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A multi-criteria sustainability and engine performance study of andropogon narudus biodiesel using the PUGH matrix and ML

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Abstract

The present work provides an experimental, sustainability, and ML-based analysis of Andropogon Nardus biodiesel as a potential second-generation green fuel for compression ignition engines. The biodiesel blends (AN20, AN30, and AN40) were then used on a single-cylinder direct-injection diesel engine over the 25–100% load range and at injection pressures of 190, 210, and 230 bar. Among the three AN30 blends tested, the improvement in engine performance at 230 bar indicates that AN30 provides nearly 15% greater brake thermal efficiency and reduces brake-specific fuel consumption by as much as 31% compared to the neat diesel level. Because of good atomization and the presence of oxygen in biodiesel, significantly lower emission levels of carbon monoxide, hydrocarbons, smoke opacity, and nitrogen oxides were achieved at optimized engine conditions. To evaluate the broader sustainability potential of the fuel, we applied a multi-criteria PUGH matrix analysis of performance (high & low) and emissions (atmospheric & land use)/sustainability (high & low) indicators. Out of all

the fuel tested, the most favorable compromise between combustion modes was achieved with AN₃₀ at 230 bar, which represents the best operating condition among the fuels tested. The experimental patterns were also employed to develop machine-learning models for predicting engine responses across an entire cruising range, and the results compared the prediction accuracy with models found ensemble-based algorithms provided the best prediction accuracy of the three models evaluated. These studies demonstrate that biodiesel produced from *Andropogon narudus* possesses decent potential as a sustainable biofuel for use in diesel engines when mixed at appropriate ratios and injected at appropriate pressures. © The Author(s) 2026.

Author keywords

Andropogon narudus biofuel; Energy efficiency; Machine learning; PUGH matrix; Sustainability assessment

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