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Global Environmental Policy Concerning Incentives for Smart Agriculture for Sustainable Farming

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Abstract

Air pollution is a major environmental and public health challenge, threatening human dignity and the right to health, especially in developing nations like Nigeria. Despite constitutional protections and environmental regulations, rising emissions from industry, vehicular pollution, gas flaring, and arbitrary waste burning increase exposure to dangerous chemicals and toxic substances. This paper explores the nexus between air pollution and the right to health in Nigeria, considering gaps in current legal mechanisms for addressing health violations arising from environmental pollution. This paper will evaluate relevant laws, analyze problems in institutions and enforcement of such laws and explore ways of enhancing environmental accountability. In this paper, the authors utilize a doctrinal approach, using analysis and description to explore primary sources such as legislation, constitutional provisions and court decisions and secondary sources such as journals, reports and international agreements. The results show poor enforcement, institutional fragmentation, and limited access to environmental justice. This study shows the need for an effective environmental health liability system that includes corporate accountability, compensation, prevention, and remedies.

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1. Introduction

Agriculture remains the bedrock of food security, economic development, and human survival, feeding people, facilitating international trade, and providing essential raw materials for industries. But the global agriculture sector now struggles to overcome numerous interrelated problems driven by climate change, environmental degradation, population growth, soil degradation, and declining water supplies. These factors have created a situation in which conventional agricultural methods raise questions about the sector's sustainability due to overreliance on chemicals and irrigation, as well as environmentally unfriendly land-use patterns. Thus, world agricultural governance has been gradually moving into a stage where agriculture is not only economically productive but also ecologically sustainable and resilient to climate change. To achieve this, innovative agricultural technologies, environmental policies, and incentives should be implemented to ensure that farmers adopt sustainable agricultural practices. Indeed, there has been recognition on the part of governments and international organizations that sustainable agriculture will not be achieved merely through voluntary commitments and environmental policies. Instead, incentives and economic tools must be used. This has highlighted the need to create effective policy instruments that encourage environmentally sustainable agriculture.

Smart agriculture is defined as an advanced agricultural approach that uses technologies, innovations, and environmentally friendly practices to increase the efficiency and sustainability of agricultural processes. The term includes precision farming, artificial intelligence, remote sensing, satellite surveillance, automated irrigation systems, agricultural drones and decision-support systems. These technologies allow farmers to control the State of the soil, detect plant diseases, use fertilisers efficiently and improve the management of water resources. As a result, smart agriculture offers opportunities to reduce agricultural waste and GHG emissions and increase resilience to climate change. The importance of innovative solutions in the sphere of agricultural production has been underlined by Gupta (2024), whereas the connection between innovative approaches to agriculture and sustainable risk management has been proven by van Asseldonk et al. (2023). In addition, the potential of modern technologies in the transformation of agricultural production has been highlighted by Vishnoi and Goel (2024) and Zhang et al. (2024). Moreover, the relevance of precision agriculture for resource-use efficiency and environmental performance has been proven by Walter et al. (2017). However, successful implementation of these technologies requires adequate financial resources, technology availability, an enabling institutional context, and appropriate policy interventions.

Global environmental policy serves as a useful tool to facilitate sustainable agricultural practice through financial, technical and institutional incentives. The incentive scheme may include agricultural subsidies, tax exemptions, low-interest lending, carbon credits, grants, insurance schemes, and payments for ecosystem services. Such measures aim to overcome the financial barriers involved in the transition from conventional agriculture to environmentally sustainable agriculture. Lipper et al. (2014) and Lipper and Zilberman (2017) analyse the link between climate-smart agriculture, investments and agricultural development, emphasising the need for appropriate economic policy. In a similar vein, Piñeiro et al. (2020) underscore the importance of

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incentives in facilitating sustainable agricultural transformation, while Scherr et al. (2012) emphasize the relevance of agricultural landscapes for solving environmental problems. Steenwerth et al. (2014) also underline the connection between agricultural sustainability and climate adaptation. At the same time, the effectiveness of such incentives requires transparency, equity, and measurable environmental outcomes. International environmental commitments, including those on climate change, biodiversity, and sustainable development, provide another rationale for applying agricultural incentives within environmental governance. For this reason, global environmental policy needs to move from making sustainability claims to implementing economic mechanisms that motivate farmers to use environmentally sustainable technologies and methods in agriculture.

Regulation of sustainable agriculture through law largely depends on international environmental agreements, national agricultural policy, and climate governance. Documents such as the Paris Agreement (2015), the Convention on Biological Diversity (1992), and the UN Sustainable Development Goals provide important grounds for climate adaptation, biodiversity protection, and promoting sustainable food production. Nonetheless, gaps remain in implementing these goals through agricultural incentive systems. The interrelatedness of agricultural sustainability, biodiversity, and environmental policy is shown in works by Campbell et al. (2014), Bopp et al. (2019). In addition, Lewis and Rudnick (2019) discuss the role of institutional and policy considerations in agricultural transitions. However, despite increasing awareness regarding smart agriculture, farmers have to face lack of funding, technological infrastructure, poor coordination and unstable governmental support. Moreover, existing agricultural subsidy schemes may stimulate production with negative environmental effects because incentives are not linked to sustainability outcomes. The core issue, therefore, is the lack of appropriate incentive frameworks that are well-coordinated, readily available, and enforceable to translate global environmental goals into tangible means of promoting sustainable agriculture.

Much of the existing literature has explored climate-smart agriculture, innovations in agricultural technology, agricultural productivity, and incentives to sustain agriculture (Mizik, 2021; Ma & Rahut, 2024; Savastano et al., 2025; Rudnicki et al., 2023). Other scholarly work addresses agricultural financing, environmental sustainability, and technology adoption (Bucci et al., 2018; Collins, 2018; Getahun et al., 2024; Hayo & Hasegawa, 2024). Yet, relatively little research has examined the potential for global environmental policy to create a legal and economic incentive framework for smart agriculture across jurisdictions. This research attempts to fill this gap by examining the connection between international environmental obligations, government incentive policies, and the use of smart agricultural technologies. The originality of the research lies in its focus on evaluating incentives as regulatory mechanisms, not just as tools for agricultural development. The paper is therefore going to assess the current environmental policies on agricultural sustainability across the globe, the economic, legal, and institutional incentives for smart agriculture, the problems that come up with regard to their implementation, and propose a coordinated policy framework that ensures equal access to technology, environmental protection, and sustainable agriculture (Kabato et al., 2025; Alexander et al., 2026; Olabanji & Chitakira, 2025).

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2. Method

The research uses a doctrinal research method, which utilizes a descriptive and analytical analysis in investigating global environmental policies with regard to the use of incentives for smart and sustainable agriculture. This methodology is applicable to the present study because it largely concentrates on legal principles, frameworks, institutional responsibilities, and policy tools that regulate the incorporation of incentives into environmental sustainability. A descriptive methodology is used to study and understand current international environmental instruments, legislation, and policies supporting smart farming. The analytical method is used to assess the suitability, effectiveness, and limitations of these legal and policy tools in promoting technological innovation, environmental protection, and sustainable farming practices. This is achieved by examining the availability of financial incentives, subsidies, tax breaks, grants, and other economic tools within the available environmental governance principles.

The study employs the use of both primary and secondary sources of legal research, which are acquired via documentary research. Primary sources are made up of international environmental treaties, declarations, conventions, protocols, resolutions, national laws, policies and court decisions in relation to environmental protection, sustainable agriculture, climate change and economic incentives. The Paris Agreement (2015), the Convention on Biological Diversity (1992), various United Nations instruments, and pertinent national environmental and agricultural laws and regulations are considered in particular. The source material is gathered from official government publications, international institution repositories and recognized legal databases. The secondary source materials are comprised of academic books, journal articles, research papers, scholarly commentaries and publications of international institutions like the Food and Agriculture Organization and the United Nations Environment Programme. They are gathered through recognized academic databases, institutional repositories and scholarly publications. The gathered source materials are analyzed, compared and interpreted in order to establish current legal positions and develop recommendations to strengthen global environmental incentives for smart agriculture.

3. Results and Discussion

3.1. Smart Agriculture for Sustainable Farming

Smart agriculture is defined as the application of scientific knowledge, digital technology, and environmentally friendly agricultural practices to enhance food production and sustainability (National Research Council et al., 2010). This definition includes not only innovations such as artificial intelligence, precision farming, satellite imagery, agricultural drones, GIS technology, irrigation automation, and farm data management but also environmentally friendly practices such as conservation agriculture, soil fertility management, agroforestry, improved seed varieties, and rational water management (Robertson, 2015). The main goal of these agricultural practices is to increase agricultural productivity without destroying the ecosystems that make agriculture possible (Islam et al., 2022). Smart agriculture also acknowledges the role of farmers' knowledge, institutions and agricultural information in sustainable agricultural production (Sneha et al., 2023). As a result, smart agriculture involves not just the application of advanced agricultural machines and tools but also the integration of technological innovation, environmental protection, and economic development (Takacs-

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Gyorgy & Takács, 2022). The final aim of smart agriculture is to build sustainable agricultural production that increases productivity, improves climate resilience, saves natural resources and ensures food security for current and future generations (Kabato et al., 2025).

Figure 2: Global land degradation and agricultural land



Source: Food and Agriculture Organization (FAO), 2025, assessment of the State of the world's land and water resources.

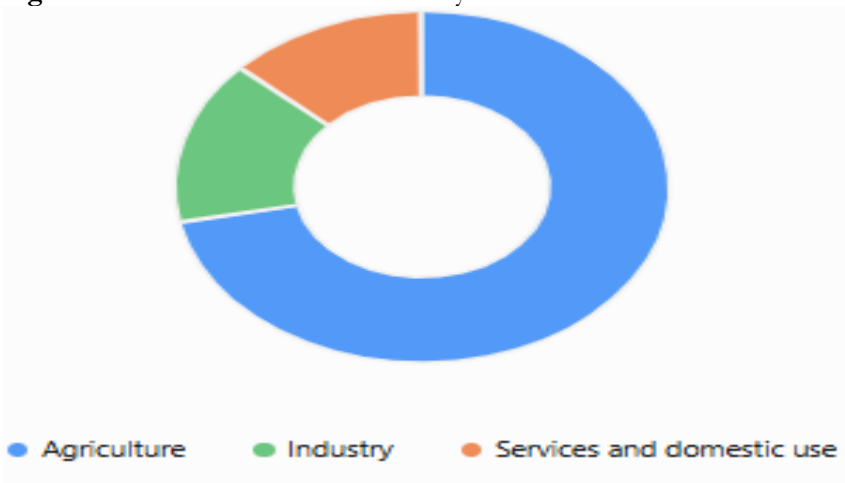
Technological innovation is an important aspect of smart agriculture in that it helps farmers make informed decisions about agricultural production, resource distribution, and environmental management (Taneja et al., 2019). Precision agriculture technology, for example, uses GPS, soil sensors, satellite imagery, and automated machines to identify differences in soil composition and crop needs and provide targeted interventions (Walter et al., 2017). Likewise, agricultural drones and remote sensing technology help monitor crops, identify pests and diseases, and assess agricultural land conditions (Kountios, 2022). In addition, artificial intelligence and digital agricultural technology can help predict weather patterns, irrigation scheduling and fertilizer and pesticide application efficiently (Petrovic & Csambalik, 2025). This technology is especially useful for overcoming the challenges associated with traditional agriculture, where uniform agricultural activities can lead to overuse of inputs, resource waste, and environmental pollution (Schieffer & Dillon, 2015). Digital transformation helps farmers access agricultural extension services, market information, and weather advisory services using mobile phones and the internet (Taylor, 2018). Nonetheless, applying technology requires electricity, internet connections, affordable tools, technological know-how, and an adequate institutional framework (Kubanza & Oladele, 2024). Thus, the development of smart agriculture should consider affordable technological innovations aligned with farmers' needs, thereby enhancing inclusive agricultural transformation (Sneha et al., 2023).

Environmental sustainability remains an integral aspect of smart agriculture, as agricultural productivity largely depends on environmental resources such as land, water, soil, and biodiversity (Neufeldt et al., 2013). Smart agricultural technologies facilitate efficient utilisation of available resources through precision irrigation, soil moisture monitoring, conservation tillage, nutrient management, and climate-adaptive crop production (Steenwerth et al., 2014). The significance of such innovations is highlighted by the pattern of water withdrawals at the global level, where the agricultural sector utilizes up to 72% of the freshwater withdrawals across the globe (UNESCO, 2024). In addition, agricultural land degradation is another major environmental issue that requires farming systems that preserve soil fertility, prevent erosion,

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and rehabilitate degraded areas (Campbell et al., 2014). Sustainable agriculture can help cope with the effects of climate change by producing drought-tolerant crops, improving weather prediction, and using agroforestry and climate-based farming (Lipper et al., 2014). These measures are essential, since intensive farming without proper safeguards leads to higher greenhouse gas emissions, biodiversity loss, and environmental pollution (Bopp et al., 2019). Therefore, sustainable smart agriculture should be evaluated not only on higher yields but also on how much it helps preserve the environment (Lipper & Zilberman, 2017).

Figure 1: Global freshwater withdrawals by economic sector



Source: UNESCO, United Nations World Water Development Report 2024.

The use of smart agriculture is highly determined by the presence of sufficient financial resources, institutions and the provision of necessary economic incentives (Schieffer & Dillon, 2015). While agricultural technologies can increase productivity and enhance environmental performance, they can be costly for farmers, especially small-scale producers (Takacs-Gyorgy & Takács, 2022). Therefore, the government and international development organisations should implement incentive schemes to foster the adoption of environmentally friendly agricultural technologies (Lewis & Rudnick, 2019). These incentives could take many forms, such as agricultural subsidies, tax exemptions, low-interest credit facilities, technology grants, agricultural insurance, carbon credits and payment for ecosystem services (Verschuuren, 2018). These incentive mechanisms will minimize the financial risks associated with switching from traditional farming practices to technologically advanced and environmentally friendly agricultural systems (Kabato et al., 2025). The role of institutions through cooperatives, research organisations, agricultural extension and public-private partnerships in improving access to technological information and infrastructure will be highly critical (Kubanza & Oladele, 2024). Nonetheless, incentive schemes must be transparent, fair, and open to all farmers, regardless of their ability to pay, geographic location, and farm size (Taylor, 2018). Without suitable institutional oversight, unsuitable subsidies can lead to unnecessary input use by farmers or disproportionately favour large-scale commercial farmers (Scherr et al., 2012). Economic incentives must therefore be tied to environmental performance so public money is used effectively to support sustainable agriculture (Lipper & Zilberman, 2017).

International environmental policies provide the necessary regulatory and institutional framework through which smart agriculture is encouraged as a tool of sustainable agriculture

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(Campbell et al., 2014). Global environmental goals related to climate change mitigation, biodiversity conservation, sustainable land management, and food security set critical policy directions for countries to support environmentally sustainable agricultural production (Neufeldt et al., 2013). However, the attainment of these goals needs international environmental commitments to be converted into national laws, agricultural development policy and financial incentives that foster innovation (Verschuuren, 2018). Such policies must create appropriate regulatory frameworks for agricultural technology, sustainable natural resources management, environmental monitoring and environmentally sustainable agricultural investment (Lewis & Rudnick, 2019). It is equally crucial to design institutional frameworks that facilitate cooperative relationships among governments, farmers, agricultural scientists, technological providers and international development agencies (Robertson, 2015). Smart agricultural practices also need to be integrated with accountability frameworks to ensure that technological progress does not lead to environmental degradation, economic harm to farmers, or discrimination in the allocation of agricultural resources (Bopp et al., 2019). From this perspective, the incentive frameworks will include rewards for measurable gains in agricultural productivity, soil conservation, efficient water use, biodiversity and climate change resilience (Lipper et al., 2014). Hence, this research is theoretically positioned on the premise that sustainable smart agriculture requires an integrated global environmental policy approach that includes innovations, economic incentives, institutional coordination, and environmental safeguards (Zhang et al., 2024).

3.2. Global Environmental Policy on Incentives on Smart Agriculture for Sustainable Farming

Environmental governance policies at the international level and disciplines put in place through the World Trade Organization Agreement on Agriculture play a significant role in determining financial incentives within domestic jurisdictions for smart agriculture. In accordance with Annex 2 to the Agreement on Agriculture, exemptions provided for in the Green Box do not compel member states to make reduction commitments where the spending is exclusively targeted at offsetting additional costs or income loss suffered by agricultural producers in implementing government environmental programs (Rudnicki et al., 2023; Ma & Rahut, 2024; Alexander et al., 2026). Nevertheless, difficulties inherent in the Aggregate Measurement of Support approach tend to constrain developing sovereign states' ability to finance costly smart agriculture technology and digital precision equipment (Musa & Basir, 2021; El Bakali et al., 2023; Frimpong et al., 2023). Despite the special and differential treatment provisions in Article 6.2, which apply to low-income or resource-poor producers in developing countries, current limits on market price support distort the economic incentives needed for digital transformation.

Multilateral climate change agreements set out clear legal obligations to integrate climate-smart agriculture into countries' climate mitigation and adaptation policy frameworks. The United Nations Framework Convention on Climate Change legally requires the parties to the convention to devise national programs involving measures to limit climate change by adopting sustainable agricultural practices and international technology transfers in line with the principle of common but differentiated responsibilities (Vărzaru, 2024; Olabanji & Chitakira, 2025; Acharyya, 2022). In addition to that, Article 2.1(a)(iii) of the Kyoto Protocol directly obliges promoting sustainable agriculture with due regard to climate change aspects in order to meet targets of aggregate emissions reduction (Mizik, 2021; Bayata & Mulatu, 2024; Bucci et al.,

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2018). Moreover, the Paris Agreement reinforces this normative complementarity by stipulating in Article 2.1(b) the need to foster climate adaptation and low-emission development without threatening food production levels. Article 6 of the Paris Agreement also provides voluntary cooperative approaches and transferable mitigation outcomes to channel international climate finance into climate-smart agriculture initiatives (Collins, 2018; Getahun et al., 2024).

Normative policy frameworks designed by the Food and Agriculture Organization outline the ways to translate international treaty-based commitments into concrete implementation approaches for climate-smart agriculture. With its fundamental basis on three interconnected pillars that consist of sustainably raising productivity and farmer incomes, increasing ecosystem resilience, and minimizing greenhouse gas emissions, climate-smart agriculture requires integrated landscape-scale ecosystem management and hybrid public-private financing systems (Hayo & Hasegawa, 2024; Islam et al., 2022; Kleftodimos et al., 2024). The Food and Agriculture Organization Strategic Framework 2022–2031 ensures the achievement of key goals by means of Programme Priority Areas such as Innovation for Sustainable Agriculture Production and Climate Change Mitigating Agri-Food Systems (Gupta, 2024; van Asseldonk et al., 2023; Siedenburg et al., 2012). Specific technical programs, such as the Economic and Policy Support for Climate-Smart Agriculture program and the Mitigation of Climate Change in Agriculture program, help Member States assess institutional trade-offs and integrate global climate finance with sustainable agricultural investment programs. These institutional guidelines effectively close the regulatory policy gap between global environmental policies and local smallholder farmers.

Governance of soil health and preservation of genetic resources are important normative cornerstones of global environmental policies that regulate sustainable agricultural incentives. The Global Soil Partnership Action Framework for 2022-2030 advocates sustainable soil management by implementing the Voluntary Guidelines for Sustainable Soil Management and launching targeted programs such as Recarbonization of Global Soils (Engel & Muller, 2016; Vishnoi & Goel, 2024; Piñeiro et al., 2020). By establishing a composite Soil Health Index and unified monitoring parameters, the Global Soil Partnership strengthens incentives for soil carbon sequestration under multilateral Rio conventions (Kabato et al., 2025; Walter et al., 2017). On the other hand, the International Treaty on Plant Genetic Resources for Food and Agriculture conserves important agricultural biodiversity under the Multilateral System of Access and Benefit-Sharing and provides legal recognition of farmers' Rights through Article 9. These international legal instruments provide incentives for the widespread adoption of climate-resilient crop varieties, participatory plant breeding, and conservation agriculture practices, thereby ensuring ecological soundness, environmental sustainability, climate resilience, and genetic diversity as basic components of global smart farming economic incentive systems.

In this case, the United Nations 2030 Agenda for Sustainable Development acts as an umbrella for the sector-specific international conventions mentioned above. More specifically, Sustainable Development Goal Target 2.4 calls for sustainable food production and resilient agricultural practices that improve land and soil quality (Steenwerth et al., 2014; Lewis & Rudnick, 2019). This fundamental target is supported by Target 12.c, which encourages governments to rationalise inefficient fossil fuel and agricultural subsidies that harm markets and the environment (Scherr et al., 2012; Bopp et al., 2019). Additionally, Target 13.2 requires

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the systematic integration of climate change measures into national policies, and Target 15.3 encourages the global community to achieve land degradation neutrality. Critically analysing these targets, it is clear that although the Sustainable Development Goals provide a holistic strategy for creating smart incentives for agriculture, their non-binding nature depends heavily on national political will, the transparency of governance institutions, and incorporation into national law.

Table 1: Overview of Global Legal Frameworks & Incentive Mechanisms

International Legal Framework / Agreement	Primary Policy Mechanism	Relevant Article / Annex	Key Incentive Function for Smart Agriculture
WTO Agreement on Agriculture (AoA)	Green Box Exemptions & AMS Caps	Annex 2 (Para 6 & 12); Article 6.2	Provides exemptions for direct environmental payments and research/extension while capping trade-distorting subsidies.
UN Framework Convention on Climate Change (UNFCCC)	National Mitigation & Technology Transfer	Article 3.3; Article 4.1(c)	Encourages states to integrate sustainable agriculture practices and climate-smart technologies.
Kyoto Protocol	Sustainable Agriculture & Sink Management	Article 2.1(a)(iii); Article 12 (CDM)	Calls upon Annex I parties to encourage sustainable agriculture practices and carbon sequestration techniques.
Paris Agreement	NDCs, Article 6 Markets & Adaptation	Article 2.1(b); Article 5; Article 6.2/6.4	Supports climate-resilient approaches without compromising food security and enables carbon finance for smart agriculture.
FAO Strategic Framework (2022).–2031	Programme Priority Areas (BP1 & BE1)	PPAs BP1, BE1, BE3	Encourages innovation and digital approaches in mitigation and adaptation efforts in national agri-food systems.
FAO Global Soil Partnership (GSP)	Sustainable Soil Management & RECSOIL	Action Areas 1 & 2; VGSSM	Aligns standards for soil health and encourages soil organic carbon recarbonization projects.

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ITPGRFA (Plant Treaty)	Multilateral System (MLS) & Farmers' Rights	Articles 6, 9, 10–13	Ensures equitable access and benefit sharing in crop genetic resources for participatory plant breeding.
UN 2030 Agenda (SDGs)	Sustainable Production & Subsidy Reform	Targets 2.4, 12.c, 13.2, 15.3	Ensures resilient farming systems and land degradation neutrality and elimination of market distortions.

3.3. Legal Issues and Challenges

Among the most critical legal issues in global environmental governance is the regulatory tension between WTO trade rules and government subsidy programs aimed at facilitating smart agriculture. The Green Box provisions in the Agreement on Agriculture stipulate that public environmental payments should not include any price support or exceed the real cost of compliance. In consequence, there arises an issue of legal vagueness in cases when states subsidize expensive digital infrastructure, precision instruments, or automatic monitoring equipment in farms (Vărzaru, 2024; Olabanji & Chitakira, 2025; Acharyya, 2022; Mizik, 2021). There exist stringent legal limitations for developing countries under the Aggregate Measurement of Support limits and de minimis levels, which strictly prohibit State agricultural support up to ten percent of production value. Therefore, when developing countries subsidise key components of smart agriculture or digital technologies for small farmers with insufficient resources, it may lead to disputes under the General Agreement on Tariffs and Trade.

Legal issues such as data governance, intellectual property rights, and digital privacy become essential challenges when scaling smart agricultural technologies around the globe. It is necessary to State that the nature of precision agriculture depends on the constant acquisition of farm-level data, digital soil maps, and satellite remote sensing, which involves serious legal questions concerning data ownership rights, farm data sovereignty, and corporate monopolies (Bayata & Mulatu, 2024; Bucci et al., 2018; Collins, 2018; Getahun et al., 2024). Transnational agri-tech firms often use proprietary software and closed data systems, thus creating a digital divide that excludes smallholder agricultural producers. In addition, the International Treaty on Plant Genetic Resources for Food and Agriculture guarantees Farmers' Rights under Article 9, giving farmers access to genetic resources; however, corporate patenting of digital sequence information and biotechnology prevents farmers from practising traditional seed saving. No existing legal framework within international law instruments regulates transparency in data governance, benefit sharing, or protection against misuse of smallholder producer data in the global agricultural value chain, digital platforms, and commercial data ecosystems.

Land tenure insecurity and fragmented property rights represent serious legal and structural obstacles to the widespread implementation of smart farming incentive programs. Various sustainable land use approaches, such as agroforestry, soil carbon sequestration projects, and the installation of precision drip irrigation systems, require significant investment and a long-term planning horizon of several years (Hayo & Hasegawa, 2024; Islam et al., 2022; Kleftodimos et al., 2024; Kountios, 2022). Nevertheless, in many developing countries, small farmers, customary landowners, pastoralists, indigenous peoples, and women producers lack legally registered land title deeds or formal land tenure documentation. The Food and

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Agriculture Organisation Voluntary Guidelines on the Responsible Governance of Tenure note that secure land tenure is a vital legal condition for environmental protection, but national legislation often provides no protection against arbitrary eviction, insecure tenure, and land grabbing by tenant farmers. Without legally secured property rights and land ownership guarantees, vulnerable farmers cannot access financial incentives from commercial banks, government incentive schemes, or international financing for climate change mitigation.

Weak legal compliance measures within fragmented international environmental regulatory regimes have significantly hindered the implementation of smart agriculture policies. Even though multilateral environmental agreements like the United Nations Framework Convention on Climate Change, the Paris Agreement, and the Convention on Biological Diversity officially acknowledge sustainable agriculture, their legal provisions lack enforcement mechanisms, relying entirely on domestic national laws (Kubanza & Oladele, 2024; National Research Council et al., 2010; Neufeldt et al., 2013; Petrovic & Csambalik, 2025; Robertson, 2015). Developing nations' national legal systems face many challenges, including gaps in regulatory institutions, bureaucratic overlaps, and a lack of technical capacity. In addition, international financing mechanisms like the Green Climate Fund and Clean Development Mechanism impose stringent legal requirements for compliance, complicated administrative processes, and rigorous measurement, reporting, and verification. These complex, restrictive administrative and legal measures make it difficult for small-scale farmer communities, local agricultural institutions, family farmers, rural communities, community leaders, and indigenous producer cooperatives to access international climate finance and results-based environmental payments.

Equitable access to finance and distributive justice are core legal challenges in the global smart agriculture policy regime. The current international environmental policy framework gives high priority to private financial resources, mobilization of markets, and financing instruments through carbon credits in international markets based on Article 6 of the Paris Agreement (Schieffer & Dillon, 2015; Sneha et al., 2023; Takacs-Gyorgy & Takács, 2022; Taylor, 2018; Taneja et al., 2019; Verschuuren, 2018). Yet, without stringent legal measures on equity, market-oriented financial incentives tend to unfairly favour large, high-tech commercial agribusinesses while discriminating against resource-poor small farmers. Article 3 of the Climate Convention and Article 2.2 of the Paris Agreement require equity and common but differentiated responsibilities, but international climate finance transfers do not provide predictable concessionary flows to vulnerable agricultural groups. Such legal disparity can be overcome only by systemic reform of national legal regimes governing tax laws, credits, and subsidies to ensure that State financial incentive policies promote social inclusion, gender equality, and poverty elimination.

4. Conclusion

Global environmental law on smart agriculture incentives represents a revolutionary legal tool for integrating global food security and ecology. International conventions, such as the WTO Agreement on Agriculture Green Box, the Paris Agreement, and the FAO strategy on sustainable soil management, sustainable intensification, and technology adoption, provide a normative legal basis for achieving these goals. But in-depth legal analysis reveals significant obstacles to effective implementation at the systemic regulatory level. Caps on trade support expenditures, fragmented environmental agreements, insecure land tenure, and legal uncertainties around farm data ownership create constant structural friction among

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international regimes. In addition, market-based climate finance mechanisms tend to marginalize resource-limited small-scale farmers, thus reinforcing global socioeconomic inequality. Without solving these contradictions through international legal reforms, global policies cannot successfully promote climate-smart agriculture.

To overcome these legal hurdles, both international regulatory institutions and states must undertake a series of legal and policy reforms. First, it is important to update the World Trade Organisation's domestic support measures to ensure that smart agriculture technology subsidies for developing countries are exempt under the Green Box approach. Second, national environmental regulations should align with international standards by incorporating the Food and Agriculture Organisation Voluntary Guidelines on Tenure to ensure tenure security for smallholder farmers. Third, an international legal framework for data governance in agriculture must be established within the UN to ensure agricultural data sovereignty, avoid corporate monopolization and promote a fair benefit-sharing system. Finally, international climate funds need to simplify accreditation procedures and increase concessional financing for small farmers, family farms, and indigenous producers to build sustainable agri-food systems.

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Conflict of Interest

Nil

References

Acharyya, A. (2022). Climate-smart agriculture in developing economies: An analysis of strategies and policies. In *Environmental economics in developing countries* (pp. 231–257).

Alexander, C., Zabala, A., & Kontoleon, A. (2026). Climate-smart agriculture and the impact of financial incentives on adoption: An econometric analysis. *Journal of Rural Studies, 123*, Article 104035.

Bayata, A., & Mulatu, G. (2024). Carbon farming, climate-smart agriculture practice and current climate change mitigation strategy in the case of Ethiopia. *International Journal of Environmental Monitoring and Analysis, 12*(6), 149–156.

Bopp, C., Engler, A., Poortvliet, P. M., & Jara-Rojas, R. (2019). The role of farmers' intrinsic motivation in the effectiveness of policy incentives to promote sustainable agricultural practices. *Journal of Environmental Management, 244*, 320–327.

Bucci, G., Bentivoglio, D., & Finco, A. (2018). Precision agriculture as a driver for sustainable farming systems: State of art in literature and research. *Calitatea, 19*(S1), 114–121.

Print ISSN: 3156-7185
e-ISSN: 3156-7177

Campbell, B. M., Thornton, P., Zougmoré, R., Van Asten, P., & Lipper, L. (2014). Sustainable intensification: What is its role in climate-smart agriculture? *Current Opinion in Environmental Sustainability, 8*, 39–43.

Collins, A. (2018). Saying all the right things? Gendered discourse in climate-smart agriculture. *The Journal of Peasant Studies, 45*(1), 175–191.

El Bakali, I., Ait El Mekki, A., Maatala, N., & Harbouze, R. (2023). A systematic review on the impact of incentives on the adoption of conservation agriculture: New guidelines for policymakers and researchers. *International Journal of Agricultural Sustainability, 21*(1), Article 2290415.

Engel, S., & Muller, A. (2016). Payments for environmental services to promote "climate-smart agriculture"? Potential and challenges. *Agricultural Economics, 47*(S1), 173–184.

Frimpong, F., Asante, M. D., Peprah, C. O., Amankwaa-Yeboah, P., Danquah, E. O., Ribeiro, P. F., Aidoo, A. K., Agyeman, K., Asante, M. O. O., Keteku, A., & Botey, H. M. (2023). Water-smart farming: Review of strategies, technologies, and practices for sustainable agricultural water management in a changing climate in West Africa. *Frontiers in Sustainable Food Systems, 7*, Article 1110179.

Getahun, S., Kefale, H., & Gelaye, Y. (2024). Application of precision agriculture technologies for sustainable crop production and environmental sustainability: A systematic review. *The Scientific World Journal, 2024*(1), Article 2126734.

Gupta, S. (2024). Government initiatives and policies for smart agriculture. In *Agriculture 4.0* (pp. 334–354).

Hayo, L., & Hasegawa, H. (2024). Enhancing emission reductions in South African agriculture: The crucial role of carbon credits in incentivizing climate-smart farming practices. *Sustainable Futures, 8*, Article 100260.

Islam, Z., Sabiha, N. E., & Salim, R. (2022). Integrated environment-smart agricultural practices: A strategy towards climate-resilient agriculture. *Economic Analysis and Policy, 76*, 59–72.

Kabato, W., Getnet, G. T., Sinore, T., Nemeth, A., & Molnár, Z. (2025). Towards climate-smart agriculture: Strategies for sustainable agricultural production, food security, and greenhouse gas reduction. *Agronomy, 15*(3), Article 565.

Kleftodimos, G., Kyrgiakos, L. S., Kartakis, S., Kleisiari, C., Vasileiou, M., Kremantzis, M. D., & Vlontzos, G. (2024). Promoting excellence or discouraging mediocrity—a policy framework assessment for precision agriculture technologies adoption. *Precision Agriculture, 25*(6), 2903–2920.

Kountios, G. (2022). The role of agricultural consultants and precision agriculture in the adoption of good agricultural practices and sustainable water management. *International Journal of Sustainable Agricultural Management and Informatics, 8*(2), 144–155.

Kubanza, N. S., & Oladele, O. J. (2024). Climate smart agricultural policy in sub-Saharan Africa: A case study of Ngaka Modiri Molema District Municipality of North West Province, South Africa. *Local Environment, 29*(12), 1579–1593.

Lewis, J., & Rudnick, J. (2019). The policy enabling environment for climate-smart agriculture: A case study of California. *Frontiers in Sustainable Food Systems, 3*, Article 31.

Print ISSN: 3156-7185
e-ISSN: 3156-7177

Lipper, L., & Zilberman, D. (2017). A short history of the evolution of the climate-smart agriculture approach and its links to climate change and sustainable agriculture debates. In *Climate-smart agriculture: Building resilience to climate change* (pp. 13–30).

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., ... Torquebiau, E. F. (2014). Climate-smart agriculture for food security. *Nature Climate Change, 4*(12), 1068–1072.

Ma, W., & Rahut, D. B. (2024). Climate-smart agriculture: Adoption, impacts, and implications for sustainable development. *Mitigation and Adaptation Strategies for Global Change, 29*(5), Article 44.

Mizik, T. (2021). Climate-smart agriculture on small-scale farms: A systematic literature review. *Agronomy, 11*(6), Article 1096.

Musa, S. F. P. D., & Basir, K. H. (2021). Smart farming: Towards a sustainable agri-food system. *British Food Journal, 123*(9), 3085–3099.

National Research Council, Division on Earth and Life Studies, Committee on Twenty-First Century Systems Agriculture. (2010). *Toward sustainable agricultural systems in the 21st century*. National Academies Press.

Neufeldt, H., Jahn, M., Campbell, B. M., Beddington, J. R., DeClerck, F., De Pinto, A., Gulledge, J., Hellin, J., Herrero, M., Jarvis, A., LeZaks, D., Meinke, H., Rosenstock, T., Scholes, M., Scholes, R., Vermeulen, S., Wollenberg, E., & Zougmoré, R. (2013). Beyond climate-smart agriculture: Toward safe operating spaces for global food systems. *Agriculture & Food Security, 2*(1), Article 12.

Olabanji, M. F., & Chitakira, M. (2025). The adoption and scaling of climate-smart agriculture innovation by smallholder farmers in South Africa: A review of institutional mechanisms, policy frameworks and market dynamics. *World, 6*(2), Article 51.

Petrovic, B., & Csambalik, L. (2025). Enhancing precision agriculture for climate change mitigation in Visegrad countries: Factors shaping adaptation. *Land, 14*(2), Article 399.

Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Morales Opazo, C., Owoo, N., Page, J. R., Prager, S. D., & Torero, M. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability, 3*(10), 809–820.

Robertson, G. P. (2015). A sustainable agriculture? *Daedalus, 144*(4), 76–89.

Rudnicki, R., Biczkowski, M., Wiśniewski, Ł., Wiśniewski, P., Bielski, S., & Marks-Bielska, R. (2023). Towards green agriculture and sustainable development: Pro-environmental activity of farms under the Common Agricultural Policy. *Energies, 16*(4), Article 1770.

Savastano, M., Samo, A. H., Abdullah, U., & Cucari, N. (2025). Toward sustainable smart agriculture in a developing country: An empirical analysis of green firms determinants. *Business Ethics, the Environment & Responsibility, 34*(4), 1942–1965.

Scherr, S. J., Shames, S., & Friedman, R. (2012). From climate-smart agriculture to climate-smart landscapes. *Agriculture & Food Security, 1*(1), Article 12.

Print ISSN: 3156-7185
e-ISSN: 3156-7177

Schieffer, J., & Dillon, C. (2015). The economic and environmental impacts of precision agriculture and interactions with agro-environmental policy. *Precision Agriculture, 16*(1), 46–61.

Siedenburg, J., Martin, A., & McGuire, S. (2012). The power of "farmer friendly" financial incentives to deliver climate-smart agriculture: A critical data gap. *Journal of Integrative Environmental Sciences, 9*(4), 201–217.

Sneha, V., Archana, P., Ashok, K., & Sunitha, G. (2023). Sustainable farming incentives: Economic perspectives. In *Innovative strategies in agricultural economics* (pp. 102–117).

Steenwerth, K. L., Hodson, A. K., Bloom, A. J., Carter, M. R., Cattaneo, A., Chartres, C. J., Hatfield, J. L., Henry, K., Hopmans, J. W., Horwath, W. R., Jenkins, B. M., Kebreab, E., Leemans, R., Lipper, L., Lubell, M. N., Msangi, S., Prabhu, R., Reynolds, M. P., Sandoval Solis, S., ... Jackson, L. E. (2014). Climate-smart agriculture global research agenda: Scientific basis for action. *Agriculture & Food Security, 3*(1), Article 11.

Takacs-Gyorgy, K., & Takács, I. (2022). Towards climate smart agriculture: How does innovation meet sustainability? *Ecocycles, 8*(1), 61–72.

Taneja, G., Pal, B. D., Joshi, P. K., Aggarwal, P. K., & Tyagi, N. K. (2019). Farmers' preferences for climate-smart agriculture an assessment in the Indo-Gangetic Plain. In *Climate smart agriculture in South Asia: Technologies, policies and institutions* (pp. 91–111).

Taylor, M. (2018). Climate-smart agriculture: What is it good for? *The Journal of Peasant Studies, 45*(1), 89–107.

van Asseldonk, M., Girvetz, E., Pamuk, H., Wattel, C., & Ruben, R. (2023). Policy incentives for smallholder adoption of climate-smart agricultural practices. *Frontiers in Political Science, 5*, Article 1112311.

Vărzaru, A. A. (2024). Assessing agricultural impact on greenhouse gases in the European Union: A climate-smart agriculture perspective. *Agronomy, 14*(4), Article 821.

Verschuuren, J. (2018). Towards an EU regulatory framework for climate-smart agriculture: The example of soil carbon sequestration. *Transnational Environmental Law, 7*(2), 301–322.

Vishnoi, S., & Goel, R. K. (2024). Climate smart agriculture for sustainable productivity and healthy landscapes. *Environmental Science & Policy, 151*, Article 103600.

Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Smart farming is key to developing sustainable agriculture. *Proceedings of the National Academy of Sciences, 114*(24), 6148–6150.

Zhang, J., Trautman, D., Liu, Y., Bi, C., Chen, W., Ou, L., & Goebel, R. (2024). Achieving the rewards of smart agriculture. *Agronomy, 14*(3), Article 452.

Print ISSN: 3156-7185
e-ISSN: 3156-7177