Harvesting of poplar clones in a silvoarable system: insights from an experimental case study in Italy

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Silvoarable systems combine tree rows and annual crops within the same area, improving ecosystem resilience and the sustainable management of agricultural landscapes. Although many experimental forest plantations aim to assess the productive and quality performance of integrating alley cropping within arable fields, some operational aspects of tree harvesting remain poorly documented, limiting the availability of benchmarking data on system performance and soil impacts. This study compared two harvesting systems with different levels of mechanization in a poplar-based silvoarable system in northern Italy. A semi-mechanized and a fully mechanized system were monitored during felling and processing operations along four poplar rows. Time motion studies, UAV photogrammetry, and field surveys were used to evaluate operational productivity and soil responses under real working conditions. The fully mechanized system achieved higher productivity, indicating that mechanized approaches can enhance harvesting efficiency and safety, if machine configuration and traffic patterns are adapted to site-specific characteristics. Soil effects were mostly confined to the upper 0–30 cm layer, involving both moderate compaction and mixing of surface horizons, while penetration resistance and bulk density values remained below critical compaction thresholds for root growth. The study contributes empirical benchmarks for integrating sustainable mechanization into agroforestry practices and provides a basis for improving cross-context comparability in future research, including applications in forest ecosystems. In this regard, by linking operational efficiency with soil disturbance processes, the study offers insights to support adaptive forest management and enhance stand-level sustainability.