with international

environmental and IP obligations for the objectivity to be consistent with UNFCCC technical guidelines.

The sixth element RRAGF proposes a legal category of 'agrarian data commons' to address the collective agricultural data exploitation gap identified. The concept of agrarian data common is based on the algorithm common where if any algorithm generated from a particular dataset must be made available to everyone for the purpose of collective benefit. Ostrom has discussed eight rules to manage the algorithm commons which includes defined boundaries, adapt to local circumstances, mandatory participation in decision making and monitoring, imposition of sanctions and will have the right to organise. This mechanism directly addresses the value extraction asymmetry without requiring personal data protection of every individual soil reading[68].

The seventh element deals with an establishment of a specific tribunal to deal with a sector-specific Agricultural AI Tribunal with small-claims jurisdiction (claims up to INR 50 lakh in the Indian context) by following the procedure and to provide compensation, where multiple farmers have suffered similar harms from the same AI system.

The eight and final element is based on UNESCO's 2021 AI Ethics Recommendation [63] and the OECD's adaptive regulatory approach, that there must be review after every five years with the sunset clauses included in the framework. Interests of multi-stakeholder governance bodies including farmer representatives, civil society organisations and environmental experts must be heard. This adaptive design accommodates the rapid pace of agricultural AI technological development while maintaining substantive farmer protections.

6.1 Feasibility of RRAGF

There are major three objections which require examination:

- It imposes excessive costs on the agricultural sector but can overcome if the tiered structure of AI risk based systems are applied uniformly along with a mandatory certification.
- The application of the concept of algorithm commons is complex and can be addressed through polycentric governance such as human oversight and government bringing it under essential commodity.
- The establishment of tribunal will help in reduction of time in adjudication of claims and burden of judiciary.

6.2 Discussion: Implications for India's Regulatory Architecture

India stands at a pivotal moment where the DPDP Act is operational with multiple frameworks are in preparation and under active development such as National Data Governance Framework and MEITY's AI governance framework respectively.

The Telecommunications Act 2023 has dealt with new challenges of implementation of AI-driven communication infrastructure in rural areas. The comparative analysis and the RRAGF proposal have three concrete implications for this moment.

Firstly, the EU AI Act must not be adopted as a whole in India as the Act's compliance of risk-based classification is not the primary issue and the domestic sector

will be disproportionately impacted with compliance costs. Secondly, the concept of agrarian commons will be in alignment with the vision of the DPDP Act by addressing the issue of data exploitation and algorithm asymmetry. Thirdly, the framework is also fulfilling the commitments which Indian constitution lays down such as distributive justice and equality. The RRAGF addresses both the issues which makes it compliant with the India's legislative framework.

7 Conclusion

This paper has demonstrated that the governance of AI in climate-smart agriculture currently exists as a regulatory patchwork assembled from fragments of environmental law, data protection, general AI governance, product liability, and intellectual property. As none of the frameworks single-handedly dealt with the AI concept. These gaps are present cross-jurisdictional and distributable harm to the smallholder farmers who are most exposed to climate risk and least equipped to seek legal redress for algorithmic failures.

The RRAGF proposed with its seven elements is inclusive of sector-specific risk classification, tiered data sovereignty, proportionate liability, algorithmic fairness mandates with Global South provisions and open data interoperability. The framework is jurisdiction-neutral in design and is the need of the hour at the time when AI systems are deployed at scale across agriculture to meet Paris Agreement NDC commitments and achieve the Farm to Fork. The price of continued regulatory inaction will be borne not by the technology developers who design agricultural AI systems, but by the farming communities who depend upon them and the ecosystems they manage. The international community through the UNFCCC, CBD, FAO, and WIPO has a complementary responsibility to ensure that the governance frameworks emerging at the domestic level are coherent with, and reinforcing of, the international environmental and intellectual property obligations that provide the normative foundation for sustainable agricultural development.

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