



Tropentag, September 10-12, 2025, hybrid conference

“Reconcile land system changes
with planetary health”

Harnessing *moringa oleifera* genetic diversity and structure for sustainable agriculture and global environmental resilience

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Abstract

Land system changes driven by agricultural expansion, climate variability, and globalisation challenge both biodiversity and planetary health. *Moringa oleifera*, a nutritionally valuable and environmentally resilient tree species, offers opportunities for sustainable food systems, reforestation, and medicinal applications across tropical regions. However, its genetic diversity remains poorly characterised, limiting its potential for sustainable deployment. This study employed SNP markers generated via DArTSEQ technology to assess the genetic structure of 95 *Moringa* accessions from 19 provenances across Africa, the Caribbean, and Southeast Asia. From an initial set of 3968 SNPs, 1913 high-quality markers were used for population structure and diversity analyses. Phylogenetic and principal coordinate analyses revealed four geographic clusters, with Caribbean and East African populations forming subsets of a broader West African group, while South African (Malawi) and Southeast Asian (Philippines) samples segregated distinctly. Analysis of molecular variance indicated high gene flow within regions (77 %) compared to among populations (23 %). Bayesian modelling in structure with best k being two still distinctly segregated the South African (Malawi) population from the other African regions. Despite shared ancestry, the genetic distinctiveness of the Malawi population from rest of African populations suggests an independent introduction pathway. The significant admixture of individuals noted in structure is typical of unnatural introductions, possibly anthropogenic events. These findings underscore the utility of genomic tools in guiding germplasm conservation, breeding programs, and land management strategies. By integrating genomic data into land system science, this study contributes to reconciling biodiversity conservation, food security, and ecological restoration—core pillars of planetary health.

Keywords: Diversity, gene pool, *Moringa*, Polymorphism, Population, structure