Study examines potential use of machine learning for sustainable development of biomass

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Biomass is widely considered a renewable alternative to fossil fuels, and many experts say it can play a critical role in combating climate change.

Biomass stores carbon and can be turned into bio-based products and energy that can be used to improve soil, treat wastewater, and produce renewable feedstock.

Yet large-scale production of it has been limited due to economic constraints and challenges to optimizing and controlling biomass conversion.

A new study led by Yale School of the Environment's Yuan Yao, assistant professor of industrial ecology and sustainable systems, and doctoral student Hannah Szu-Han Wang, analyzed current machine learning applications for biomass and biomass-derived materials (BDM) to determine if machine learning is advancing the research and development of biomass products. The study authors found that machine learning has not been applied across the entire life cycle of BDM, limiting its ability for development.

Yao's research investigates how emerging technologies and industrial development will affect the environment with a focus on bioeconomy and sustainable production. Wang worked in the production of biomaterials during her master's research. The two researchers said they were interested in pursuing this study to find out if machine learning could help with best practices for creating BDM, a chief component of a bio-based economy, as well as predicting their performance as sustainable materials.

"There are so many combinations of biomass feedstock, conversion technologies, and BDM applications. If we want to try each combination using the traditional trial-and-error experimental approach, this will take a lot of time, labor, effort, and energy. We already generate a lot of data from these past experiments, so we are asking, can we apply machine learning to help us to figure out how we can better design BDM?" Yao explains.

For the study, which was published in Resources, Conservation and Recycling, Yao and Wang reviewed more than 50 papers published since 2008 to understand the capabilities, current limitations, and future potential of machine learning in supporting sustainable development and applications of BDM. What they found is that while a few studies applied machine learning to address data challenges for life cycle assessment, most studies only applied machine learning to predict and optimize the technical performance of biomass conversion and applications. None reviewed machine learning applications across the entire lifecycle, from biomass cultivation to BDM production and end-use applications.

"Most studies are applying machine learning to just a very small part of the entire lifecycle of BDM," Yao says. "Our argument is that if you really want to incorporate sustainability into development of this material, we need to consider the entire lifecycle of the materials, from how they are generated to their potential environmental impact. We believe machine learning has the potential to support sustainability-informed design for biomass-derived materials."

Wang said the study has led to further research on data gaps in machine learning on biomass-derived materials.

"We found a future direction that people have not yet explored in terms of sustainability assessments for BDM. There needs to be a full pathway prediction to enhance our understanding of how various factors regarding BDM interact and contribute to sustainability," she says.

More information: Hannah Szu-Han Wang et al, Machine learning for sustainable development and applications of biomass and biomass-derived carbonaceous materials in water and agricultural systems: A review, *Resources, Conservation and Recycling* (2023). DOI: 10.1016/j.resconrec.2022.106847

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