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Civil Liability for Environmental Damages Arising from the Use of Artificial Intelligence Technologies in Fertilizers and Pesticides: An Analytical Comparative Study

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ABSTRACT: This study explores civil liability for environmental damages arising from the use of artificial intelligence (AI) technologies in fertilizers and pesticides, adopting an analytical and comparative approach across national and international contexts. While AI

applications in agriculture have enhanced productivity, resource efficiency, and crop management, they simultaneously generate complex risks, including pollution of soil, water, and air, biodiversity loss, and adverse impacts on human health. These risks raise fundamental legal challenges regarding causation, responsibility attribution, and compensation mechanisms. The research problem centers on the adequacy of traditional civil liability rules in addressing such damages and ensuring fair remedies. The study employs analytical and comparative methodologies, examining civil and environmental legal texts, judicial trends, and legislative approaches, with particular focus on Jordanian and French frameworks. The literature review reveals persistent gaps: globally, operational and institutional mechanisms remain underdeveloped; in Arab scholarship, legislative provisions and evidentiary tools are insufficient; and in national contexts, judicial practice is limited, with reliance on general civil rules that fail to capture the complexity of AI-related environmental harms.

Findings indicate that existing liability frameworks are inadequate to address the distinctive nature of environmental damage linked to smart agricultural technologies. The study recommends enacting specialized legislation, empowering environmental associations and public authorities to initiate collective actions, modernizing evidentiary standards to ease the burden of proof, and strengthening environmental funds to guarantee compensation when direct responsibility cannot be established. These measures are essential to bridge the gap between doctrinal innovation and practical enforcement, and to achieve a balance between technological advancement, sustainable development, and environmental justice.

1. INTRODUCTION

1.1 Subject of the Study: In recent years, the agricultural sector has witnessed a rapid digital transformation driven by the employment of artificial intelligence technologies in managing various agricultural operations, most notably determining the quantities of fertilizers and pesticides, the timing of their use, and the mechanisms of their distribution. These applications have contributed to improving agricultural productivity, rationalizing the use of natural resources, and enhancing crop management efficiency (Uddin, Chowdhury, & Kabir, 2024). However, the increasing reliance on intelligent systems to guide fertilization and pest control operations may raise multiple environmental risks, including soil, water, and air pollution, damage to biodiversity, as well as negative impacts that may extend to human health and property (Al-Fatlawi, 2001). In light of these developments, new legal challenges have emerged regarding the adequacy of traditional civil liability rules in addressing environmental damages arising from the use of AI-based fertilizers and pesticides (Borghetti, 2025; Soyer & Tettenborn, 2022). This challenge is particularly evident given the complexity of causation, the multiplicity of parties involved in designing and operating these systems, and the specific nature of environmental damage, which may extend across time and space (Dumery, 2025). Accordingly, this study seeks to examine civil liability rules and compensation mechanisms for such damages through the analysis and comparison of relevant legislation, with the aim of reaching a legal vision that contributes to enhancing environmental protection and achieving a balance between technological development and the requirements of sustainable development (Al-Zaydeen, 2017).

1.2 Significance of the Study: The significance of this study stems from the importance of the subject itself, as artificial intelligence applications represent one of the most prominent manifestations of the modern technological revolution in the agricultural field. Their use in managing fertilizers and agricultural pesticides has become a practical reality that imposes increasing legal and environmental challenges. Moreover, the environmental damages resulting from these technologies may take complex and interrelated forms that exceed the scope of traditional liability, which necessitates a reassessment of the adequacy of existing legal rules in confronting these developments. The study also derives its significance from the scarcity of Arabic legal studies that have directly addressed civil liability for environmental damages arising from the use of artificial-intelligence-based fertilizers and agricultural pesticides, as well as from the importance of the findings that could contribute to developing environmental and civil legislation, and to providing effective legal solutions for compensating those harmed and ensuring environmental protection amid the growing expansion in the use of smart technologies in the agricultural sector.

1.3 Objectives of the Study: This study aims to clarify the legal framework of civil liability arising from environmental damages resulting from the use of artificial-intelligence-based fertilizers and agricultural pesticides, by identifying the nature of such damages, analyzing the conditions for establishing civil liability and the mechanisms for bringing related lawsuits, and clarifying the legal provisions governing them in light of national and comparative legislation.

The study also aims to assess the adequacy of current legal rules in addressing the issues raised by agricultural artificial-intelligence applications, to clarify appropriate legal means for compensating environmental damages, and to propose legislative solutions that contribute to strengthening the legal protection of the environment and those harmed, in keeping with modern technical developments and fulfilling the requirements of environmental justice and sustainable

Development.

1.4 Problem of the Study: The problem of the study revolves around the following main question:

To what extent are the rules of traditional civil liability sufficient to address the environmental damages arising from the use of artificial-intelligence-based fertilizers and agricultural pesticides, and to ensure that those harmed obtain fair and effective compensation?

This question branches into a number of sub-issues, most notably: the extent to which it is possible to identify the party responsible for environmental damage given the multiplicity of parties involved in developing and operating smart systems; the extent to which traditional rules of evidence are suitable for establishing the causal relationship between the use of such systems and environmental damage; as well as the adequacy of existing compensation mechanisms in

Addressing the particular nature of purely environmental damages and damages that extend across time and place.

1.5: Methodology of the Study: The study relied on the analytical method by analyzing the relevant civil and environmental legal texts related to civil liability for environmental damage, and clarifying the extent of their applicability to damages arising from the use of artificial-intelligence-based fertilizers and agricultural pesticides, while reviewing the jurisprudential and judicial trends related to the subject of the study. The study also relied on the comparative method by comparing the position of the Jordanian legislator with certain comparative legislations, particularly French legislation, with the aim of identifying similarities and differences and deriving the most appropriate legal solutions to address the challenges posed by artificial intelligence applications in the agricultural field and to protect the environment from the damages resulting therefrom.

2. LITERATURE REVIEW:

The literature review in this study aims to present and analyze previous research on civil liability for environmental damages associated with the use of artificial intelligence technologies in agriculture. It seeks to highlight global, Arab, and national trends, while clarifying strengths and weaknesses, and identifying research gaps that call for the development of more suitable legislative frameworks and mechanisms to protect the environment and ensure environmental justice.

2.1 Global Studies: The global literature on civil and environmental liability has moved beyond proving the existence of the problem to addressing the design of practical liability systems that balance risk distribution with innovation. Scholars such as Tran (2026), Soyer (2022), and De Sio (2021) highlight the persistent difficulty of attributing harmful acts within AI systems, given the multiplicity of actors (developers, operators, users). This challenge is compounded by the blurred boundaries of responsibility in autonomous systems, where causation and foreseeability are often contested. The debate also extends to the limits of legal personality (Chesterman, 2020; Chen & Burgess, 2019) and whether AI should be treated as a legal subject or remain within the framework of human accountability. Proposals for strict liability and insurance-based mechanisms (Wendehorst, 2020) attempt to simplify attribution, but they raise concerns about stifling innovation and creating disproportionate burdens. Environmental law studies, including Taylor (2018) and Foulon (2019), expand liability to ecological damage and compensation funds, reflecting a growing recognition of purely environmental harm beyond individual interests. Yet, practical testing of these models remains limited, with few judicial precedents or operational mechanisms to demonstrate their effectiveness. The literature also acknowledges the difficulty of addressing cross-border damages, where ecological harm and AI-related risks transcend national jurisdictions. Compensation mechanisms remain fragmented, and institutional safeguards are underdeveloped. In summary, the central gap in global studies lies in operational and institutional mechanisms. While theoretical frameworks are rich and diverse, judicial application, empirical Testing, and cross-border compensation remain underdeveloped, leaving a significant disconnect between doctrinal innovation and practical enforcement.

2.2 Arab Studies: Arab scholarship emphasizes normative and comparative analysis but suffers from weak empirical and judicial application. Works such as Al-Mamari (2025), Aldmour (2025), and Alayaydeh et al. (2024) show that most Arab legislations still rely on general civil rules without specialized provisions for AI or environmental harm. Studies highlight recurring gaps in causation and evidence (Abouhaiba, 2026), as digital damage and autonomous errors are difficult to link to a specific human actor. Moreover, complementary mechanisms such as mandatory insurance, auditing, and transparency are underexplored (Leal, 2024). While Arab literature acknowledges the insufficiency of current frameworks, few studies test these proposals against actual disputes or court rulings. The gap is therefore legislative specialization and evidentiary adaptation, with limited focus on institutional tools to ensure compensation and governance.

2.3 Jordanian Studies: Jordanian literature reveals a dual deficiency in both legislative and judicial application. Studies such as Al-Hawamdeh (2024), Shawabkeh (2025), and Al-Qaisi et al. (2026) note the absence of judicial precedents in AI liability and the inadequacy of general civil rules in addressing complex environmental and technological harms. The Environmental Protection Law (2006) and Fund Law (2018) provide a framework, but practical integration with AI-related damages remains weak.

The gap is most acute in judicial practice: courts rarely apply liability rules to AI or environmental disputes, leaving victims dependent on general provisions that do not fit autonomous systems or diffuse pollution. Institutional tools, such as environmental funds, are insufficiently linked to compensation and preventive governance. Thus, the Jordanian gap is primarily judicial and operational, reflecting a mismatch between legal texts and real-world application.

Table (1) provides a reference map of the most significant studies addressing civil liability and environmental damages associated with the use of artificial intelligence in agriculture. It outlines the objectives of each study, records their main contributions, and simultaneously identifies the research gaps that remain. The table shows that global studies have largely focused on theoretical innovation but lack practical enforcement mechanisms, Arab studies reveal legislative and evidentiary shortcomings, while Jordanian studies highlight pronounced judicial and institutional deficiencies. Thus, Table (1) offers a comprehensive comparative overview that situates this research within the broader academic context and underscores the need for more effective legislative frameworks and mechanisms to achieve a balance between technological progress and environmental protection.

Table (1): Key References, Objectives, and Research Gaps, By Researchers

Reference	Objectives	Contribution	Research Gap
Tran (2026)	Design liability systems for AI	Highlights attribution challenges	Lack of operational models
Soyer & Tettenborn (2022)	Assess need for new liability regime	Comparative civil liability analysis	Limited judicial application
Borghetti (2025)	French perspective on AI liability	Expands doctrinal debate	Weak empirical testing
Chesterman (2020)	Limits of legal personality	Defines AI vs human accountability	No practical enforcement
Chen & Burgess (2019)	Boundaries of personhood	Explores AI, companies, animals	Theoretical, not judicial
Wendehorst (2020)	Strict liability for AI	Proposes insurance mechanisms	Institutional safeguards missing
Dumery (2025)	Compensation capacity of civil law	Evaluates damages caused by AI	No case law validation

Taylor (2018)	Ecological harm in French law	Extends tort law to environment	Limited cross-border scope
Foulon (2019)	Recognition of ecological damage	Introduces compensation funds	Weak operational mechanisms
De Sio (2021)	AI responsibility models	Risk distribution frameworks	No empirical testing
Al Abady (2022)	Civil liability of smart robots	Jordanian legislative analysis	No judicial precedents
Al-Fatlawi (2001)	Civil liability & environment	Early Arab perspective	Outdated, lacks AI focus
Al-Khawaldah et al. (2023)	Penal liability for oil spill	Case study in Jordan	Focused on criminal, not civil
El-Refaie & Alsharqawi (2022)	Pollution crimes in Jordan	Legislative confrontation	No compensation framework
Manasra et al. (2022)	Tort liability for pollution	Arab comparative study	Weak causation analysis
Al-Sarayrah (2017)	Adequacy of civil rules	Jordanian civil code evaluation	Insufficient for AI damages
Shawabkeh (2025)	AI liability in Jordan	Notes absence of precedents	Judicial gap persists
Almahasneh (2025)	Climate change liability	Expands tort liability scope	No AI integration
Emar & Abu Issa (2021)	Shortcomings in Jordanian law	Compares with international law	Weak institutional tools
Zhuk (2023)	AI ecological costs	Highlights hidden impacts	No legal remedies proposed

Notes:

The table maps the most influential references, showing that global studies emphasize doctrinal innovation but lack operational enforcement, Arab studies highlight legislative insufficiency, and Jordanian studies reveal acute judicial and institutional gaps.

2.3. Research Gap: The comparative analysis of global, Arab, and Jordanian studies reveals a clear imbalance in the coverage of civil and environmental liability dimensions. Global literature demonstrates relatively strong attention to responsibility attribution, causation, and compensatory mechanisms, yet it remains underdeveloped in terms of judicial application and operational enforcement. Arab studies, while offering valuable normative and comparative insights, suffer from weak empirical grounding and limited judicial practice, leaving proposals largely theoretical. Jordanian studies show the most acute gap, with reliance on general civil rules and scarce judicial precedents, resulting in a mismatch between legislative texts and real-world application.

This disparity reveals three main levels of deficiency in addressing civil liability for environmental damages associated with the use of artificial intelligence in agriculture. At the global level, theoretical frameworks remain rich and diverse, yet they lack effective operational and institutional mechanisms to ensure enforcement and cross-border compensation. In Arab scholarship, there is heavy reliance on general civil provisions without specialized rules tailored to the particular nature of environmental harm or AI technologies, alongside weak evidentiary tools. At the national level, judicial practice is limited, with no established precedents and insufficient integration of environmental funds or institutional mechanisms, leaving victims with restricted avenues for redress. Taken together, these gaps highlight the urgent need for more comprehensive legislation, stronger evidentiary standards, and enhanced institutional frameworks to ensure environmental protection and achieve environmental justice.

Table (2) illustrates the comparative disparities among global, Arab, and Jordanian studies in covering the dimensions of civil liability for environmental damages linked to artificial intelligence in agriculture. The evidence shows that global literature pays greater attention to responsibility attribution, causation, and compensatory mechanisms, yet remains weak in judicial application. Arab studies appear narrower in scope, reflecting legislative and evidentiary shortcomings, while Jordanian studies demonstrate the lowest coverage, particularly in judicial practice, which reveals a clear gap between legal texts and actual enforcement. Thus, Table (2) provides both quantitative and qualitative insight into the strengths and weaknesses of existing scholarship, underscoring the need for more applied research and specialized legislation to achieve a balance between technological innovation and environmental protection.

Table. (2): Coverage of liability research across global, Arab, and Jordanian studies

Studies	Responsibility Attribution	Causation & Evidence	Compensatory Tools	Judicial Application
Global	10	9	7	5
Arab	7	5	3	2
Jordanian	6	4	3	1

Notes: Global studies cover liability dimensions more broadly, especially responsibility and causation. Arab studies are moderate but weak in judicial application. Jordanian studies show the lowest coverage, with a clear gap in court practice versus legal texts.

3. ENVIRONMENTAL DAMAGE FROM AI-BASED FERTILIZERS AND PESTICIDES:

The right to resort to a civil liability lawsuit arises when the use of fertilizers and pesticides based on artificial intelligence systems results in environmental damage affecting individuals or various environmental elements (Segerson, 1990; Son, Chen, & Syu, 2024; Zhuk, 2023). This is the legal means that enables the affected party to claim compensation if the responsible party refuses to redress the damage. To explain this lawsuit, we will study it as follows:

3.1 Environmental Damage Lawsuits from AI-Based Fertilizers and Pesticides: A civil liability lawsuit is the legal mechanism through which an injured party seeks compensation for environmental damages caused by the use of artificial intelligence systems in fertilizers and pesticides, brought against the responsible party in accordance with established procedural rules. Such lawsuits raise specific legal challenges when shared environmental elements are harmed, requiring clarification of the parties involved and addressing the issue of claims in cases of purely environmental damage, which researchers will examine.

Figure (1), illustrates the sequence linking the agricultural use of pesticides to the resulting environmental damages, leading to remediation mechanisms and legal proof. The process begins with pesticide spraying, which contaminates essential environmental elements such as soil, water, and air. The figure then highlights modern detection methods, including colorimetry, electrochemistry, and fluorescence, alongside photocatalytic and enzymatic degradation techniques for pollutant treatment. In the final stage, artificial intelligence plays a crucial role in analyzing data and rapidly detecting contaminants, enabling these results to be used as evidence in court to establish causation between agricultural activity and environmental harm. This integration strengthens civil liability claims and demonstrates how science can serve as a supportive tool for environmental justice, encapsulated in the sequence: Use of agricultural pesticides → Soil, water, and air contamination → Detection and remediation mechanisms → proving it in court.

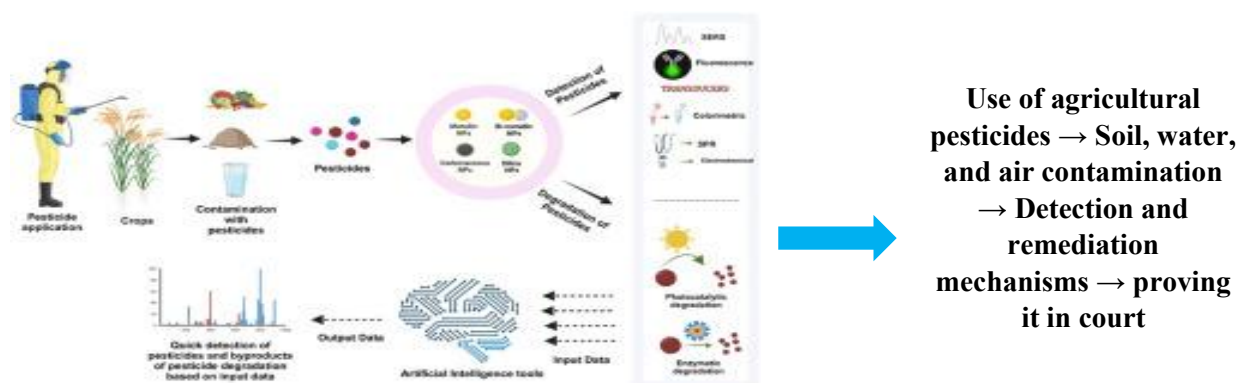


Figure. (1): AI-nanotech pesticide contamination and Remediation, <https://doi.org/10.1016/j.envres.2023.117601>

3.1.1 Parties to the Lawsuit: The provisions relating to the parties to the lawsuit will be explained as follows:

3.1.1.1 The Plaintiff in Environmental Damage Claim: The right to claim compensation for environmental damage caused by AI-based fertilizers and pesticides is granted to any party who has suffered harm. The injured party holds the legal standing to file a civil liability lawsuit seeking redress. For the lawsuit to be admissible, the plaintiff must have the required legal capacity; if absent, a legal representative may act on their behalf under general principles. A legitimate interest is also necessary, represented by the legal, material, or moral benefit sought through compensation or protection of a violated right. If the harm affects only one person, the right to claim is exclusive to them. If multiple victims are involved, each may file separately or join in a single lawsuit, provided that compensation is assessed individually according to the extent of each party's damage.

3.1.1.2 The Defendant Responsible for Environmental Damage: A civil liability lawsuit for environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems is filed against the person or entity responsible for causing the damage, known in the lawsuit as the defendant. Identifying the defendant is particularly important in this context due to the multitude of parties involved in the production, development, operation, or marketing of related agricultural products using intelligent systems, as well as the potential contribution of other factors to the environmental damage (Wendehorst, 2020). Liability may arise against the manufacturer, developer, operator, or distributor of the intelligent system if their contribution to the environmental damage in question is proven (Chesterman, 2020; Chen & Burgess, 2019; Soyer & Tettenborn, 2022; Al Abady, 2022), in accordance with Articles (256, 262, and 291) of the Jordanian Civil Code No. (43) Of 1976. In cases of environmental damage caused by AI-based fertilizers and pesticides, legislation differs in defining the defendant. Some systems apply general civil liability principles, allowing lawsuits against any person or entity responsible for the harm, whether through direct actions or activities under their control. Others adopt specific criteria tied to the nature of the environmental activity, targeting manufacturers, developers, operators of smart systems, or users of such fertilizers and pesticides provided their role in the damage is proven. Liability may also extend beyond direct perpetrators to include entities legally designated to compensate environmental damages, such as funds or specialized bodies, when the responsible party cannot be identified or compelled. While identifying distributors, producers, or importers is straightforward when the user operates in a fixed location, complexity arises when other harmful environmental activities overlap with the use of these products.

Despite the particular nature of environmental damage arising from the use of artificial intelligence systems in fertilizers and pesticides, the general rules of civil liability remain applicable when multiple parties are responsible. If the developer, operator, or user contributes to the damage, the injured party may claim compensation on the basis of joint liability, whereby each party is obliged to fully compensate the victim, with the right of recourse against the others according to their share. Where it is impossible to determine each party's contribution, liability is divided equally under the general rules and Article (266) of the Jordanian Civil Code. However, this principle presupposes the ability to identify those responsible and prove their role, which is often difficult in complex environmental cases due to overlapping factors and challenges in establishing causation. Accordingly, there is a need for special legal provisions that account for the distinctive nature of environmental harm and the smart technologies applied in agriculture.

3.1.1.2 The problem of litigation in cases of purely environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems: Environmental elements are divided into private elements owned by individuals or specific entities, and public or shared elements that benefit everyone, such as water, air, and soil. Damage to private elements does not pose significant problems, as the owner of the right to them can file a civil liability lawsuit and claim compensation. However, the real problem arises when purely environmental damage results from the use of fertilizers and pesticides based on artificial intelligence systems, affecting shared environmental elements without directly harming a specific person or private right. In this case, the question arises as to who has the standing and interest to sue for remediation of the environmental damage or compensation, especially since public environmental elements represent a collective interest that transcends individual interests. Hence, the concept of a class action lawsuit (Gao & Whittaker, 2019; Xie & Xu, 2022) This passage can be condensed while preserving its rigor, legal concepts, and scholarly tone as follows:

A lawsuit filed to protect the public environmental interest seeks to empower individuals, authorities, or associations to halt harmful activities and remedy environmental impacts from smart agricultural technologies. Jurists, however, are divided: one view rejects such lawsuits for lacking the requirement of direct personal interest, which underpins standing in civil litigation. Accordingly, only those whose rights or legal status are directly affected may sue, excluding individuals acting solely on behalf of society unless expressly authorized by law. In contrast, a second trend reflected in international jurisprudence supports collective actions, noting that the International Court of Justice has recognized rights of a collective nature concerning the international community. This view treats shared and transboundary environmental resources as common interests, justifying class actions despite the absence of explicit legal rules, in line with modern developments in international environmental law and the right of states to a healthy environment. Domestically, some jurisprudence extends this reasoning, recognizing environmental damage as a public interest that legitimizes collective lawsuits even without direct personal harm. French law illustrates this evolution: while courts initially resisted granting environmental associations standing, later jurisprudence and legislation, notably Article L.142-2 of the French Environmental Code, affirmed their right to litigate in defense of collective environmental interests, equating them with professional unions.

Researchers conclude that this second approach is more consistent with the nature of purely environmental damage caused by AI-based fertilizers and pesticides, and aligns with modern legislative trends expanding environmental litigation to ensure effective protection.

However, the Jordanian legislator, in the Environmental Protection Law No. (6) Of 2017, adopted a more conservative stance (El-Refaie & Alsharqawi, 2022). The law limited environmental associations to the right to report environmental violations without explicitly granting them the right to file class-action lawsuits to claim compensation for damages to the environment or any of its components. The role of environmental associations is thus confined to demanding preventive and remedial measures, without extending to seeking compensation for purely environmental damages that affect the collective interests for which these associations were established. As for administrative bodies, the French legislature has granted them an active role in environmental protection by recognizing their right to file class-action lawsuits. Article L.132-1 of the French Environmental Code stipulates that several public bodies and institutions, including the Environment Agency, the Energy Agency, the National Water and Aquatic Environment Agency, water agencies, the National Hunting and Wildlife Office, and the National Monuments Center, enjoy the rights of a civil plaintiff in cases involving actions that directly or indirectly harm the interests these bodies were established to defend, provided that such actions violate legislation relating to the protection of the environment and nature. The French legislature also granted local governments the same right under Article L.142-4 of the same code. In Jordan, the legislature has granted competent administrative bodies the right to resort to the judiciary to protect the environment, particularly the Environmental Affairs Agency. Environmental Protection Law No. (6) of 2017 (Emar & Abu Issa, 2021; Manasra, Al Mamari, Gharibeh, Najm, Younes, & Alsharqawi, 2022) empowers the agency to seek legal recourse for appropriate compensation to address damages resulting from environmental violations committed by facility owners who fail to remove or rectify the violation within the legally specified period after being notified by the competent administrative authority. The Ministry's right to initiate environmental litigation can also be inferred indirectly from the powers granted to it against those responsible for environmental damage. It has the authority to notify the polluting entity of the necessity to remove the damage, compensate for its effects, and restore the situation to its original state within a specified period. If the entity refuses to comply or neglects to fulfill its obligations, the Ministry can pursue legal action.

Researchers believe that the Jordanian legislator has indirectly granted the Ministry of Environment the status of plaintiff in claims for compensation for damages inflicted on the natural environment itself that is, damages to the environment as an independent collective interest. The Jordanian legislator must remove the legal and procedural obstacles hindering this type of lawsuit and establish a comprehensive legislative framework that defines its conditions, procedures, and legal consequences in a manner appropriate to the specific nature and severity of environmental damages. Clear legislative frameworks would enhance the effectiveness of judicial protection and ensure appropriate compensation for damages to the environment or its components, or to individuals and their property.

3.2 Provisions for civil liability claims against environmental pollution damages arising from the use of fertilizers and pesticides based on artificial intelligence systems: We will address the provisions for civil liability claims against environmental pollution damages arising from the use of fertilizers and pesticides based on artificial intelligence systems as follows:

3.2.1 The Applicable Law: Most countries subject non-contractual obligations to the law of the place where the harmful act occurred, such as the use of fertilizers and pesticides. Yet this solution is not definitive, since the act may occur in one country while the damage appears in another or extends across several states for example, pollution from pesticides used in Jordan harming consumers in Syria or Lebanon. Jurisprudence has diverged: one view applies the law of the place of harm, emphasizing compensation; another applies the law of the wrongful act, as liability is based on the act itself; while a third, adopted in German jurisprudence, allows the injured party to choose the law most favorable to them. French jurisprudence, in cross-border cases, applies the law of the state where the primary or first harm occurred. The Jordanian legislator, however, left the matter to judicial discretion, merely stipulating application of the law of the country where the act creating the obligation occurred. In cases of pollution affecting elements not belonging to a specific country, such as seawater or air, the principle of applying the law of the forum (*lex fori*) prevails as subsidiary jurisdiction, a principle well-established in private international law. Almahasneh (2025) noted that the Jordanian legislative framework lacks clear provisions for addressing environmental liability, which necessitates a flexible interpretation of tort rules. This aligns with comparative approaches in French and German jurisprudence.

3.2.2 Defenses Available to the Defendant: The legislator has provided the person responsible for environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems with a range of legal means to defend against their civil liability. Some of these defenses are based on the general rules of civil liability, while others are based on specific legal provisions established by legislation to address particular cases. For example, the responsible party can deny their liability by proving the existence of an external cause that led to the environmental damage independently of their action, such as force majeure, the fault of a third party, or the fault of the injured party. This breaks the causal link between the harmful act and the environmental damage, thus exempting them from civil liability.

The plea of prescription is one of the most prominent pleas based on general rules that can be invoked in the face of claims for compensation for environmental damages arising from the use of smart technologies in managing or directing the processes of using fertilizers and agricultural pesticides. The statute of limitations is mentioned in Article (2219) of the French Civil Code. With regard to claims of civil liability for environmental damages resulting from the use of fertilizers and agricultural pesticides based on artificial intelligence systems, civil legislation has set a time range that the injured party must adhere to when claiming compensation. Article (272/1) of the Jordanian Civil Code stipulates that: “The claim for compensation arising from the unlawful act is extinguished by prescription after three years from the day on which the injured party became aware of the occurrence of the damage and the person responsible for it. This claim is extinguished in any case after fifteen years from the day of the occurrence of the unlawful act.” The importance of this plea is highlighted in the field of environmental damages related to agricultural artificial intelligence systems. The effects of environmental pollution may be delayed or appear after a period of time following the use of smart systems or their applications related to fertilizers and pesticides. This raises the issue of determining the moment of knowledge of the damage and the person responsible for it, and consequently, determining when the statute of limitations begins to run. This matter is particularly important given the complex technical nature of these systems and the multiple parties involved in their design, operation, and use. However, Jordanian civil law includes a specific provision concerning cases where a harmful act constitutes a crime. Article 272, paragraph 2, stipulates that a claim for compensation is not subject to the statute of limitations as long as the criminal case arising from the same act remains pending and has not been dismissed. The French legislator, however, adopted a different stance regarding the statute of limitations for tort claims. Article 2226 of the French Civil Code stipulates that non-contractual civil liability claims are subject to a ten-year statute of limitations,

commencing from the date the damage occurred. The statute of limitations is further extended to the date the damage worsens if new effects emerge or the severity of the damage increases after its initial occurrence. This aligns with the evolving nature of some environmental damages, whose effects may gradually unfold over time. Recognizing the unique characteristics of environmental damage, particularly those whose effects may persist for many years before being fully detected, the French legislator adopted a specific statute of limitations for environmental cases. French Environmental Law No. 2000-914, issued on September 18, 2000 (Taylor, 2018; Foulon, 2019), stipulates a long statute of limitations of up to thirty years for claims for compensation for environmental damage, beginning from the date the environmental damage occurred. This legislative approach reflects an awareness of the unique and complex nature of environmental damage.

Researchers believe that the French legislature's position is more consistent with the nature and requirements of environmental damage, as it provides better protection for those affected and ensures that their right to compensation is not lost due to the expiration of traditional statutes of limitations before the damage appears or is discovered. Therefore, we urge the Iraqi legislature to adopt specific legislation regarding statutes of limitations for claims arising from environmental damage, particularly those related to the use of fertilizers and pesticides that rely on artificial intelligence systems. This can be achieved by stipulating longer statutes of limitations in specific environmental legislation, similar to the French legislature, thus ensuring effective legal protection for the environment and those affected by such damage, and enhancing the chances of obtaining fair compensation even in cases where the environmental damage appears late or the responsible source is not identified.

Among the other defenses based on general legal rules that the defendant can rely on to defend his civil liability for environmental damages arising from the use of fertilizers and agricultural pesticides based on artificial intelligence systems is the defense of waiver and settlement. The law has allowed the plaintiff to waive a claim for compensation after it has been filed, by requesting the annulment of the lawsuit petition in accordance with the provisions of Article (121) of the Jordanian Civil Procedure Law No. (24) Of 1988. Article (67, 120) of the same law also stipulated that the annulment of the lawsuit petition is considered as if it had never been filed. However, this ruling is subject to what is stated in Article (20) of the Jordanian Evidence Law No. (30) Of 1952, which prohibits the withdrawal of documents that affect the resolution of the dispute except in accordance with the controls set forth by the law. One of the most important forms of waiver that leads to the final resolution of a dispute is the waiver by the party in whose favor a judgment was issued. This results in the forfeiture of the established right and precludes any future legal action based on it, as waiver constitutes a relinquishment of the right, and what is legally forfeited cannot be reinstated. Furthermore, the law permits the injured party and the party responsible for the environmental damage to resolve the dispute through settlement, provided that the parties to the settlement have the legal capacity to dispose of the rights subject to the settlement, in accordance with Article (648) of the Jordanian Civil Code. These defenses are considered among the most important means grounded in general legal principles. One of the most prominent is the plea of prior existence (priority defense), which assumes that the harmful activity was legitimate and pre-existing before the injured party settled nearby. Some jurists argue this exempts the activity's owner from liability, as the newcomer implicitly accepted potential harms. Yet this view has been criticized for burdening later arrivals without effective recourse, contradicting justice and the principle of non-harm. Another school of thought holds that prior existence alone is insufficient unless linked to the nature and designated purpose of the area. If the area is zoned for agriculture and modern technologies, including AI-based fertilization and pest control, then residents must accept inherent risks. Still, this justification is inadequate in modern environmental liability, as it risks perpetuating harmful activities without accountability. Importantly, prior existence cannot be invoked against purely environmental damage (soil, water, biodiversity), since these elements predate human activity.

A further defense is the administrative license authorizing the activity. However, Article (66) of the Jordanian Civil Code explicitly states that such a license does not bar affected parties from claiming compensation. French jurisprudence likewise affirms that administrative authorization is merely regulatory and does not permit harm to others. As Almahasneh, Y. (2025) notes, the administrative license does not exempt from civil liability, and the injured party retains the right to compensation, consistent with Article (66) of the Jordanian Civil Code and French judicial practice.

4. PENALTY FOR BREACH OF ENVIRONMENTAL LIABILITY IN AI-BASED FERTILIZERS AND PESTICIDES:

In order to understand the penalties resulting from civil liability for environmental damage arising from the use of fertilizers and pesticides based on artificial intelligence systems, it is necessary to state the most appropriate legal method for compensating this type of damage, then to clarify the foundations and standards on which the assessment of the compensation due is based,

and finally to examine the legal and financial mechanisms through which those affected can be guaranteed to receive appropriate compensation. Accordingly, this section is divided into three requirements as follows:

4.1 The appropriate method for compensating for environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems: This requirement will be divided into two sections; the first section will address in-kind compensation, while the second section will address compensation in kind, as follows:

4.1.1 In-Kind Compensation: There is no doubt that those harmed by environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems seek compensation that ensures the removal of the damage or minimizes its effects as much as possible. In-kind compensation is perhaps the most effective means of achieving this goal.

The Jordanian legislator indicated the possibility of awarding in-kind compensation in Article (269) of the Jordanian Civil Code, making it an exception to be applied only at the request of the affected party and according to the circumstances of each case. In contrast, environmental legislation tends to consider in-kind compensation the norm in addressing environmental damage, based on the unique nature of the environment and the necessity of preserving it. Therefore, many legal texts obligate the party responsible for environmental damage to remove its effects and restore the situation to its state before it occurred. This includes Article (20) of the Jordanian Environmental Protection Law, which requires the responsible party to remove the damage and restore the situation to its previous state within a period specified by the competent authorities. If the responsible party fails to do so, the ministry or competent authority will remove the pollution or damage at their expense, plus (25%) of the total cost as administrative fees. These amounts are collected in accordance with the Public Funds Collection Law. Regarding environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems, to what extent is in-kind compensation capable of removing this damage? In this regard, we believe that this type of compensation is theoretically the most suitable because it aims to eliminate the damage at its source and obligates the responsible party to repair the damage they caused at their own expense within a specified timeframe. Furthermore, the persistent nature of some forms of pollution resulting from the improper use of smart systems in fertilization or pest control (Linaza et al., 2021) means that monetary compensation alone is insufficient. The effects of the damage remain and could worsen in the future, potentially leading to new disputes and compensation claims due to ongoing environmental harm.

The application of in-kind compensation in the environmental field faces practical and technical challenges, especially with purely environmental damage affecting elements such as soil, water, and biodiversity. It requires precise knowledge of the pre-damage condition and specialized data that may not always be available. Courts therefore rely on experts to assess the extent of damage and possible remedies. Yet in-kind compensation may be hindered by scientific or physical impossibility for example, the extinction of a species or permanent changes in environmental properties or by costs exceeding the liable party's capacity. Thus, its scope is limited to cases where repair or mitigation is feasible and affordable, though it remains the most appropriate remedy for environmental damage caused by AI-based fertilizers and pesticides.

In-kind compensation takes two main forms: direct remediation, such as removing pollutants from soil or water, and alternative environmental compensation, such as creating a similar environment elsewhere when restoration is impossible. Measures must be proportionate to the nature and extent of the damage, with judges ordering only appropriate technical and legal steps to restore the environment as closely as possible to its prior state. The French legislature has adopted this approach in Article (L.160-1) of the Environmental Code, affirming the "polluter pays" principle to balance environmental protection with reasonable societal costs.

If the responsible party refuses to act, the Jordanian legislator empowers administrative authorities to intervene directly, remedying pollution at the expense of the liable party to ensure swift response and prevent escalation. In-kind compensation may also extend beyond restoration to halting or permanently terminating the harmful activity itself. Dupuy (1991) observed that in-kind compensation in environmental law faces technical and scientific obstacles but remains the most consistent remedy for purely environmental damage, provided it is adapted to balance protection with cost, as reflected in French law. There are instances where the continuation of an activity poses a permanent environmental risk, making it impossible to mitigate or eliminate the damage except by ceasing the activity or closing the facility carrying it out. Within the scope of environmental damages arising from the use of fertilizers and agricultural pesticides based on artificial intelligence systems, this may be achieved by closing the violating facilities, canceling the license granted to them, or preventing them from continuing to practice the activity causing the damage. The Jordanian Environmental Protection Law, in Article (24), allows the court to rule to close the

violating facility (Al-Khawaldah, Rshdan, Al Makhmari, Al Mamari, Al Haf, & Alsharqawi, 2023) temporarily or permanently, suspend the effect of the license granted to the facility for the period it deems appropriate, or cancel it.

4.1.2 Compensation by way of consideration: While in-kind compensation is considered the ideal means of redressing environmental damage and restoring the situation to its state before the damage occurred, or preventing its effects from worsening, it is not always feasible. The most prominent example is the impossibility of restoring the environment to its previous condition. For this reason, courts sometimes hesitate to impose significant in-kind measures, such as closing down establishments or economic facilities operating under legal licenses and forming part of the overall economic activity. Furthermore, in-kind compensation may be unattainable if the affected party or the competent authorities have already removed the environmental damage or mitigated its effects at the expense of the responsible party, whether with judicial authorization or in urgent cases requiring immediate intervention. In such instances, the obligation to provide in-kind redress transforms into an obligation to bear the expenses and costs incurred in removing the damage, which effectively leads to compensation in kind. The Jordanian legislator, in Article (20) of the Environmental Protection Law, affirmed this by authorizing the relevant ministry to take the necessary measures to remove the damage and seek reimbursement from the party responsible for the expenses and costs incurred. Therefore, if an impediment prevents a judgment of in-kind compensation for environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems, the judiciary has no option but to resort to monetary compensation. This compensation takes two main forms: monetary and non-monetary.

Monetary compensation is the norm in the general rules of civil liability, where it is assessed as a sum of money equivalent to the damage incurred. Article (269/1) of the Jordanian Civil Code affirmed this principle by establishing monetary compensation as the norm and in-kind compensation as an exception left to the discretion of the court and the request of the injured party. However, the specific nature of environmental damage has led environmental legislation to consider in-kind compensation as the norm, while monetary compensation becomes a fallback measure to be resorted to when in-kind remediation is not possible. While monetary compensation is a suitable means of redressing damages to individuals or property resulting from the illegal or improper use of fertilizers and pesticides based on artificial intelligence systems, its effectiveness appears limited in the realm of purely environmental damage. Damage to ecosystems, natural resources, or biodiversity often cannot be remedied simply by paying a sum of money. Pollution can lead to the loss of environmental elements or natural resources that are difficult, or even impossible, to compensate for monetarily. Furthermore, assessing the financial value of such damage presents significant challenges due to the multiplicity of affected environmental elements and the complexity of methods for measuring environmental loss. Nevertheless, these difficulties do not diminish the importance of monetary compensation. It remains the most realistic option in cases where in-kind redress is unattainable or impossible. Awarding monetary compensation ensures that environmental damage does not go unaddressed legally and prevents those responsible from escaping accountability for the harm caused by their actions. Monetary compensation is usually awarded as a lump sum, though courts may allow installment or periodic payments depending on the nature and duration of the damage. The amount may be reassessed if the injured party's condition changes or certain effects disappear, and guarantees may be required to secure fulfillment of the obligation. On-monetary compensation, on the other hand, obliges the responsible party to take specific measures to remedy the damage without paying money. The Jordanian Civil Code, Article (269/1), authorizes courts to impose such obligations. In environmental cases, this may involve technical modifications to pesticide and fertilizer systems, installing monitoring equipment, or implementing health and environmental programs. Often, non-monetary compensation alone is insufficient, so it can be combined with monetary or in-kind remedies. This combination is considered the most effective way to ensure environmental protection, mitigate harm, and prevent recurrence.

4.2 Assessing Compensation for AI-Driven Environmental Damage:

To clarify how a judge assesses compensation for environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems, the nature of the subject necessitates dividing this requirement as follows:

4.2.1 Compensation for AI-Related Environmental Damage: Specific environmental damage caused by AI-based fertilizers and pesticides can be divided into material and moral harm. Material damage includes financial losses (such as crop destruction or reduced yields) and physical harm to health. Compensation for financial damage is assessed based on actual loss and lost profits, while property damage is measured either by repair costs or the decrease in value. Physical harm requires compensation for medical expenses, rehabilitation, and lost income, and in cases of death, support for dependents under Article (266) of the Jordanian Civil Code. Moral damage refers to psychological suffering, loss of enjoyment of life, or deprivation of a clean

environment. Unlike financial damage, it is not measured by fixed standards but by judicial discretion, considering the victim's circumstances and the extent of suffering. Courts may award compensation for chronic illness, disfigurement, or loss of hobbies and activities, ensuring fairness and recognition of non-financial harm. In practice, the Jordanian judiciary supported by Article (81/1) of the Evidence Law may consult experts to assess losses and determine appropriate compensation. This flexible approach ensures that both material and moral damages are addressed, achieving effective protection for those affected.

4.2.2 Issues that Supplement the Assessment of Compensation for Environmental Damage: To clarify the issues that supplement the assessment of compensation for environmental damage, researchers must explain them as follows:

4.2.2.1 The Impact of Circumstances on Compensation Assessment: When assessing compensation for environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems, the question arises of the extent to which the circumstances surrounding the damage influence the determination of the amount of compensation due. These circumstances vary, ranging from those related to the affected party, such as their health, social, and economic status, to those related to the party responsible for the damage, whether they are the producer, importer, or distributor of the fertilizers and pesticides, or the operator of the associated intelligent systems. Legal scholars are divided on whether all these circumstances fall within the scope of compensation assessment, or whether only some are considered. The first view held that the circumstances to be considered when assessing compensation are only the personal circumstances surrounding the injured party, given that the compensation aims to redress the harm suffered by him alone. The second view held that it is necessary to consider all the surrounding circumstances related to both the injured party and the person responsible for the harm, as they have an impact on achieving justice when determining the amount of compensation. The Jordanian legislator referred to this in Articles (264-266) of the Jordanian Civil Code, which obliged the judge to consider the surrounding circumstances when assessing compensation, without specifying what is meant by these circumstances or clarifying whether they are limited to the circumstances related to the injured party or extend to include the circumstances of the person responsible for the harm. The Jordanian judiciary has settled on taking into account the personal circumstances of the injured party when assessing compensation. Whenever it is found that the harm has affected a person who suffers from special health conditions or has led to a multiplication of the effects of his personal and social situation, this must be reflected in the amount of compensation awarded. The Iraqi judiciary also adopted this principle when considering the victim's previous health condition in assessing compensation for damages that contributed to the deterioration of their condition or hastened their death. This was confirmed by the Jordanian Court of Cassation in its decision (2115/2018).

The circumstances surrounding the responsible party play an indirect but important role in how compensation is assessed. While civil legislation does not explicitly adopt the severity of fault as an independent criterion, judicial practice shows that courts often consider it when determining compensation. This is particularly evident in cases of gross negligence or disregard for environmental obligations, such as failing to comply with technical regulations for AI-based fertilization and pest control or ignoring known risks. The impact of fault severity is most apparent in shared liability cases, where both the responsible party and the injured party contributed to the damage. In such situations, compensation is apportioned proportionally. The Jordanian Court of Cassation, in decision (3025/2019), affirmed that compensation must reflect each party's contribution to the harm, indirectly highlighting the weight of fault severity in judicial reasoning. Researchers emphasize that the primary basis for compensation remains the personal circumstances of the injured party health, social, and economic conditions. However, the severity of the responsible act can guide the court in exercising its discretionary power to achieve justice and ensure full redress.

4.2.2.2 The Time at Which Compensation Is Assessed: The issue of timing in compensation assessment is a fundamental one when there is a gap between the occurrence of damage and the issuance of judgment, as the court faces two possible dates: the date of the damage or the date of the judgment. Stable damages, such as permanent crop or livestock death due to pollution, are usually assessed at the time of occurrence since the harm is fixed. Evolving damages, such as worsening pollution or progressive health impacts, raise debate: one view favors assessment at the time of judgment to reflect the actual extent of harm, while another insists on the date of occurrence, since the right to compensation arises once liability is established. Legal scholarship (Al-Jundi, 2008) emphasized that distinguishing between the moment the right to compensation arises and the moment of assessment is closer to legal logic, while experts in environmental law (Dupuy, 1991; Bergkamp, 2001) noted that environmental damages often evolve over time, requiring assessment at judgment to reflect their true extent and economic changes.

4.2.2.3 The Fate of Monetary Compensation in Pure Environmental Damage: In cases of pure environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems, monetary compensation is not directed to the claimant as a private benefit but is instead allocated to repairing and rehabilitating the damaged environment. Compensation funds are dedicated to projects and measures that mitigate pollution and restore ecological balance. Modern environmental law scholars, particularly Bergkamp (2001), have emphasized that this approach reflects a fundamental shift in civil liability systems, directing remedies toward collective environmental restoration rather than individual compensation. Recent empirical analysis of environmental compensation cases (Mohan, 2021) demonstrates that modern jurisdictions increasingly adopt this model, allocating compensation amounts to environmental restoration funds rather than direct claimant benefits, particularly in cases of pure ecological harm. This legislative trend is exemplified in the Jordanian Environmental Protection Law No. 52 of 2006, which established the Environmental Protection Fund under Article 16, designating it as the repository for environmental fines and compensation amounts to be allocated exclusively to environmental protection and restoration projects (Jordanian Environmental Protection Law, 2006). The implementation framework was further detailed in the Environmental Protection Fund System No. 18 of 2018, which specified the mechanisms for depositing and allocating compensation amounts. These resources are then spent on legally defined environmental purposes, ensuring that compensation serves its true purpose: repairing and protecting the environment while strengthening the effectiveness of the civil liability system in addressing damages caused by AI-based fertilizers and pesticides (Faure, 2009).

4.3 Compensation Mechanisms for AI-Based Agricultural Damages: The role of the Environmental Protection Fund is not limited to compensation alone, but also extends to prevention. It contributes to supporting programs and projects aimed at reducing environmental pollution, addressing its effects, and strengthening environmental monitoring and protection measures. This helps to reduce the risks associated with the use of modern technologies, including artificial intelligence systems used in the agricultural sector. Given the importance of this mechanism in the field of environmental civil liability, studying the Environmental Protection Fund requires addressing it from two complementary perspectives, as follows:

4.3.1 The Philosophy of Establishing the Environmental Protection Fund: The need arises for establishing an Environmental Protection Fund as a legal and financial instrument capable of supporting the application of both preventive and remedial approaches (Ivanov, 2024). On the one hand, the Fund provides the necessary financial resources to finance preventive measures and procedures aimed at reducing environmental risks associated with the use of smart systems in the agricultural sector (Maltby, 2013). On the other hand, it contributes to compensating those affected and redressing environmental damages in cases where full compensation cannot be obtained according to traditional rules of civil liability.

The idea of establishing funds is a modern legislative trend aimed at strengthening guarantees for compensating victims of environmental pollution, particularly in cases where traditional rules of civil liability cannot be applied or are insufficient to achieve full compensation. Therefore, some legal scholars believe that these funds were created to address shortcomings in both the civil liability system and the liability insurance system. The fund intervenes to compensate victims when the party responsible for the damage fails to fulfill their obligation or when insurance amounts are insufficient to cover all the damages incurred. Furthermore, the philosophy and importance of establishing an environmental protection fund lie in facilitating access to appropriate compensation for those affected by environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems, especially in cases where proving civil liability or enforcing a judgment is difficult (Fu & Li, 2023). The fund also contributes to reducing the time and effort required to obtain compensation and alleviates the burden on the judiciary, although recourse to the courts remains an option in cases where the fund refuses compensation or the damage exceeds the legally prescribed financial limits. The fund also plays a significant role in financing the repair of purely environmental damage that affects the environment itself, which is among the most difficult types of damage to assess and compensate for. Environmental protection funds also fulfill a dual function: a supplementary role and a reserve role. The supplementary role emerges when compensation or insurance payouts are insufficient to cover the full extent of environmental damage. In such cases, the fund intervenes to bridge the gap and ensure complete redress. The reserve role is evident in situations where the party responsible for the damage is unknown, insolvent, or has a legal exemption from liability. In these cases, the fund guarantees that the affected party is not deprived of their right to compensation.

Regarding the impact of the environmental protection fund on the functions of civil liability, some might argue that the fund's involvement in paying compensation weakens the compensatory and deterrent functions of civil liability. However, this view is not entirely accurate. The fund does not bear the ultimate burden of compensation in all cases. Rather, it retains the right to

seek reimbursement from the party responsible for the damage, in accordance with the rules governing legal recourse. Therefore, civil liability maintains its compensatory function in redressing damage and its deterrent function in encouraging individuals and entities involved in agricultural activities to comply with environmental and legal regulations. Despite the criticisms leveled against environmental compensation funds, most notably that the protection they provide is limited to specific categories of victims and that they operate under different legal frameworks, these criticisms do not diminish their practical importance. These funds represent a modern trend toward strengthening environmental protection and achieving social solidarity in the face of environmental risks. They also reflect an evolution in the concept of civil liability from its traditional individual framework to a more comprehensive one that aims to protect both society and the environment. Therefore, addressing the shortcomings of these systems does not mean abolishing them, but rather developing and expanding them, and improving their legislative framework to achieve more effective protection for both victims and the environment Wang et al. (2025).

4.3.2 The Legal Framework of the Environmental Protection Fund: Most modern environmental legislation has adopted the establishment of specialized environmental protection funds as legal and financial mechanisms to support preventive and remedial efforts against environmental damage. The Jordanian legislator has regulated this fund through provisions defining its legal nature, competencies, and management mechanisms (Fu & Li, 2023), with Article (16) of the Jordanian Environmental Protection Law stipulating the creation of the “Environmental Protection Fund.” The importance of such funds is particularly evident in addressing environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems, given the potential for severe harm requiring substantial financial resources for remediation and compensation (Wang et al., 2025). According to Article (16/b) of the law, the fund is managed by a board of directors formed in accordance with applicable legislation and regulations. This council oversees administrative, financial, and technical affairs, formulates general policy, and regulates the use of resources, with a vice-chair elected from among its members. Regular meetings are held to make decisions by the legally required majority.

Thus, the Environmental Protection Fund constitutes a fundamental pillar for enhancing the effectiveness of civil liability for environmental damage caused by these technologies. Its role extends beyond compensatory protection to include support for preventive and remedial programs, thereby achieving a balance between agricultural and technological development on one hand, and the preservation and sustainability of natural resources on the other (Abu-Morad, 2025). However, an analysis of the texts regulating the Environmental Protection Fund reveals that the Jordanian legislator focused primarily on the preventive and protective function of the Fund, while not giving sufficient attention to the issue of compensating those affected by environmental damage as an independent and direct objective of the Fund. The legal texts addressed multiple cases of the Fund's intervention, but did not establish a general and explicit rule stipulating its obligation to compensate those affected whenever it is impossible to obtain compensation from the person responsible for the environmental damage (Almasaeid & Al-Jarrah, 2024). Hence, it seems that the need is for the legislator to explicitly stipulate the obligation of the Environmental Protection Fund to compensate for environmental damages arising from the use of fertilizers and agricultural pesticides based on artificial intelligence systems, whether these damages affected people or their property or affected the environment itself, whenever it is impossible to obtain compensation from the direct person responsible for any reason, such as insolvency, bankruptcy, unknown perpetrator, or insufficient financial guarantees available to him (Shamaileh, 2016). Nevertheless, the compensatory role of the Fund remains in practice, especially in cases of pollution of unknown origin, insolvency of the person responsible for the damage, or the existence of legal or financial limits that are insufficient to cover all environmental damages. In these cases, the Fund intervenes to ensure that damage is not left unaddressed or uncompensated, thus achieving the goals of environmental justice and protecting the rights of those affected (Al-Sarayrah, 2017).

The Jordanian legislature acted wisely in subjecting the Fund's operations and accounts to the oversight of independent financial bodies, namely the Jordanian Audit Bureau. This oversight provides guarantees of integrity, transparency, and sound management of public funds allocated for environmental protection and compensation for environmental damage. In conclusion, the Environmental Protection Fund represents one of the most important modern mechanisms supporting the effectiveness of civil liability for environmental damage resulting from the use of fertilizers and pesticides based on artificial intelligence systems. It provides the necessary protection for those affected in cases where traditional rules of civil liability fail to provide full compensation. It also contributes to supporting environmental prevention and remediation efforts, while maintaining ultimate responsibility for the actual cause of the damage. This makes it an effective legal tool for achieving environmental justice and ensuring the sustainability of natural resources. The Environmental Protection Fund's budget, as

stipulated in Article (17), is financed from a range of financial resources specified by law. These include allocations in the general budget, donations, grants, and bequests received by the Fund (provided that the Cabinet approves any non-Jordanian sources), returns on the Fund's investments, and any sums, fines, or compensations collected under the provisions of this law or any other legislation that mandates their transfer to the Fund.

However, it should be noted that the Jordanian Environmental Protection Law does not explicitly mention a crucial financial resource: environmental taxes levied on polluting activities, including those related to the production, distribution, or use of fertilizers and pesticides that utilize artificial intelligence systems. Therefore, it appears appropriate for the legislature to add this resource to the Fund's funding sources. This would align with the "polluter pays" principle and provide additional resources to finance environmental protection programs and compensate those affected.

5. CONCLUSIONS AND RECOMMENDATIONS:

This section represents the culmination of the research effort, marking the transition from detailed analysis and presentation of results to a concise synthesis that highlights the key findings and conclusions, while offering practical and legislative recommendations that may contribute to the development of the legal framework or the improvement of practical practices

5.1 Conclusions: The study demonstrates that both Jordanian and French law recognize compensation for material and moral damages within contractual and tort liability, with tort liability providing a more appropriate basis for moral damages in cases involving agricultural pesticides. Civil liability claims thus serve as the procedural mechanism through which victims, as well as environmental associations and administrative authorities, may seek redress for pollution damages caused by AI-based pesticides. Furthermore, while traditional civil legislation treats in-kind compensation as an exceptional remedy, environmental legislation regards it as the primary response, reserving monetary compensation for cases where restoration is impossible an approach more consistent with the nature of purely environmental harm. Finally, the Environmental Protection Fund emerges as a vital mechanism to safeguard victims' rights when the responsible party cannot be identified or compelled to pay, reinforcing the principle of victim protection and enhancing the effectiveness of environmental liability systems.

5.2 Recommendations: This part represents a natural extension of the conclusion, as the role of the research is not limited to presenting results and findings, but extends further to offering practical and legislative recommendations that may contribute to the development of the legal framework and enhance the effectiveness of civil liability in addressing environmental damages arising from the use of artificial intelligence systems in agriculture.

- Regulate the legal provisions governing collective actions for compensation of purely environmental damages arising from the use of AI-based pesticides, by enabling affected individuals, environmental protection associations, and competent administrative authorities to initiate such claims.
- The Jordanian legislator should adopt modern approaches and comparative legislative trends regarding the proof of causation in civil liability claims for environmental damages caused by pesticide use, particularly in cases characterized by technical and scientific complexity.
- Expand reliance on judicial and scientific presumptions and appropriate legal assumptions whenever justified, thereby alleviating the burden of proof on the victim and enabling them to overcome practical difficulties in establishing the causal link between harmful activity and the environmental damage in dispute. This would lead to more effective protection of victims' rights and the achievement of environmental justice.

REFERENCES:

- [1] Jordanian Civil Code No. (43) Of 1976, Articles 256, 262, 266, and 291.
- [2] Jordanian Environmental Protection Law No. (6) Of 2017, Article 16 and Article 16/b.
- [3] Jordanian Environmental Protection Law (2006).
- [4] Jordanian Environmental Fund Law (2018).
- [5] French Environmental Code, Article L.142-2.
- [6] French Environmental Code, Article L.132-1.
- [7] French Environmental Code, Article L.142-4.
- [8] International Court of Justice (ICJ) jurisprudence recognizing collective rights of the international community (case

- law reference in environmental litigation context).
- [9] Abu-Morad, M. (2025). The Concept of Illicit Enrichment: The Parallel Lines between Criminalization and Prosecution End without Meeting. *Jordanian Journal of Law and Political Science*, 17(2). <https://doi.org/10.35682/jjpls.v17i2.962>
 - [10] Al Abady, H. (2022). Towards a legal framework for civil liability of smart robots in Jordanian legislation. *International Journal of Cyber Criminology*, 16(2).
 - [11] Alayaydeh, H. A. S., Abusmhadaneh, A. M. N., Altarawneh, S. M. D., Altarawneh, M. H. M., & Alhusban, O. A. K. (2024). The role of environmental law in promoting environmental health: A sustainable development perspective [O papel do direito do ambiente na promoção da saúde ambiental: Uma perspectiva de desenvolvimento sustentável]. *Relações Internacionais no Mundo Atual*, 4(46). <https://doi.org/10.21902/Revrima.v4i46.7970> (Alayaydeh et al., 2024)
 - [12] Alayaydeh, H. A., Awaisheh, S. M., Al-Taani, M., Al-Dabbas, N. A., Alqudah, A. M.-A., & Awaisheh, S. M. (2025). The Problem of Establishing Civil Liability for Harmful Effects of Smart Robots. *Indian Journal of Information Sources and Services*, 15(4), 31–39. <https://doi.org/10.51983/ijiss-2025.IJISS.15.4.04>
 - [13] Al-Fatlawi, S. O. (2001). The role of civil liability in protecting the environment from pollution in light of scientific and technical progress [in Arabic]. *Al-Balqa Journal for Research and Studies*, 8(2), 31.
 - [14] Al-Khawaldah, M. H. A., Rshdan, A. A. M. H., Al Makhmari, M. R. A., Al Mamari, S. A. H., Al Haf, R. A., & Alsharqawi, A. H. (2023). Penal liability for the oil leak incident “heavy fuel” in the Jordanian Port of Aqaba and its impact on the environment. *Journal of Environmental Management and Tourism*, 14(3), 754–758. [https://doi.org/10.14505/jemt.14.3 \(67\).14](https://doi.org/10.14505/jemt.14.3 (67).14) (doi.org in Bing)
 - [15] Almahasneh, Y. (2025). Tort Liability for Environmental Damages Resulting from Climate Change. *An-Najah University Journal for Law and Economics*, 1(2), 107–116. <https://doi.org/10.35552/anujrle.1.2.2474>.
 - [16] Almasacid, N. M. M., & Al-Jarrah, J. (2024). Payment of Civil Liability for Damages Arising from the Use of Artificial Intelligence Technologies. *Global Journal of Politics and Law Research*, 12(6), 1–19. <https://doi.org/10.37745/gjplr.2013/vol12n6119>
 - [17] Al-Qaisi, A. H., Alamawi, M. A. A., Juwaihian, M. A. A., Altarawneh, S. M. D., Al-Momani, S. M., Jaber, M. R., & Al-Btoush, A. (2026). Programming and material defects in AI technologies as bases for civil liability: A study within the scope of Jordanian law and EU legislation. *Corporate Law & Governance Review*, 8(1), 155–161. <https://doi.org/10.22495/clgrv8i1p13>
 - [18] Al-Sarayrah, I. S. (2017). The adequacy of general rules in compensating for environmental damage under the Jordanian Civil Code. *Journal of Arts and Social Sciences*, 8(2). <https://doi.org/10.53542/jass.v8i2.2292>
 - [19] Banerjee, D., Adhikary, S., Bhattacharya, S., Chakraborty, A., Dutta, S., Chatterjee, S., Ganguly, A., Nanda, S., & Rajak, P. (2023). Breaking boundaries: Artificial intelligence for pesticide detection and eco-friendly degradation. *Environmental Research*, 117601. <https://doi.org/10.1016/j.envres.2023.117601>
 - [20] Bergkamp, L. (2001). Liability and environment: Private and public law aspects of civil liability for environmental harm in an international context. Kluwer Law International. <https://ssrn.com/abstract=266365>
 - [21] Borghetti, J.-S. (2025). Responsabilité civile et intelligence artificielle : un regard français. *Revue internationale de droit comparé*, 77(1), 47–58. <https://doi.org/10.3917/ridc.771.0047>
 - [22] Chen, J., & Burgess, P. (2019). The boundaries of legal personhood: How spontaneous intelligence can problematize differences between humans, artificial intelligence, companies and animals. *Artificial Intelligence and Law*, 27(1), 73–92. <https://doi.org/10.1007/s10506-018-9229-x>
 - [23] Chesterman, S. (2020). Artificial intelligence and the limits of legal personality. *International & Comparative Law Quarterly*, 69(4), 819–844. <https://doi.org/10.1017/S0020589320000366>
 - [24] Dumery, A. (2025). La capacité du droit de la responsabilité civile à indemniser les dommages causés par l'intelligence artificielle. *Revue économique*, 76(1), 63–85. <https://doi.org/10.3917/reco.761.0063>
 - [25] Dupuy, Pierre-Marie (1991). *Liability for Environmental Damage in International Law: Recent Developments*. Review of European Community & International Environmental Law (RECIEL), Vol. 1, Issue 2.
 - [26] Dixit, A., Parmar, T., Yadav, S. (2026). Evaluating The Implementation of Section 89 Cpc In Haryana's Civil Justice System. *International Journal of Engineering Sciences & Research Technology*, 15(2), 1-10, <https://doi.org/10.64149/ijesrt.15.2.1-10>
 - [27] El-Gendy, M. S. (2008). Liability for material damage resulting from a harmful act: A study in Jordanian Civil Law

- and UAE Civil Transactions Law – A comparison with Islamic and Western jurisprudence (Part I). Kuwait University Journal of Law, 32(2), 123-165. <https://doi.org/10.34120/jol.v32i2.1577>
- [28] El-Refaie, A. M., & Alsharqawi, A. H. (2022). Legislative confrontation of the crime of environmental pollution in Jordan. *Pakistan Journal of Criminology*, 14(1), 29–42.
- [29] Emar, O., & Abu Issa, H. (2021). The legislative shortcomings aspects in the Jordanian environmental law: Comparison with international law. *Journal of Environmental Management and Tourism*, 12(7), 1850–1860. [https://doi.org/10.14505/jemt.v12.7 \(55\).10 \(doi.org in Bing\)](https://doi.org/10.14505/jemt.v12.7 (55).10 (doi.org in Bing))
- [30] Environmental Protection Fund System No. 18 of 2018. Official Gazette of the Hashemite Kingdom of Jordan. Retrieved from <https://www.ecolex.org/details/legislation/environmental-protection-fund-law-no-18-of-2018-lex-faoc177447/>
- [31] Faure, M. G. (2009). Environmental liability. In M. G. Faure (Ed.), *Tort law and economics* (pp. 247-286). Edward Elgar Publishing. <https://ssrn.com/abstract=1503405>
- [32] Foulon, J. (2019). Recent developments in French environmental law: Recognition and implementation of ecological damage in French tort law. *Environmental Law Review*, 21(4), 309–317. <https://doi.org/10.1177/1461452919883441>
- [33] Fu, B.-C., & Li, H. (2023). Legal advice on the Chinese compensatory fund system for oil pollution damage caused by ships from the perspective of marine environmental governance. *Frontiers in Marine Science*, 9. <https://doi.org/10.3389/fmars.2022.1083624>
- [34] Gao, Q., & Whittaker, S. (2019). Standing to sue beyond individual rights: Who should be eligible to bring environmental public interest litigation in China? *Transnational Environmental Law*, 8(2), 327–347. <https://doi.org/10.1017/S2047102519000141>
- [35] Hamdulay N. A., (2026). A Study on Comparative analysis of AI regulation in the EU, US, and China. *International Journal of Artificial Intelligence, Machine Learning and Data Analytics*, 1(1), 1-12. <https://www.ijaimda.org/index.php/ijaimda/article/view/5>
- [36] Ivanov, M. O. (2024). On the Necessity of Targeted Environmental Funds. *Izvestiâ Bajkal'skogo Gosudarstvennogo Universiteta*, 34(3), 439–446. [https://doi.org/10.17150/2500-2759.2024.34\(3\).439-446](https://doi.org/10.17150/2500-2759.2024.34(3).439-446)
- [37] Jordan Environmental Protection Law No. 52 of 2006. Official Gazette of the Hashemite Kingdom of Jordan. Retrieved from <https://faolex.fao.org/docs/pdf/jor070738E.pdf>
- [38] Linaza, M. T., Posada, J., Bund, J., Eisert, P., Quartulli, M., Döllner, J., Pagani, A., Olaizola, I. G., Barriguinha, A., & Moysiadis, T. (2021). Data-driven artificial intelligence applications for sustainable precision agriculture. *Agronomy*, 11(6), 1227. <https://doi.org/10.3390/agronomy11061227>
- [39] Maltby, L. (2013). Ecosystem services and the protection, restoration, and management of ecosystems exposed to chemical stressors. *Environmental Toxicology and Chemistry*, 32(5), 974–983. <https://doi.org/10.1002/etc.2212>
- [40] Manasra, M. W., Al Mamari, S. A. H., Gharibeh, A., Najm, M., Younes, A. S., & Alsharqawi, A. H. (2022). Tort liability for environmental pollution. *Journal of Environmental Management and Tourism*, 13(5), 1294–1299. [https://doi.org/10.14505/jemt.v13.5\(61\).07 \(doi.org in Bing\)](https://doi.org/10.14505/jemt.v13.5(61).07 (doi.org in Bing))
- [41] Mohan, M. P. R., & Kini, E. R. (2021). Compensation for environmental damage: Progressively casting a wider net, but what's the catch? *Vanderbilt Journal of Transnational Law*, 54(3), 611-680. <https://scholarship.law.vanderbilt.edu/vjtl/vol54/iss3/3/>
- [42] Segerson, K. (1990). Liability for groundwater contamination from pesticides. *Journal of Environmental Economics and Management*, 19(3), 227–243. [https://doi.org/10.1016/0095-0696\(90\)90071-6 \(doi.org in Bing\)](https://doi.org/10.1016/0095-0696(90)90071-6 (doi.org in Bing))
- [43] Shamaileh, A. Y. (2016). An evaluation of the effectiveness of environment policy in Jordan. *The International Journal of Business and Management*, 11(2), 92–101. [https://doi.org/10.5539/ijbm.v11n2p92 \(doi.org in Bing\)](https://doi.org/10.5539/ijbm.v11n2p92 (doi.org in Bing))
- [44] Son, N., Chen, C.-R., & Syu, C.-H. (2024). Towards artificial intelligence applications in precision and sustainable agriculture. *Agronomy*, 14(2), 239. <https://doi.org/10.3390/agronomy14020239>
- [45] Soyer, B., & Tettenborn, A. (2022). Artificial intelligence and civil liability—do we need a new regime? *International Journal of Law and Information Technology*, 30(4), 385–397. <https://doi.org/10.1093/ijlit/caad001>.
- [46] Singh. R., Verghese. S. P., Bansal A. (2026). Silver Nanoparticles For Environmental Sustainability And Their Role In Biological Activities. *International Journal of Engineering Sciences & Research Technology*, 15(3), 1–8. <https://doi.org/10.64149/j.jesrt.15.3-1-8>

- [47] Taylor, S. (2018). Extending the frontiers of tort law: Liability for ecological harm in the French Civil Code. *Journal of European Tort Law*, 9(1), 81–103. <https://doi.org/10.1515/jetl-2018-0102>
- [48] Uddin, M., Chowdhury, A., & Kabir, M. A. (2024). Legal and ethical aspects of deploying artificial intelligence in climate-smart agriculture. *AI & Society*, 39(1), 221–234. <https://doi.org/10.1007/s00146-022-01421-2>
- [49] Wang, Y., Wang, Y., & Pan, X. (2025). Optimization of the environmental compensation fund system for the area: an analysis based on the ISA 2025 draft exploitation regulations. *Frontiers in Marine Science*, 12. <https://doi.org/10.3389/fmars.2025.1638999>
- [50] Wendehorst, C. (2020). Strict liability for AI and other emerging technologies. *Journal of European Tort Law*, 11(2), 150–180. <https://doi.org/10.1515/jetl-2020-0140>
- [51] Xie, L., & Xu, L. (2022). The successes and obstacles of environmental public interest litigation in China: Findings from 570 court cases brought by NGOs, public prosecutors and local government. *Journal of Environmental Law*, 34(1), 53–81. <https://doi.org/10.1093/jel/eqab029>
- [52] Zhuk, A. (2023). Artificial intelligence impact on the environment: Hidden ecological costs and ethical-legal issues. *Journal of Digital Technologies and Law*, 1(4), 932–954. <https://doi.org/10.21202/jdtl.2023.40>