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Community seed banks and the emergence of multifunctional agroecosystems in climate-vulnerable smallholder systems: Evidence of sustainability trade-offs in Kenya

Tosin Akingbemisilu[1], Lilian Aluso[1], Emeline Clotuche[2], Ruben Savels[2], Rosina Wanyama[1], Céline Termote[1]

[1] *The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya*
[2] *Ghent University, Dept. of Food Technology, Safety and Health; Fac. of Bioscience Engineering, Belgium*

Abstract

Background: Agroecological transitions are increasingly promoted as pathways to climate-resilient and sustainable food systems, yet empirical evidence on how specific interventions shape multidimensional outcomes remains limited. Community seed banks (CSBs) are widely recognised for strengthening local seed systems and agrobiodiversity, but their broader contributions to agroecosystem transformation are not well understood.

Methods: This study evaluates the role of a nutrition-sensitive CSB intervention in driving agroecological transitions and sustainability outcomes among smallholder farmers in Vihiga County, Kenya. Using cross-sectional data from 239 households, we apply the FAO Tool for Agroecology Performance Evaluation (TAPE) combined with propensity score matching and mixed-effects regression models to estimate intervention effects and isolate relationships between agroecological elements and sustainability outcomes.

Results: Results show that CSB participation is associated with significantly higher agroecological transition levels, with mean CAET scores of 54.2 in intervention sites compared to 41.1 in non-intervention areas ($p < 0.001$). Over half (55 %) of participating households reached transition stages, compared to 16.8 % in comparison sites, and 7.5 % achieved advanced agroecological status, while none did in non-intervention areas. The intervention strongly improved knowledge co-creation, governance, and circular economy practices.

However, direct impacts on sustainability outcomes were uneven. While pesticide exposure reduction improved significantly (+12 percentage points, $p = 0.019$), effects on income, dietary diversity, and soil health were limited or non-significant. Instead, overall agroecological transition levels showed stronger and more consistent associations with key outcomes, including food security ($= 0.45$, $p = 0.001$), soil health ($= 0.19$, $p = 0.009$), and agricultural biodiversity ($= 0.24$, $p < 0.001$).

Disaggregated analysis reveals important trade-offs. Diversity practices were positively linked to economic performance, while efficiency improved environmental outcomes but reduced income. Resilience practices enhanced land tenure and women's empowerment but were associated with lower short-term economic returns.

Conclusions: These findings demonstrate that while CSBs can catalyze agroecological transitions, sustainability outcomes depend on how different agroecological elements interact. Improvements in transition levels and key elements such as diversity and efficiency

Contact Address: Tosin Akingbemisilu, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, ICIPE Duduville Campus , P.O. Box 823-00621 Nairobi, Kenya, e-mail: T.Akingbemisilu@cgiar.org

also suggest potential gains in adaptive capacity within smallholder systems. Designing climate-resilient agroecosystems therefore requires integrated, context-specific strategies that balance ecological, economic, and social objectives.

Keywords: Agroecological transitions, climate-resilient agroecosystems, community seed banks, multidimensional sustainability, smallholder farming systems