



Tropentag, September 10-12, 2025, hybrid conference

“Reconcile land system changes
with planetary health”

Shade tree leaf phenology in cocoa agroforestry management: insights into soil-foliar nutrient dynamics

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Abstract

The optimisation of nutrient dynamics through strategic shade tree management is a key factor for enhancing soil health, productivity and climate resilience in cocoa agroforestry systems. This study investigates how shade tree leaf functional groups, categorised as evergreen, brevi-deciduous and completely deciduous, influence soil and foliar nutrient parameters across a spatial gradient. The research was conducted in the Northern cocoa belt of Ghana, including 13 regionally common tree species in six phenological subgroups, sampled across three radial impact zones (inner, mid, outer). With four replicates per species, soil (0–30 cm depth) and leaf samples (from shade trees and cocoa plants) were examined for nitrogen (N), phosphorus (P), potassium (K), carbon (C), and soil pH. Statistical evaluation comprised Spearman’s rank correlation and linear mixed-effects modelling. The data revealed compelling trends in both soil and foliar nutrient parameters: In general, significant soil enrichment of N and C near shade trees translated only to higher N in the foliage of cocoa. By contrast, results for P and K were subtle and less consistent, likely reflecting competitive interactions and high mobility. Among the functional groups, evergreens showed the most pronounced accumulation of nutrient parameters, while other groups exhibited neutral or negative influence. Soil pH declined with distance outward, notably affecting nutrient solubility and accessibility under brevi-deciduous species. Altogether, differences in timing and duration of leaf fall significantly shaped nutrient patterns, although clear enrichment was often nuanced. These findings demonstrate that shade tree phenology could modulate nutrient cycling through distinct seasonal litter inputs, directly impacting nutrient availability and the nutrition of cocoa plants. Identifying such effects will allow for targeted selection and complementary management of shade tree species, optimised nutrient dynamics and improved livelihoods of smallholder farmers across West Africa.

Keywords: Cocoa agroforestry, functional traits, nutrient dynamics, shade tree phenology

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