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OPINION ARTICLE

Trait-based restoration in African dryland restoration projects: overcoming systemic and scientific barriers for a viable future

Paulina N. Naupu[1,2], Theo D. Wassenaar[1,3], Rolf W. Becker[3], Ezekeil Kwembeya[4]

Abstract

Introduction: African dryland restoration continues to show low success rates despite major pledges, due to persistent water scarcity, ecological complexity, and limited use of trait-based restoration (TBR). Functional trait-based approaches, which match species selection to adaptive traits, could strengthen ecosystem recovery under arid conditions, yet adoption in Africa remains rare.
Objectives: This opinion article examines why TBR remains underutilized in African drylands and argues for its systematic integration into restoration planning and policy.
Methods: A narrative synthesis of recent research and practitioner reports was used to assess the scope of TBR and identify institutional, scientific, and socio-economic barriers limiting adoption.
Results: Restoration projects across Africa often emphasize socio-economic outcomes over ecological function. Only a few African studies explicitly link plant functional traits to dryland restoration. Key barriers include scarce trait data for native species, limited long-term trials, weak integration of Indigenous Ecological Knowledge, and short donor-driven project cycles.
Conclusion: Functional TBR offers a practical framework for improving ecosystem resilience in African drylands but requires region-specific research, inclusive co-design, and policy alignment.

Implications for Practice: Adopting trait-based restoration (TBR) can improve restoration outcomes in Africa when grounded in region-specific ecological realities. Integrating functional traits with Indigenous Ecological Knowledge can strengthen species selection, reduce seedling mortality, and enhance ecosystem resilience. Policymakers can embed trait criteria into restoration planning, while practitioners may use traits linked to drought tolerance, water-use efficiency, and regeneration capacity. Strengthening collaboration among researchers, communities, and government agencies is essential for scaling TBR approaches.

Key words: African drylands, dryland restoration, functional traits, trait-based restoration, water-use efficiency

Introduction

The United Nations (UN) Decade on Ecosystem Restoration (2021–2030) underscored the urgent need to reverse ecological degradation and build resilience in ecosystems that sustain biodiversity and livelihoods (Aronson et al. 2020; Waltham et al. 2020). Among the most vulnerable ecosystems are drylands (aridity index 0.03–0.65) (Zomer et al. 2022), which cover over 40% of the Earth's land surface and are home to over 2 billion people (Martínez-Valderrama et al. 2023). In Africa, drylands face escalating pressures from desertification, land degradation, and climate change (Burrell et al. 2020).

Globally, trait-based restoration (TBR) has gained traction as an emerging framework for improving restoration outcomes in water-limited and degraded ecosystems. Studies from Mediterranean drylands, Latin America, and Australia have demonstrated that matching species to environmental filters and functional traits can substantially improve plant survival and ecosystem function (Laughlin et al. 2017; Giannini et al. 2017; Werden et al. 2018; del Campo et al. 2020). These global advances highlight the potential of TBR to address the limitations of traditional restoration approaches that rely on taxonomic or convenience-based species selection.

Despite major restoration commitments such as the Bonn Challenge, the Great Green Wall, and AFR100, restoration outcomes in African drylands remain limited (Chomba et al. 2020; Sacande & Muir 2023). Poor seedling survival and weak ecosystem recovery are frequently reported, largely because species are introduced without sufficient consideration of functional traits required under extreme water limitation (Gebirehiwot 2023;

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[1]Biodiversity Research Centre, School of Agriculture and Natural Resources Sciences, Namibia University of Science and Technology, Private Bag, 13388, Windhoek, Namibia
[2]Address correspondence to P. N. Naupu, email pnaupu@nust.na
[3]Carbon Cycling Research Group, Ongava Research Centre, Private Bag, Windhoek 13419, Namibia
[4]Department of Environmental Science, University of Namibia, Private Bag, 13301, Windhoek, Namibia

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Asmelash & Rannestad 2024; Chapungu & Zhanda 2025). Effective restoration, therefore, demands frameworks that prioritize drought tolerance and water-use efficiency (WUE).

The TBR offers such a framework by aligning species selection with measurable traits that predict performance and survival (Laughlin 2014; Balazs et al. 2020). However, its application across Africa remains limited. Barriers include scarce trait data, minimal integration of Indigenous Ecological Knowledge (IEK), and weak links between research, policy, and implementation (Djenontin et al. 2018; Wells et al. 2021; Sacande & Muir 2022).

This article argues that improving restoration outcomes in African drylands requires moving beyond symbolic planting targets toward trait-informed approaches that integrate ecological science, policy support, and community knowledge.

Functional Trait-Based Restoration: The Missing Link

Global experience has shown that TBR can significantly enhance restoration success by improving species–site matching, WUE, and resilience under extreme climatic conditions (Laughlin 2014; Balazs et al. 2020). These insights provide a critical foundation for understanding how functional traits influence ecosystem recovery across diverse dryland ecosystems. However, translating these lessons to African contexts requires careful adaptation, as ecological baselines, species pools, and implementation constraints differ substantially from those in the Global North and Latin America.

Studies from Mediterranean drylands, Costa Rica, and Brazil demonstrated that traits such as rooting depth, wood density, and stomatal dynamics can predict survival and guide species choice (Giannini et al. 2017; Werden et al. 2018; del Campo et al. 2020). Tools such as the Restoring Ecosystem Services Tool (REST) help translate these traits into practice (Rayome et al. 2019). These global case studies demonstrate the potential of TBR, yet they cannot be assumed to transfer directly to African drylands due to differing species pools, socioecological contexts, and implementation constraints.

In African drylands, evidence for functional TBR remains limited. A review by Ben-Enukora and Ejem (2024) showed that most projects rely on participatory approaches rather than trait-based methods. Two East African studies demonstrated the utility of functional traits. Lohbeck et al. (2018) linked functional diversity to improved soil carbon and reduced erosion, while Mens et al. (2023) related woody traits to better soil hydrology. These examples underscore the potential of TBR but also reveal the continent's lag compared to other regions.

Barriers to Implementing TBR in Africa

A major constraint to adopting TBR in Africa is the lack of trait data for native dryland species (Merchant et al. 2023). Most existing plant trait knowledge comes from temperate or humid regions (Hortal et al. 2015), leaving the functional ecology of African species poorly documented (Karlsson et al. 2007; Hortal et al. 2015; Wilson et al. 2016). Limited research investment further restricts practitioners' ability to select species based on functional performance.

Large-scale trait databases like TRY exist, but they are heavily biased toward non-African flora (Kattge et al. 2020). High environmental variability across Africa's drylands also challenges the transfer of generic trait–environment frameworks (Eviner & Hawkes 2008). Few long-term trials test trait–performance relationships, and short project cycles rarely support the monitoring needed to validate trait relevance in field conditions (Carlucci et al. 2020).

Initiatives such as the Great Green Wall have engaged local communities in species selection, yet choices often prioritize socioeconomic benefits over ecological suitability (Sacande et al. 2015; Sacande & Berrahmouni 2016). The IEK holds valuable observations of plant resilience, drought behavior, and regrowth under stress (Fremout et al. 2021), but this knowledge is seldom translated into measurable trait frameworks in African drylands.

Overcoming the Barriers

Strengthen Locally Relevant Research

Advancing TBR in Africa requires expanding empirical studies on native dryland species. Despite global progress, trait-based work across Africa's semiarid zones remains scarce (Wassenaar et al. 2013; Chomba et al. 2020; Mills et al. 2023). More regionally grounded field trials and long-term monitoring are needed to test how traits influence species survival and ecosystem recovery. Without locally derived data, restoration continues to rely on assumptions that often fail under African conditions.

Integrate Indigenous Ecological Knowledge

Initiatives such as the Great Green Wall have engaged local communities in species selection, yet choices often prioritize socio-economic benefits over ecological suitability (Sacande et al. 2015; Sacande & Berrahmouni 2016). Although IEK holds valuable observations on drought tolerance and species performance, it is seldom translated into measurable trait frameworks in African contexts (Sacande & Berrahmouni 2016; Constant & Taylor 2020; Obiero et al. 2023). This gap represents a major opportunity for co-designed projects that merge local experience with ecological science. Restoration initiatives that systematically combine both knowledge systems are more likely to succeed ecologically and socially (Constant & Taylor 2020; Obiero et al. 2023).

Focus on Practical, Measurable Traits

Given limited resources, restoration in African drylands should emphasize traits that are easy to measure and directly relevant to water-limited conditions (Loureiro et al. 2023). Specific leaf area (SLA) is one such trait. Defined as the ratio of leaf area to dry mass, SLA provides insight into a plant's resource-use strategy (Wilson et al. 1999; Costa-Saura et al. 2016; Wellstein et al. 2017). Low SLA values suggest a conservative water-use strategy well suited to arid environments (Hodgson et al. 1999; Dwyer et al. 2014). Leaf dry matter content (LDMC) is another key trait. Higher LDMC typically signals better tolerance to water stress, herbivore resistance, and a "slower" economic strategy (Wilson et al. 1999; Blumenthal et al. 2020). On the other hand, stomatal density serves as a simple proxy for drought response and gas-exchange regulation (Lawson et al. 2014; Hepworth et al. 2015). These traits can be assessed with minimal equipment, making them feasible for student-led or community-based restoration.

Crassulacean acid metabolism (CAM) is not a trait in the strictest sense, but it defines a group of species that are well adapted to dry conditions due to their nocturnal carbon fixation strategy (Winter et al. 2015). Confirming CAM at a biochemical level requires gas exchange or isotopic measurements. However, it can often be inferred based on plant growth form or literature records, making it a practical and informative proxy in the African context.

Prioritizing such response traits (those that determine how plants tolerate stress) offers immediate, scalable benefits. Focusing on a small suite of ecologically meaningful and low-cost traits might help practitioners to apply functional TBR approaches even in resource-constrained settings. This entry point can help bridge science, policy, and local practice, paving the way for more resilient restoration outcomes across Africa's drylands.

Conclusion

Africa's drylands are central to global restoration targets, yet current approaches remain fragile, with low survival rates and uncertain ecological outcomes. Large-scale initiatives still prioritize planting numbers over the functional traits that underpin resilience in water-limited ecosystems. Although isolated East African studies show the value of TBR, these remain exceptions compared to more developed frameworks elsewhere. Integrating functional TBR into African restoration is both urgent and feasible. A step forward should focus on a small set of measurable traits, systematically incorporating IEK, and aligning policy with ecological resilience.

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LITERATURE CITED

Aronson J, Goodwin N, Orlando L, Eisenberg C, Cross AT (2020) A world of possibilities: six restoration strategies to support the United Nation's Decade on Ecosystem Restoration. Restoration Ecology 28:730–736. https://doi.org/10.1111/rec.13170

Asmelash F, Rannestad MM (2024) Challenges and a strategy for successful restoration of dry evergreen Afromontane forests of Ethiopia. Ecological Restoration 42:220–237. https://doi.org/10.3368/er.42.3.220

Balazs KR, Kramer AT, Munson SM, Talkington N, Still S, Butterfield BJ (2020) The right trait in the right place at the right time: matching traits to environment improves restoration outcomes. Ecological Applications 30:e02110. https://doi.org/10.1002/eap.2110

Ben-Enukora CA, Ejem AA (2024) Environmental responsiveness towards desertification and land degradation: A review of literature on restoration strategies in dryland communities in Africa. In: 2024 International Conference on Science, Engineering and Business for Driving Sustainable Development Goals (SEB4SDG). https://doi.org/10.1109/SEB4SDG60871.2024.10630402

Blumenthal DM, Mueller KE, Kray JA, Ocheltree TW, Augustine DJ, Wilcox KR (2020) Traits link drought resistance with herbivore defence and plant economics in semi-arid grasslands: the central roles of phenology and leaf dry matter content. Journal of Ecology 108:2336–2351. https://doi.org/10.1111/1365-2745.13454

Burrell AL, Evans JP, De Kauwe MG (2020) Anthropogenic climate change has driven over 5 million km2 of drylands towards desertification. Nature Communications 11:1. https://doi.org/10.1038/s41467-020-17710-7

Carlucci MB, Brancalion PHS, Rodrigues RR, Loyola R, Cianciaruso MV (2020) Functional traits and ecosystem services in ecological restoration. Restoration Ecology 28:1372–1383. https://doi.org/10.1111/rec.13279

Chapungu L, Zhanda K (2025) Soil-based dryland restoration practices in southern Africa: a systematic review. Pages 185–208. In: Khan YDI, Purohit S, Jibrin JM, Gholkar MD (eds) Land restoration through ecosystem-based approach. Springer Nature, Singapore. https://doi.org/10.1007/978-981-95-0389-6_10

Chomba S, Sinclair F, Savadogo P, Bourne M, Lohbeck M (2020) Opportunities and constraints for using farmer managed natural regeneration for land restoration in sub-Saharan Africa. Frontiers in Forests and Global Change 3: 571679. https://doi.org/10.3389/ffgc.2020.571679

Constant NL, Taylor PJ (2020) Restoring the forest revives our culture: ecosystem services and values for ecological restoration across the rural–urban nexus in South Africa. Forest Policy and Economics 118:102222. https://doi.org/10.1016/j.forpol.2020.102222

Costa-Saura JM, Martínez-Vilalta J, Trabucco A, Spano D, Mereu S (2016) Specific leaf area and hydraulic traits explain niche segregation along an aridity gradient in Mediterranean woody species. Perspectives in Plant Ecology, Evolution and Systematics 21:23–30. https://doi.org/10.1016/j.ppees.2016.05.001

del Campo AD, Segura-Orenga G, Ceacero CJ, González-Sanchis M, Molina AJ, Reyna S, Hermoso J (2020) Reforesting drylands under novel climates with extreme drought filters: the importance of trait-based species selection. Forest Ecology and Management 467:118156. https://doi.org/10.1016/j.foreco.2020.118156

Djenontin I, Foli S, Zulu L (2018) Revisiting the factors shaping outcomes for forest and landscape restoration in sub-Saharan Africa: a way forward for policy, practice and research. Sustainability 10:906. https://doi.org/10.3390/su10040906

Dwyer JM, Hobbs RJ, Mayfield MM (2014) Specific leaf area responses to environmental gradients through space and time. Ecology 95:399–410. https://doi.org/10.1890/13-0412.1

Eviner VT, Hawkes CV (2008) Embracing variability in the application of plant–-soil interactions to the restoration of communities and ecosystems. Restoration Ecology 16:713–729. https://doi.org/10.1111/j.1526-100X.2008.00482.x

Fremout T, Gutiérrez-Miranda CE, Briers S, Marcelo-Peña JL, Cueva-Ortiz E, Linares-Palomino R, et al. (2021) The value of local ecological knowledge to guide tree species selection in tropical dry forest restoration. Restoration Ecology 29:e13347. https://doi.org/10.1111/rec.13347

Gebirehiwot HT (2023) Review on factors affecting early survival of tree /shrub seedlings and its remedy in restoration sites of Ethiopia. Journal of Landscape Ecology 16:128–148. https://doi.org/10.2478/jlecol-2023-0007

Giannini TC, Giulietti AM, Harley RM, Viana PL, Jaffe R, Alves R, et al. (2017) Selecting plant species for practical restoration of degraded lands using a multiple-trait approach. Austral Ecology 42:510–521. https://doi.org/10.1111/aec.12470

Hepworth C, Doheny-Adams T, Hunt L, Cameron DD, Gray JE (2015) Manipulating stomatal density enhances drought tolerance without deleterious effect on nutrient uptake. New Phytologist 208:336–341. https://doi.org/10.1111/nph.13598

Hodgson JG, Wilson PJ, Hunt R, Grime JP, Thompson K (1999) Allocating C-S-R plant functional types: a soft approach to a hard problem. Oikos 85:282. https://doi.org/10.2307/3546494

Hortal J, De Bello F, Diniz-Filho JAF, Lewinsohn TM, Lobo JM, Ladle RJ (2015) Seven shortfalls that beset large-scale knowledge of biodiversity. Annual Review of Ecology, Evolution, and Systematics 46:523–549. https://doi.org/10.1146/annurev-ecolsys-112414-054400

Karlsson S, Srebotnjak T, Gonzales P (2007) Understanding the north–south knowledge divide and its implications for policy: a quantitative analysis of the generation of scientific knowledge in the environmental sciences. Environmental Science & Policy 10:668–684. https://doi.org/10.1016/j.envsci.2007.04.001

Kattge J, Bönisch G, Díaz S, Lavorel S, Prentice IC, Leadley P, et al. (2020) TRY plant trait database – enhanced coverage and open access. Global Change Biology 26:119–188. https://doi.org/10.1111/gcb.14904

Laughlin DC (2014) Applying trait-based models to achieve functional targets for theory-driven ecological restoration. Ecology Letters 17:771–784. https://doi.org/10.1111/ele.12288

Laughlin DC, Strahan RT, Huffman DW, Sánchez Meador AJ (2017) Using trait-based ecology to restore resilient ecosystems: historical conditions and the future of montane forests in western North America. Restoration Ecology 25:S135–S146.

Lawson T, Simkin AJ, Kelly G, Granot D (2014) Mesophyll photosynthesis and guard cell metabolism impacts on stomatal behaviour. New Phytologist 203:1064–1081. https://doi.org/10.1111/nph.12945

Lohbeck M, Winowiecki L, Aynekulu E, Okia C, Vågen T (2018) Trait-based approaches for guiding the restoration of degraded agricultural landscapes in East Africa. Journal of Applied Ecology 55:59–68. https://doi.org/10.1111/1365-2664.13017

Loureiro N, Mantuano D, Manhães A, Sansevero J (2023) Use of the trait-based approach in ecological restoration studies: a global review. Trees 37:1287–1297. https://doi.org/10.1007/s00468-023-02439-9

Martínez-Valderrama J, Guirado E, Maestre FT (2023) Drylands. Opportunities, challenges and threats. Metode Science Studies Journal 13:6–7.

Mens LP, Bargués-Tobella A, Sterck F, Vågen T, Winowiecki LA, Lohbeck M (2023) Towards effectively restoring agricultural landscapes in East African drylands: linking plant functional traits with soil hydrology. Journal of Applied Ecology 60:91–100. https://doi.org/10.1111/1365-2664.14311

Merchant TK, Henn JJ, De Silva I, Van Cleemput E, Suding KN (2023) Four reasons why functional traits are not being used in restoration practice. Restoration Ecology 31:e13788. https://doi.org/10.1111/rec.13788

Mills AJ, Duker R, Lechmere-Oertel RG, Van Mazijk R, Potts AJ (2023) Science is the fuel required for lifting ecosystem restoration into the orbit of hundreds of millions of hectares. Frontiers in Conservation Science 4: 1283262. https://doi.org/10.3389/fcosc.2023.1283262

Obiero KO, Klemet-N'Guessan S, Migeni AZ, Achieng AO (2023) Bridging Indigenous and non-Indigenous knowledge systems and practices for sustainable management of aquatic resources from East to West Africa. Journal of Great Lakes Research 49:S128–S137. https://doi.org/10.1016/j.jglr.2022.12.001

Rayome D, DiManno N, Ostertag R, Cordell S, Fung B, Vizzone A, Pante P, Tate R (2019) Restoring Ecosystem Services Tool (REST): a program for selecting species for restoration projects using a functional-trait approach (No. PSW-GTR-262; p. PSW-GTR-262). U.S. Department of Agriculture, Forest Service, Pacific, Southwest Research Station, Albany, California. https://doi.org/10.2737/PSW-GTR-262

Sacande M, Berrahmouni N (2016) Community participation and ecological criteria for selecting species and restoring natural capital with native species in the Sahel. Restoration Ecology 24:479–488. https://doi.org/10.1111/rec.12337

Sacande M, Berrahmouni N, Hargreaves S (2015) Community participation at the heart of Africa's Great Green Wall restoration model 1.

Sacande M, Muir G (2022) Restoring Sahelian landscapes with people and plants: insights from large-scale interventions. Restoration Ecology 30:e13656. https://doi.org/10.1111/rec.13656

Sacande M, Muir G (2023) Restoring food systems with nutritious native plants: experiences from the African drylands. Food and Nutrition Bulletin 44: S58–S68. https://doi.org/10.1177/03795721231190779

Waltham NJ, Elliott M, Lee SY, Lovelock C, Duarte CM, Buelow C, et al. (2020) UN Decade on Ecosystem Restoration 2021–2030—what chance for success in restoring coastal ecosystems? Frontiers in Marine Science 7:71. https://doi.org/10.3389/fmars.2020.00071

Wassenaar TD, Henschel JR, Pfaffenthaler MM, Mutota EN, Seely MK, Pallett J (2013) Ensuring the future of the Namib's biodiversity: ecological restoration as a key management response to a mining boom. Journal of Arid Environments 93:126–135. https://doi.org/10.1016/j.jaridenv.2012.05.012

Wells HBM, Kirobi EH, Chen CL, Winowiecki LA, Vågen T, Ahmad MN, Stringer LC, Dougall AJ (2021) Equity in ecosystem restoration. Restoration Ecology 29:e13385. https://doi.org/10.1111/rec.13385

Wellstein C, Poschlod P, Gohlke A, Chelli S, Campetella G, Rosbakh S, Canullo R, Kreyling J, Jentsch A, Beierkuhnlein C (2017) Effects of extreme drought on specific leaf area of grassland species: a meta-analysis of experimental studies in temperate and sub-Mediterranean systems. Global Change Biology 23:2473–2481. https://doi.org/10.1111/gcb.13662

Werden LK, Alvarado JP, Zarges S, Calderón ME, Schilling EM, Gutiérrez LM, Powers JS (2018) Using soil amendments and plant functional traits to select native tropical dry forest species for the restoration of degraded Vertisols. Journal of Applied Ecology 55:1019–1028. https://doi.org/10.1111/1365-2664.12998

Wilson KA, Auerbach NA, Sam K, Magini AG, StL MA, Langhans SD, Budiharta S, Terzano D, Meijaard E (2016) Conservation research is not happening where it is most needed. PLoS Biology 14:e1002413. https://doi.org/10.1371/journal.pbio.1002413

Wilson PJ, Thompson K, Hodgson JG (1999) Specific leaf area and leaf dry matter content as alternative predictors of plant strategies. New Phytologist 143:155–162. https://doi.org/10.1046/j.1469-8137.1999.00427.x

Winter K, Holtum JAM, Smith JAC (2015) Crassulacean acid metabolism: a continuous or discrete trait? New Phytologist 208:73–78. https://doi.org/10.1111/nph.13446

Zomer RJ, Xu J, Trabucco A (2022) Version 3 of the global aridity index and potential evapotranspiration database. Scientific Data 9:409. https://doi.org/10.1038/s41597-022-01493-1

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