

Tree Structural Composition and Aboveground Carbon Stocks in Smallholder Agroforestry Systems of Western Kenya: Evidence of Structural–Carbon Decoupling

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## Abstract

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Smallholder agroforestry systems are increasingly recognized as important components of climate mitigation and rural livelihood strategies, yet the relationship between stand structural composition and aboveground carbon storage remains insufficiently understood in heterogeneous tropical landscapes. This study examined tree structural composition and aboveground carbon stocks in smallholder agroforestry systems surrounding Kakamega Forest in western Kenya, with particular emphasis on the relationship between structural configuration and carbon storage. Tree inventory data were collected from 12 villages comprising 3892 trees with diameter at breast height (DBH)  $\geq 10$  cm. Structural composition was characterized using DBH-class distributions ( $< 25$  cm, 25–50 cm, and  $> 50$  cm), and a Structural Composition Index (SCI), defined as the proportion of trees with DBH  $< 50$  cm, was used as a descriptive indicator of stand size-class structure. Aboveground carbon stocks were estimated using standard pan-tropical allometric equations. Results showed substantial spatial variation in both structural composition and carbon storage across agroforestry systems. Aboveground carbon stocks ranged from 56.20 to 301.34 t C ha<sup>-1</sup>, while SCI ranged from 47.92% to 71.99%. Despite this variability, SCI exhibited no significant relationship with aboveground carbon stocks ( $r = -0.127$ ,  $p = 0.694$ ), indicating a weak coupling between structural composition and carbon storage at the landscape scale. Carbon stocks were primarily associated with the presence and dominance of large-diameter trees, whereas SCI reflected variation in overall size-class distribution driven by site-specific management histories. These findings demonstrate that structural composition and carbon storage represent partially independent dimensions of agroforestry system organization. The results further highlight that biomass-based carbon assessments alone may not adequately capture structural

heterogeneity in smallholder systems. Structural indicators derived from cross-sectional data should therefore be interpreted as descriptors of stand organization rather than proxies for demographic processes or carbon sequestration dynamics. We conclude that integrating structural and biomass-based indicators provides a more complete understanding of agroforestry system variability, particularly in complex smallholder-managed landscapes where management practices strongly shape both structure and carbon outcomes.