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Regulating Agro-Terrorism in the Digital Era: Role of Cyber Security in Protecting Agricultural and Biological Systems

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Abstract

Agro-terrorism, a specialised form of bioterrorism, involves the deliberate introduction of harmful biological agents—such as pathogens, pests, or toxins—into agricultural systems with the objective of causing economic destabilisation, food insecurity, and widespread public panic. In agrarian economies like India, where a significant proportion of the population depends on agriculture for livelihood, such threats pose serious implications not only for national security but also for socio-economic stability. In the contemporary digital era, the nature of agro terrorism has undergone a significant transformation due to the increasing integration of advanced technologies, including Artificial Intelligence (AI), the Internet of Things (IoT), big data analytics, and precision agriculture systems.

While these technological advancements have revolutionised agricultural productivity, improved resource efficiency, and enabled data-driven decision-making, they have simultaneously expanded the attack surface for malicious actors. Cyber vulnerabilities in smart farming infrastructure—such as connected irrigation systems, automated machinery, and cloud-based agricultural databases—can be exploited to manipulate data, disrupt operations, or even facilitate biological attacks. For instance, tampering with crop monitoring systems or disease detection algorithms can lead to delayed responses, resulting in large-scale agricultural damage.

This paper critically examines the intersection of agro-terrorism and cyber security by analysing how digital agricultural ecosystems can be targeted and compromised. It further evaluates the effectiveness of existing legal and regulatory frameworks in India, alongside relevant international instruments, in addressing these emerging threats. By identifying key regulatory gaps, the study highlights the urgent need for a comprehensive, integrated approach that combines biosecurity measures with robust cyber security protocols. The paper ultimately proposes policy recommendations aimed at strengthening legal preparedness, enhancing institutional coordination, and ensuring the resilience of agricultural and biological systems against evolving agro-terrorism threats.

Keywords: Agro-terrorism, Cyber Security, Precision Agriculture, Biological Threats, Food Security, IoT, AI, Legal Framework

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1. Introduction

Agriculture constitutes the backbone of many national economies, particularly in developing countries such as India, where it remains a primary source of livelihood, employment, and food security. In recent years, the agricultural sector has undergone a profound transformation driven by rapid technological advancements. The integration of digital technologies—such as smart irrigation systems, drone-based crop monitoring, satellite imaging, and genetically modified crops—has ushered in an era of precision agriculture. These innovations enable farmers to optimise resource utilisation, improve crop yields, and make data-driven decisions, thereby enhancing overall productivity and sustainability.[3]However, this increasing reliance on digital infrastructure has simultaneously exposed the agricultural sector to new and complex vulnerabilities.

The digitisation of agriculture has created interconnected systems that are susceptible to cyber threats, ranging from data breaches to large-scale system disruptions. Agro terrorism, which traditionally involved the deliberate spread of pests or diseases to damage crops and livestock, has now evolved to encompass cyber dimensions. Malicious actors can exploit weaknesses in digital platforms to manipulate agricultural data, interfere with automated farming equipment, or disrupt supply chain logistics.[4] For instance, cyber-attacks targeting food distribution networks or storage facilities can result in artificial shortages, economic losses, and public panic, thereby amplifying the impact of traditional agro terrorism.

In this context, the convergence of biological threats and cyber vulnerabilities necessitates a comprehensive regulatory approach. Addressing agro terrorism in the digital era requires not only robust legal frameworks but also the integration of cyber security measures, technological safeguards, and coordinated national security strategies.[5] A multidisciplinary response involving policymakers, technologists, law enforcement agencies, and agricultural stakeholders is essential to ensure the resilience and security of agricultural and biological systems against emerging threats.

2. Conceptual Framework of Agro-Terrorism

2.1 Definition and Scope

Agro-terrorism, as a distinct subset of bioterrorism, refers to the deliberate and malicious use of biological agents—such as harmful pathogens, pests, or toxins—to inflict damage on agricultural resources. The primary objective behind such acts is not only to destroy crops or livestock but also to trigger broader economic instability, threaten food security, and create widespread fear among the population. Unlike conventional forms of terrorism, agro terrorism targets the foundational systems that sustain human life, making its impact both direct and far-reaching.[6]

The scope of agro terrorism is wide and multifaceted. It includes the contamination of crops through the introduction of invasive species or plant diseases, which can lead to large-scale agricultural losses. Similarly, the intentional spread of infectious diseases among livestock can devastate animal husbandry sectors, affecting both food supply and rural livelihoods. Additionally, agro terrorism may involve the disruption of food supply chains, whether through biological contamination or indirect interference, thereby affecting the availability, accessibility, and safety of food. These acts, when executed strategically, can have cascading effects on national economies and public health systems.

[3] *Food & Agriculture Organization, Digital Technologies in Agriculture and Rural Areas (FAO 2019).*
[4] *National Research Council, Countering Agricultural Bioterrorism (Nat'l Academies Press 2003).*
[5] *OECD, Digital Security Risk Management in Agriculture (2020).*
[6] *National Research Council, Countering Agricultural Bioterrorism (Nat'l Academies Press 2003).*

2.2 Evolution in the Digital Era

In the modern era, agriculture has increasingly embraced digital technologies, transforming traditional farming into a data-driven and highly automated sector. Farm management systems now rely heavily on cloud-based platforms that store and analyse vast amounts of agricultural data. Internet of Things (IoT) devices are widely used to monitor critical variables such as soil quality, weather conditions, and crop health in real time. Furthermore, Artificial Intelligence (AI) tools are employed to predict crop yields, detect plant diseases at early stages, and optimise farming practices.[7]

While these technological advancements have significantly enhanced efficiency and productivity, they have also introduced new vulnerabilities. The interconnected nature of digital agricultural systems makes them potential targets for cyber-attacks. Hackers can manipulate data, disrupt automated processes, or even sabotage entire farming operations by exploiting weaknesses in digital infrastructure. For example, tampering with sensor data could lead to incorrect irrigation or fertilisation decisions, ultimately harming crop output.[8]Thus, the evolution of agro terrorism in the digital era reflects a shift from purely biological threats to a hybrid model that combines biological and cyber dimensions, requiring more sophisticated and integrated security responses.

3. Cyber Vulnerabilities in Agricultural Systems

3.1 Internet of Things (IoT) Risks

The increasing adoption of Internet of Things (IoT) technologies in agriculture has significantly enhanced efficiency, enabling real-time monitoring and automation of farming practices. Devices such as smart irrigation systems, soil sensors, and automated fertilisation units allow farmers to optimise resource use and improve crop productivity. However, this growing reliance on interconnected devices also introduces serious cyber vulnerabilities. Many IoT devices operate with limited security features, making them easy targets for hackers. If compromised, these systems can be manipulated to alter irrigation schedules, leading to either overwatering or drought-like conditions. Similarly, attackers can disrupt fertilisation cycles by changing nutrient inputs, which may damage soil quality and reduce crop yield. In extreme cases, coordinated cyber-attacks could result in large-scale crop destruction, thereby threatening food security and causing economic losses.[9]

3.2 Data Manipulation

Modern agriculture is increasingly driven by data, with digital platforms storing vast amounts of information related to crop health, weather patterns, soil conditions, and market trends. While this data-driven approach improves decision-making, it also creates opportunities for malicious actors to manipulate information for strategic or economic gain. For instance, false disease alerts can be injected into agricultural systems, causing panic among farmers and leading to unnecessary crop destruction or excessive pesticide use. Similarly, cyber interference with agricultural market data can artificially inflate or deflate prices, disrupting market stability. In more severe scenarios, manipulated data can create the illusion of food shortages, leading to hoarding, inflation, and public unrest.[10]

3.3 Supply Chain Attacks

The agricultural supply chain—from production and storage to transportation and distribution—has bec-

[7] *OECD, Digital Transformation in Agriculture and Food Systems (2019).*
[8] *K. Sharma, Cybersecurity and Critical Infrastructure Protection (2022).*
[9] *OECD, Digital Security Risk Management in Agriculture (2020).*
[10] *World Bank, Harvesting Prosperity: Technology and Productivity Growth in Agriculture (2019).*

ome highly digitised and interconnected. While this enhances efficiency, it also exposes critical logistics systems to cyber threats. Attackers can target transportation networks, warehouse management systems, or cold storage facilities to disrupt the movement of agricultural goods.[11]

Such cyber-attacks can delay the transportation of perishable goods, resulting in spoilage and wastage. Additionally, disruptions in distribution networks can prevent food from reaching markets on time, leading to shortages and price volatility. These attacks not only affect farmers and businesses but also have direct consequences for consumers, particularly in regions heavily dependent on timely food supply chains.

3.4 Bioinformatics and Genetic Data Threats

Advancements in biotechnology and bioinformatics have led to the creation of extensive genetic databases containing valuable information about crops, seeds, and livestock. While these databases play a crucial role in agricultural research and development, they also represent a significant security risk if accessed without authorisation.[12]

Unauthorized access to such sensitive data can enable the development of targeted biological agents designed to exploit specific genetic vulnerabilities in crops or animals. This could lead to highly effective agro-terrorism attacks with devastating consequences. Additionally, the theft of genetic data raises concerns about intellectual property rights, as proprietary seed technologies and research innovations may be misused or commercially exploited without consent.[13]

4. Legal and Regulatory Framework

4.1 International Framework

4.1.1 Biological Weapons Convention (BWC)

At the international level, the Biological Weapons Convention (BWC), 1972 represents a cornerstone in regulating the misuse of biological agents. It explicitly prohibits the development, production, acquisition, and use of biological and toxin weapons. The Convention reflects a global consensus that biological agents should only be used for peaceful purposes, including agriculture, medicine, and scientific research.[14]

However, despite its significance, the BWC suffers from a major limitation—its lack of a robust verification and enforcement mechanism. Unlike other arms control treaties, it does not provide for strict monitoring or compliance systems, making it difficult to detect violations or hold states accountable. This gap becomes particularly relevant in the context of agro-terrorism, where biological agents can be covertly deployed and increasingly integrated with cyber tools, thereby complicating attribution and enforcement.[15]

4.1.2 Food and Agriculture Organization (FAO) Guidelines

The Food and Agriculture Organization (FAO) has developed several guidelines and frameworks aimed at strengthening global biosecurity and protecting agricultural systems from biological threats. These guidelines emphasise preventive measures such as disease surveillance, risk assessment, and capacity building among member states.

However, FAO guidelines are largely advisory in nature and lack binding legal force. Their implementation depends on the willingness and capacity of individual countries, leading to inconsistencies in biosecurity standards across jurisdictions. In the digital era, where cyber threats transcend borders, the

[11] *K. Sharma, Cybersecurity and Critical Infrastructure Protection (2022).*
[12] *National Academies of Sciences, Safeguarding the Bioeconomy (2020).*
[13] *OECD, Global Biosecurity Risks and Challenges (2019).*
[14] *Convention on the Prohibition of Biological Weapons, 1972.*
[15] *Malcolm Dando, Biological Weapons and International Security (2015).*

non-binding character of these guidelines limits their effectiveness in addressing complex agro-terrorism risks.

4.2 Indian Legal Framework

4.2.1 Information Technology Act, 2000

In India, the Information Technology Act, 2000 serves as the primary legislation governing cyber activities. It addresses a wide range of cyber offences, including hacking, data theft, and unauthorized access to computer systems. Sections 43 and 66 specifically deal with damage to computer systems and related offences, imposing civil and criminal liability.

While the Act provides a foundational framework for tackling cyber threats, it does not explicitly address the unique vulnerabilities of the agricultural sector. Nevertheless, its provisions can be applied to cyber-attacks targeting digital agricultural infrastructure, making it indirectly relevant in combating agro-terrorism in the digital domain.

4.2.2 Bharatiya Nyaya Sanhita, 2023

The Bharatiya Nyaya Sanhita, 2023 (BNS), which replaces the Indian Penal Code, incorporates provisions relating to offences such as mischief, sabotage, and acts endangering national security. These provisions can be invoked in cases where agro-terrorism results in large-scale destruction of crops, livestock, or food systems.[16]Although the BNS does not explicitly define agro-terrorism, its broad framework allows authorities to prosecute acts that threaten public safety, economic stability, or essential resources. However, the absence of specific provisions dealing with the intersection of cyber and biological threats highlights a significant legal gap.[17]

4.2.3 Disaster Management Act, 2005

The Disaster Management Act, 2005 provides a comprehensive institutional framework for managing disasters, including biological emergencies. It empowers central and state authorities to take preventive, mitigative, and responsive measures during crises such as disease outbreaks affecting crops or livestock. While the Act is crucial for emergency response, it is largely reactive in nature and does not specifically address the prevention of cyber-enabled agro-terrorism. Its focus remains on disaster management rather than risk anticipation in digitally integrated agricultural systems.[18]

4.2.4 Biological Diversity Act, 2002

The Biological Diversity Act, 2002 aims to conserve biological resources, regulate access to genetic materials, and ensure equitable sharing of benefits arising from their use. It plays a vital role in safeguarding India's rich biodiversity, which is essential for agricultural sustainability[19].However, the Act was enacted in a pre-digital context and does not adequately address cyber threats to biological data or genetic resources. With the increasing digitisation of bioinformatics databases, there is a growing need to update the legal framework to protect against unauthorized access, data theft, and potential misuse of genetic information in agro-terrorism activities.[20]

[16] *Bharatiya Nyaya Sanhita, 2023 (India).*
[17] *K.D. Gaur, Criminal Law: Cases and Materials (2023).*
[18] *National Disaster Management Authority, Guidelines on Biological Disasters (2008).*
[19] *Biological Diversity Act, 2002 (India).*
[20] *OECD, Global Biosecurity Risks and Challenges (2019).*

5. Role of Cyber Security in Preventing Agro-Terrorism

5.1 Protection of Agricultural Infrastructure

Cyber security plays a crucial role in safeguarding modern agricultural infrastructure, which is increasingly dependent on digital technologies. As farming systems become more interconnected, protecting sensitive agricultural data becomes essential. The use of encryption techniques ensures that critical information—such as crop data, irrigation schedules, and farm management records—remains secure from unauthorized access.[21]In addition, securing IoT-based farming devices is equally important. Smart sensors, automated irrigation systems, and connected machinery must be protected through robust authentication mechanisms and secure network protocols to prevent external interference. Real-time monitoring systems further enhance security by enabling continuous surveillance of agricultural operations, allowing early detection of suspicious activities or anomalies.[22] Together, these measures help build a resilient digital agricultural ecosystem capable of withstanding cyber threats.

5.2 Early Warning Systems

The integration of advanced technologies such as Artificial Intelligence (AI) has significantly improved the ability to detect and respond to potential threats in agriculture. AI-based systems can analyse large volumes of data to identify unusual patterns that may indicate cyber intrusions or biological risks.[23] Moreover, the sharing of cyber intelligence among government agencies, research institutions, and private stakeholders strengthens collective preparedness. Timely exchange of information regarding emerging threats enables faster and more coordinated responses. In parallel, disease outbreak prediction tools, powered by data analytics and machine learning, can help identify potential risks to crops and livestock at an early stage, thereby minimising damage and preventing large-scale disruptions.

5.3 Securing Supply Chains

Agricultural supply chains are highly vulnerable to cyber-attacks due to their complexity and reliance on digital systems. Ensuring their security is essential to maintaining food availability and market stability. One effective solution is the use of blockchain technology, which enhances transparency and traceability in food systems. By creating tamper-resistant records, blockchain helps ensure the authenticity and integrity of agricultural products throughout the supply chain.

Additionally, digital tracking systems enable real-time monitoring of food movement from farms to markets, reducing the risk of diversion or contamination. Cyber security measures also play a vital role in

[21] *OECD, Digital Security Risk Management in Agriculture (2020).*
[22] *Food & Agriculture Organization, The State of Food and Agriculture (2022).*
[23] *World Bank, Artificial Intelligence in Agriculture (2019).*

preventing tampering with logistics and storage systems, thereby protecting perishable goods from spoilage and ensuring timely delivery.[24]

5.4 Capacity Building

Beyond technological solutions, strengthening human capacity is a key component of cyber security in agriculture. Farmers and other stakeholders often lack awareness of cyber risks, making them vulnerable to attacks. Providing targeted training programs can help them understand basic cyber hygiene practices and recognise potential threats.[25]Cyber awareness initiatives, including workshops and digital literacy campaigns, further contribute to building a secure agricultural environment. Additionally, fostering public-private partnerships can enhance resource sharing, innovation, and the development of effective security solutions. Collaboration between government bodies, technology providers, and agricultural communities is essential for creating a comprehensive defence mechanism against agro terrorism in the digital era.[26]

6. Challenges in Regulation

6.1 Lack of Specific Legislation

One of the most significant challenges in regulating agro terrorism in India is the absence of a dedicated legal framework that specifically addresses this emerging threat. Existing laws, such as cyber and criminal statutes, can be applied in a fragmented manner; however, they do not comprehensively cover the intersection of biological and cyber risks in agriculture. This legislative gap creates ambiguity in enforcement, jurisdiction, and accountability, making it difficult for authorities to effectively prevent, investigate, and prosecute agro-terrorism-related offences. As a result, there is an urgent need for a specialised law that clearly defines agro-terrorism and provides a structured regulatory approach.[27]

6.2 Technological Complexity

The rapid advancement of technology in agriculture has outpaced the development of corresponding legal frameworks. Innovations such as Artificial Intelligence (AI), Internet of Things (IoT), and precision farming tools are evolving continuously, creating new forms of vulnerabilities that are not adequately addressed by existing regulations. Legislators often struggle to keep up with the dynamic nature of technological change, leading to outdated or insufficient legal provisions. This gap not only weakens regulatory effectiveness but also provides opportunities for malicious actors to exploit emerging technologies for harmful purposes.[28]

6.3 Coordination Issues

Another major challenge lies in the lack of effective coordination among various governmental and institutional agencies responsible for agriculture, cyber security, and national security. In India, responsibilities are distributed across multiple bodies, including agricultural departments, cybercrime units, and disaster management authorities. However, the absence of a unified strategy or centralised authority often results in fragmented responses and delays in addressing threats. This lack of coordination can significantly undermine the ability to detect, prevent, and respond to agro-terrorism incidents in a timely and efficient manner.[29]

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[24] *K. Sharma, Cybersecurity and Critical Infrastructure Protection (2022).*
[25] *FAO, Digital Agriculture and Capacity Development (2021).*
[26] *World Economic Forum, Cybersecurity in Food Systems (2020).*
[27] *K.D. Gaur, Criminal Law and Emerging Threats (2023).*
[28] *OECD, Digital Transformation in Agriculture and Food Systems (2019).*
[29] *National Disaster Management Authority, Guidelines on Biological Disasters (2008).*

6.4 Limited Awareness

Limited awareness among farmers and agricultural stakeholders further exacerbates the problem. Many farmers, particularly in rural areas, are not adequately informed about cyber risks associated with modern agricultural technologies. This lack of knowledge makes them more vulnerable to cyber-attacks, such as phishing, data breaches, or manipulation of smart farming systems. Without proper training and awareness programs, even the most advanced technological safeguards may prove ineffective. Therefore, enhancing digital literacy and promoting cyber awareness at the grassroots level is essential for building resilience against agro terrorism.

7. Comparative Analysis

7.1 United States

The United States has established a relatively robust and proactive framework to counter agro terrorism by treating agriculture as a component of critical infrastructure. Agencies such as the Department of Homeland Security (DHS), along with the Department of Agriculture (USDA), play a central role in identifying, monitoring, and responding to threats affecting agricultural and food systems. Agro terrorism is addressed through a coordinated national security strategy that integrates both biosecurity and cyber security measures. A key strength of the U.S. model lies in its multi-agency coordination and emphasis on Agro terrorism Mechanisms for intelligence sharing, risk assessment, and emergency response are well-developed, allowing authorities to respond swiftly to both biological and cyber incidents. Additionally, the U.S. invests heavily in research and technological innovation, including advanced surveillance systems and cyber defence tools, which enhances its ability to prevent and mitigate complex threats in the agricultural sector.[30]

7.2 European Union

The European Union adopts a comprehensive and regulatory-driven approach, focusing strongly on food safety, biosecurity, and cyber resilience. EU policies are designed to ensure that agricultural systems are not only productive but also secure from both biological contamination and digital threats.[31]One of the defining features of the EU framework is its strict data protection regime under the General Data Protection Regulation (GDPR). This regulation ensures that sensitive data, including agricultural and genetic information, is processed securely and protected from unauthorized access. In addition, the EU promotes resilience through coordinated action among member states, encouraging the sharing of best practices and the implementation of uniform standards. This collective approach strengthens the region's ability to respond effectively to agro-terrorism and related risks.

7.3 Lessons for India

The comparative experiences of the United States and the European Union offer valuable insights for India in strengthening its approach to agro terrorism. Firstly, there is a pressing need for an integrated regulatory framework that combines elements of cyber security, biosecurity, and agricultural governance. Fragmented laws and policies are inadequate to address the complex and evolving nature of threats in the digital era.

Secondly, India must focus on strengthening its institutional mechanisms by establishing better coordination among various agencies involved in agriculture, cyber security, and national security. A centralised authority or nodal agency could significantly improve information sharing, policy

[30] *U.S. Department of Homeland Security, Critical Infrastructure Security and Resilience (2021).*
[31] *National Research Council, Countering Agricultural Bioterrorism (Nat'l Academies Press 2003).*

implementation, and crisis response. Furthermore, investment in technological innovation, capacity building, and awareness programs will be crucial in enhancing resilience. By adopting a holistic and coordinated approach, India can better safeguard its agricultural systems against emerging agro-terrorism threats.

RECOMMENDATIONS

1.Enact a Dedicated Agro-Terrorism Law

- Clearly define agro-terrorism, covering both biological (crop/livestock attacks) and cyber threats (hacking of Agri-systems).
- Prescribe strict penalties, including enhanced punishment for attacks on food security.
- Provide investigative powers to specialised agencies.

Example:

A hacker releases malware into a smart irrigation system causing widespread crop failure. A dedicated law would allow authorities to prosecute it as a national security offence, rather than just under general cybercrime provisions.

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2. Strengthen Cyber Infrastructure in Agriculture

- Introduce mandatory cybersecurity standards for agri-tech devices like drones, sensors, and smart irrigation systems.
- Establish certification mechanisms for Internet of Things (IoT)-based agricultural tools.
- Encourage regular security audits for agri-tech companies.

Example:

Before being sold in India, a smart irrigation device must pass a government-approved cybersecurity certification, ensuring it cannot be remotely hijacked by attackers.

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3. Establish a National Agro-Cyber Security Authority

- Create a centralised authority to monitor threats to agriculture from cyber and biological domains.
- Develop a real-time incident response system for rapid action.
- Coordinate between ministries such as agriculture, home affairs, and IT.

Example:

If a ransomware attack hits multiple grain storage facilities, the authority can immediately coordinate response, isolate affected systems, and prevent nationwide supply disruption.

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4. Promote Research and Development (R&D)

- Invest in AI-based early warning systems to detect unusual crop disease patterns or cyber intrusions.
- Encourage collaboration between government, universities, and private sector.
- Provide funding for indigenous agri-cyber technologies.

Example:

An AI system developed by a university detects abnormal pest spread patterns, indicating a possible deliberate biological attack, enabling early containment.

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5. Enhance International Cooperation

- Strengthen cross-border intelligence sharing on agro-terror threats.
- Participate in joint research programmes on food security and cyber resilience.
- Align domestic laws with global frameworks.

Example:
India collaborates with the Food and Agriculture Organization (FAO) to share data on crop disease outbreaks, helping identify whether an incident is natural or a coordinated agro-terror attack.

Conclusion

The increasing convergence of agriculture with digital technologies has fundamentally transformed the sector into a complex cyber-physical ecosystem, where traditional farming practices are now deeply integrated with data-driven tools, smart devices, and automated systems. While this transformation has enhanced productivity, efficiency, and sustainability, it has simultaneously expanded the threat landscape. Agro-terrorism in the contemporary digital era is no longer confined to conventional biological attacks such as crop contamination or livestock diseases; it now encompasses sophisticated cyber intrusions targeting precision agriculture systems, supply chains, storage infrastructure, and agri-fintech platforms. Such attacks have the potential to disrupt entire food systems, destabilize markets, and threaten national security.

In the Indian context, the risks are particularly significant due to the country's heavy dependence on agriculture for livelihood and economic stability. Despite the existence of legal frameworks such as the Information Technology Act, 2000 and provisions under the Bharatiya Nyaya Sanhita, 2023, the current regime remains fragmented and inadequate to address the multidimensional nature of agro-terrorism. These laws primarily focus on general cyber offences and fail to capture the unique intersection of biological, technological, and national security concerns inherent in agro-terror threats.

Therefore, India must adopt a proactive and integrated approach. This includes enacting a dedicated legal framework specifically addressing agro-terrorism, strengthening cybersecurity infrastructure in agriculture, and establishing specialized institutions for monitoring and response. Investment in research and innovation—particularly in artificial intelligence and early warning systems—will be crucial for threat detection and mitigation. Equally important is fostering collaboration among government agencies, private stakeholders, and international organizations to ensure coordinated and timely responses.

Ultimately, a comprehensive regulatory regime is indispensable to safeguard food security, protect economic interests, and uphold national security. As agriculture becomes increasingly digitized, ensuring its resilience against emerging cyber and biological threats must be treated as a strategic priority for India's future.

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