Blockchain-Enabled Green Supply Chain Management: Innovating Agricultural Plastic Waste Recovery and Reverse Logistics

Dimitra Tzanetou[1], Stavros T. Ponis[1[0000-0002-9544-9219]], George Plakas[1[0000-0002-6974-9218]] and Theodoros Nikolaos Maroutas[1]

[1] National Technical University Athens, School of Mechanical Engineering, Heroon Polytechniou 9, 15780 Athens, Greece

Abstract. In the scientific field of green supply chain management and reverse logistics, addressing the escalating issue of plastic pollution stands as a critical challenge, particularly within the agricultural sector. The integration of sustainable practices and innovative technologies in managing agricultural plastic waste is paramount to advancing environmental stewardship and operational efficiency. In that direction, the research presented in this paper delves into the development of a novel approach that harmonizes with the principles of reverse logistics and green supply chain management, aiming to mitigate the environmental footprint of agricultural plastics. Central to this study is the exploration of an advanced system for the management of agriplastic waste, leveraging Blockchain technology to foster a transparent, efficient, and sustainable supply chain. This system proposes a decentralized platform that enables seamless interaction between stakeholders, including farmers and waste collectors, facilitating the effective tracking, collection, and recycling or energy recovery of agricultural plastics. By establishing a reliable network for the detailed reporting of agriplastic usage and disposal, the research underscores the potential of digital ledger technologies to enhance traceability and accountability in waste management processes. Furthermore, this research emphasizes the importance of reverse logistics in the lifecycle management of agricultural plastics, from their initial deployment to their final disposal or repurposing. Through the creation of a mobile application and the formulation of a comprehensive business model, the study aims to facilitate the recovery and recycling of materials and thus, to contribute to the reduction of environmental pollution, the promotion of sustainable agricultural practice and the broader objectives of environmental conservation and sustainability.

Keywords: Green Supply Chain Management, Blockchain, Agricultural plastic waste, Reverse Logistics, Circular Economy, Waste-to-energy

1 Introduction

Plastic pollution is a critical global issue, exacerbating environmental, economic, health, and aesthetic challenges with each passing day (Soares et al., 2021). The surge in plastic usage across various agricultural operations over recent decades has notably contributed to this dilemma. Although the agricultural sector is not the primary culprit, its substantial utilization of plastics in numerous applications adds significant strain (Batista et al., 2022). This issue is particularly pronounced in countries like Greece, where the absence of effective agri-plastic waste management systems results in a substantial portion of waste being improperly discarded on land, in the sea, or being illegally burned, thereby inflicting a broad spectrum of environmental damages (Andrea et al., 2020). Adding to the complexity, research indicates that the improper disposal of agricultural plastics can lead to soil degradation, water contamination, and a reduction in biodiversity, highlighting an urgent need for sustainable waste management practices (Hajam et al., 2023). Furthermore, studies emphasize the potential of recycled agricultural plastics in creating economic opportunities through the production of value-added products, thus underscoring the economic as well as environmental benefits of recycling (Hoffman et al., 2023). The environmental impact of plastic waste in oceans has also been well-documented, with agricultural plastics contributing to the vast expanses of marine litter that harm marine life and ecosystems (Thushari & Senevirathna, 2020). Moreover, the health implications for humans through the bioaccumulation of toxic substances from plastics in the food chain have been a growing concern among scientists (Smith et al., 2018).

Given these multifaceted impacts, there is a critical need to design, develop, and implement comprehensive systems for the detection, tracking, recovery, and, where feasible, the energy utilization or safe disposal of agri-plastics. Such systems would not only aim to mitigate agri-plastic waste pollution but also promote the agricultural sector's alignment with sustainability and circular economy principles. By embracing innovative solutions and fostering international collaboration, it is possible to address the pressing challenges posed by agricultural plastic pollution, thereby ensuring a more sustainable future for global agriculture and the environment at large. BLOCK AGROWASTE attempts to accommodate this need by developing a state-of-the-art, environmentally friendly and economically viable innovative agri-plastic waste management system. The project will focus on the development of a decentralized platform based on Blockchain technology, providing continuous communication between contract farmers and collectors of agri-plastic waste. In particular, the objective of the proposed project is to create a highly reliable information network for all stakeholders, through which, farmers will be able to inform the collectors about the type, quantity, date of placement and geographical location of agri-plastics in their greenhouses, using an online distributed ledger. At a later stage and after the end of the useful/ functional service life of the agri-plastics, the registered quantity will be able to be declared available for recycling, while the collectors will be notified accordingly through a specially designed mobile application. The latter will collect the waste and

transport it to suitable units for further processing, recycling and energy utilization, thus successfully completing its management cycle.

The successful implementation of the proposed project will lead to the development of an effective agri-plastic waste management system, capable of enhancing the traceability of agri-plastics at the end of their useful life and their final use as waste, i.e. their separation by type and gathering by farmers, their collection by non-hazardous waste collection companies, and finally, their utilization by waste-to-energy companies. The ultimate goal of BLOCK AGROWASTE is to formulate a detailed business plan for the sustainable and commercially successful introduction of a complete solution, exploitable in both domestic and international markets, by issuing thorough technical instructions to potentially participating companies, regarding the creation of cooperative relations aimed at the collection, transport, management and utilization of agri-plastic waste.

2 Methodology of the proposed project

In order to fulfill the objectives outlined for the BLOCK AGROWASTE initiative, the research methodology adheres to a structured framework comprising four sequential phases: **(a)** an investigative study into the prevailing circumstances within the agri-plastic waste management domain alongside technological exploration for the development of the information system; **(b)** the construction of the project's technological infrastructures; **(c)** rigorous evaluation and testing to ensure functionality and system interoperability; and **(d)** pilot implementation followed by a comprehensive analysis of the project outcomes. Delving further into the methodological steps, the approach is delineated into five key points crucial for the project's success:

- The comprehensive documentation of the current state of agri-plastic waste management, including all types of plastic waste distinguished by their chemical properties (e.g., PE films, HDPE, etc.), utilization, disposal timelines, and requirements for pre-recovery treatment processes.
- The smart design of an innovative agri-plastic management system designed for optimal accumulation and transportation to suitable facilities for subsequent recycling and processing. This system bifurcates into two technological pillars: a subsystem dedicated to the collection and analysis of big data, which will collect real-time data for visualization purposes, and an application subsystem, which will be utilized as the project's backbone, to deliver services of high importance to both farmers and agri-plastic waste collectors.
- The successful integration of technology to ensure the operational efficiency of the system and the seamless progression of agricultural activities through the adoption of a Blockchain platform. This enables farmers to join a networked ecosystem, facilitating the dissemination of agri-plastic waste data as streaming inputs to a cloud computing setup for further analysis. Conversely, collectors of agri-plastic waste are apprised of plastic quantities through an easy-to-use Web UI/UX accessible via their mobile devices.

- The seamless development of the Blockchain platform's data collection and analytic subsystem, alongside the effective data processing and visualization, plays a critical role in reinforcing the successful execution of the agri-plastics management framework.
- The emphasis on the mobile application's user-friendly design is anticipated to augment its acceptability among end-users, namely, the farmers and agri-plastic waste collectors. The application interface is designed to be intuitive, directing farmers in the disposal of agri-plastic waste and assisting collectors in the acquisition and subsequent transport for recycling, processing, and energy recovery.

These methodological facets collectively constitute the foundation upon which the BLOCK AGROWASTE project aspires to revolutionize agri-plastic waste management, leveraging state-of-the-art technologies to address environmental challenges, thus steering the agricultural sector towards sustainability and circular economy paradigms.

3 Conclusions

In summary, the BLOCK AGROWASTE project adopts a holistic approach, initiating with an evaluation of existing waste management methods and the creation of a sophisticated information system. It proposes a dual-component system that integrates extensive data gathering and analysis with a user-friendly mobile app. This initiative aims to enhance the efficiency of collecting, transporting, and recycling agricultural plastics by employing blockchain technology for the instant sharing and processing of data. The approach emphasizes the integration of technology, ease of use, and the project's pilot testing to verify its effectiveness and potential for expansion. Furthermore, the project is a deliberate effort to reduce the environmental footprint of agricultural plastic waste. Through the application of advanced technology and a systematic strategy, it seeks to provide a sustainable solution that not only tackles the current challenges of waste management in the agricultural sector but also supports wider objectives of sustainability and the circular economy. This effort is expected to significantly better the handling of agricultural plastics, diminish pollution, and promote a more sustainable agricultural sector.

Acknowledgments. This research has been co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Attica 2014-2020, for the Action Entitled “Research synergies and Innovation in the Region of Attica” (project code: ATTP4-0325411)

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Andrea, V., Mpeza, P., Barelos, D., & Stylios, C. (2020). Unraveling the role of plastic waste pollution in the Amvrakikos wetlands national park, Greece: the stakeholders’ views. Journal of Marine Science and Engineering, 8(8), 549.

2. Batista, T., Cansado, I. P. D. P., Tita, B., Ilhéu, A., Metrogos, L., Mourão, P. A. M., ... & Matos, G. (2022). Dealing with plastic waste from agriculture activity. Agronomy, 12(1), 134.
3. Hajam, Y. A., Kumar, R., & Kumar, A. (2023). Environmental waste management strategies and vermi transformation for sustainable development. Environmental Challenges, 100747.
4. Hofmann, T., Ghoshal, S., Tufenkji, N., Adamowski, J. F., Bayen, S., Chen, Q., ... & Wilkinson, K. J. (2023). Plastics can be used more sustainably in agriculture. Communications Earth & Environment, 4(1), 332.
5. Smith, M., Love, D. C., Rochman, C. M., & Neff, R. A. (2018). Microplastics in seafood and the implications for human health. Current environmental health reports, 5, 375-386.
6. Soares, J., Miguel, I., Venâncio, C., Lopes, I., & Oliveira, M. (2021). Public views on plastic pollution: Knowledge, perceived impacts, and pro-environmental behaviours. Journal of hazardous materials, 412, 125227.
7. Thushari, G. G. N., & Senevirathna, J. D. M. (2020). Plastic pollution in the marine environment. Heliyon, 6(8).