Plastic Waste Forecasting and Interventions for Environmental Footprints Mitigation

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Plastic waste and its environmental hazards have been attracting public attention as a global sustainability issue. Plastic pollution, like other major environmental issues such as climate change, has the characteristics of a "wicked problem" that resists clear resolution. Entrenched socio-economic factors and business practices often hinder efforts to maximise recycling. A vicious cycle occurs that tends to favour unsustainable practices – company decisions on new product choices are constrained by market preferences, while public behaviour is in turn influenced by currently available products. The complex interdependencies that influence plastic use and waste generation lead to "vicious networks", resulting in persistent unsustainable behaviour (Tan et al., 2021). Given the capability to handle highly complex systems, data-driven machine learning approaches can draw insights into how to curb the plastic pollution problem and support future plastic pollution mitigation policies. However, current literature only sheds light on applying machine learning to mitigate plastic pollution through micro-level technologies (e.g., using artificial intelligence to identify plastic waste for sorting). Studies that focus on the macro-level application of machine learning to analyse country-level trends from public statistics are comparatively scarce. An exception is a macro-level analysis considering five different global scenarios conducted by Lau et al. (2020); this work considered the big picture but lacked the regional resolution to give useful insights for local policy development. Their estimation of pollution is based on the Monte Carlo simulation. This notable research gap provides opportunities for developing a data-driven approach to reducing plastic pollution and its environmental hazards.

This study builds a neural network model to forecast plastic waste generation of the EU-27 in 2030 and evaluates how the interventions could mitigate the adverse impact of plastic waste on the environment. Artificial Neural Networks (ANN) are a widely utilised machine learning modelling approach for sustainability issues (. They have already been used for various applications for tens of years. ANNs have also been successfully implemented to predict waste generation, demonstrated for domestic, commercial, and construction waste. ANN generally has higher predictive power and lower sensitivity to outliers than the regression method in forecasting waste generation. It can model nonlinear and complex relationships and has been successfully applied for various solid waste management modelling. However, it is a black-box model. The black-box model is interpreted using SHapley Additive exPlanations (SHAP) for managerial insights. The analyses and model are built-in Jupyter notebook, Version 6.3.0 (Jupyter, 2021), using Python programming language (Python Software Foundation, 2021). TensorFlow Keras 2.3.0 (TensorFlow, 2021), a neural network library, is applied in training the ANN model. The dependence on predictors (i.e., energy consumption, circular material use rate, economic complexity index, population, and real gross domestic product) and their interactions are discussed.

The projected plastic waste generation of the EU-27 is estimated to reach 17 Mt/y in 2030, equivalent to 37.8 kg/cap/y. With an EU targeted recycling rate (55%) in 2030, the environmental impacts would still be higher than in 2018, especially global warming potential and plastic marine pollution. This result highlights the importance of plastic waste reduction, especially for the clustering algorithm-based grouped countries with a high amount of untreated plastic waste per capita. Compared to the other assessed scenarios, Scenario 4 with waste reduction (50% recycling, 47.6% energy recovery, 2.4% landfill) shows the lowest impact in acidification, eutrophication, marine aquatic toxicity, plastic marine pollution, and abiotic depletion. However, the global warming potential (8.78 Gt CO_2eq) is higher than that in 2018, while Scenario 3 (55% recycling, 42.6% energy recovery, 2.4% landfill) is better in this aspect than Scenario 4. The dependence on predictors (i.e., energy consumption, circular material use rate, economic complexity index, population, and real gross domestic product) and their interactions are discussed. An observable trend is that a higher GDP contributes to a lower SHAP value (lower plastic waste), which supports the Environmental Kuznets Curve hypothesis, where EU-27 generally reaches the turning point. No apparent conclusion can be drawn whether the population contributes to a lower or higher plastic waste generation. This comprehensive analysis provides pertinent insights into policy interventions towards environmental hazard mitigation.

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