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Innovative Approaches to Sustainable Food System: Cumulative Energy Demand and Environmental Impact of Apple Orchard Systems in Northern Italy

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ABSTRACT

This study evaluates the energy-environmental life cycle assessment of apple orchard systems in Northern Italy's mountain regions, through a cradle-to-farm gate life cycle assessment (LCA), focusing on sustainability concerns. The comparison involves two orchard systems: Tall Spindle (TS) and Guyot (GS), using one kilogram of apples as a functional unit. Data were collected via surveys and questionnaires from a nursery, apple growers, and an experimental farm, supported by background data from commercial databases. The analysis utilized SimaPro 9.6.0 with the Environmental Footprint 3.1 methodology, including uncertainty and sensitivity analyses. The results demonstrate that the GS offers a lower environmental impact, with significant reductions in resource use (-39.17%), freshwater ecotoxicity (-15.83%), and fossil consumption (-7.93%) compared to the TS system. It also demonstrates advanges in acidification, climate chage, and particultur matter categories. Coversly, TS system showed marginally better performance in eutrophication and human toxicity categories. Contribution analysis identified key impact drivers such as fertilizers, diesel, and irrigation, with pesticides primarily influencing ecotoxicity. The Cumulative Energy Demand (CED) is slightly higher in TS (1.85 MJ) than in GS (1.70 MJ), with non-renewable fossil fuels being the dominant energy source in both systems. Diesel and chemical fertilizers are primary inputs, although electric platform use is significantly more pronounced in TS system. The overall findings suggest that the Guyot system has a more sustainable profile, mainly due to reduced pesticide use, lower material intensity, and machinery requirements. To enhance sustainability,
both systems should prioritize reducing diesel dependency, optimizing fertilizer use, and adopting renewable energy sources for machinery. This findings provide actionable insights for orchard management, advocating energy-efficient practices and strategies to mitigate environmental footprints, thereby supporting sustainable apple production.

Keywords: Life cycle assessment (LCA), Cumulative energy demand (CED), Apple orchard systems, Mountain agriculture, Environmental hotspots

Themes: Climate-Smart Agriculture Practices, Organic Farming and Eco-friendly Impact