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Scaling models for Regreening Africa: enhancing agroecological integration through smallholders' assets and agency in Kenya

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Urgent action is needed to address climate change, land degradation, and biodiversity loss. The Regreening Africa project (2017–2023), recently recognized as a UN World Restoration Flagship, aimed to reverse land degradation over large areas of land for the triple benefit of people, biodiversity, and climate in eight African countries. Based on projections and early lessons learned, the project sought to identify sustainable scaling models to achieve its ambitious targets. The so-called "Asset-Based Community-driven Development (ABCD) in Regreening" project aimed to demonstrate the positive contribution of deliberate community engagement and co-design. The project introduced ABCD sessions to 30 purposively selected community groups in the Regreening intensification sites in western Kenya. ABCD combines a unique set of framings, methods, and processes that focus on people's assets and agency, and emphasizes the importance of their attitudes toward self and others for sustainable behavior change. To evidence that ABCD *intrinsically* contributes to sustainable adoption and scaling of Regreening practices, the project developed the F-ACT+ tool to assess the alignment between ABCD and agroecological practices, and collected baseline and endline data from 300 project and 300 non-project participants. Results showed accelerated agroecological integration among ABCD project participants. ABCD participants showed significant improvements in nine agroecological principles and eight system components, particularly in the economic diversification, social values and diets, and knowledge co-creation principles, as well as in the pest and disease, household, and value chain system components. Summary ATT between ABCD and non-ABCD respondents was positive and significant in 10 principles and eight system components. The results support the synergistic contribution of ABCD to projects targeting sustainable behavior change at the individual and collective levels. Due to its focus on outcomes, this study provided limited insight into the specific mechanisms of ABCD, which are the subject of a separate publication on parallel theory-based contribution analysis work.

KEYWORDS

Regreening Africa, agroecology, agency, land restoration, asset-based community development, ABCD, sustainable scaling

1 Introduction

With six of the nine planetary boundaries being crossed (Richardson et al., 2023), urgent action is needed to combat climate change, land degradation, and biodiversity loss, and to address food and nutrition security in an inclusive and equitable manner. One such large-scale restoration project is the Regreening Africa project. Recognized as a UN World Restoration Flagship in February 2024, the project was implemented in eight African countries, including Senegal, Mali, Niger, and Ghana in West Africa, and Rwanda, Kenya, Somalia, and Ethiopia in East Africa from 2017 to 2023, with funding from the European Union. The goal of the project was "to restore large areas of land for the triple benefit of people, biodiversity, and climate" (Bourne, 2024). In Kenya, the project aimed to reverse land degradation on 150,000 ha of farmland and to encourage 50,000 smallholder farmers to adopt sustainable restoration practices over 5 years. The project aimed to engage 20% of them through direct interventions (Regreening Africa, 2018).

Although the targets acknowledged the need for sustainable land restoration by land stewards, mobilizing 10,000 farmers for long-term behavior change was challenging, particularly because it required long-term behavior change (Regreening Africa, 2018). Regreening Africa's baseline study also identified barriers to successful land restoration at the local level, including biophysical, socio-economic, and behavioral factors. Key biophysical factors included land degradation, climate change, limited access to water, and limited access to high quality seeds and germplasm. Socio-economic barriers included inadequate markets and investment, limited policy enforcement, and insecure land tenure, while some of the behavioral factors included women's limited decision-making power, as well as negative perceptions about the role and impact of restoration, about trees competing with crops, and about time lags in financial returns from restoration (Hughes et al., 2020). Given these predictions and early experiences, Regreening Africa actively sought to identify sustainable scaling models that could support achieving the project targets in Kenya and could potentially be replicated in the other project sites. In response to this challenge, the CIFOR-ICRAF teams focusing on Regreening Africa, and Asset-Based Community-driven Development (ABCD) collaborated on the so-called "ABCD in Regreening" project. The project was implemented from 2021 to 2023 in Homa Bay County, which was one of the Regreening Africa intensification sites. The project and its primary objective join other efforts in agricultural research and policy in recent decades that seek to investigate the drivers of adoption decisions and behavior change (e.g., Arslan et al., 2022; Ewert et al., 2023; Knowler and Bradshaw, 2007; Nikiema et al., 2023; Pannell et al., 2006; Prokopy et al., 2008). Specifically, rather than looking at socio-economic or behavioral determinants, this study contributes to the body of work investigating the effects of intentional engagement, knowledge co-creation, and extension processes (e.g., Glover et al., 2019; Lukuyu et al., 2012; Wossen et al., 2017). In the context of this project, we further consider scaling in terms of engaging "more people over a wider geographical area, more quickly, more equitably, and more lastingly" (Gonsalves, 2000, p. iv).

ABCD builds on people's agency and capacity. The approach was first theorized and popularized by Kretzmann and McKnight (1993, 2005) at the Institute for Policy Research at Northwestern University in Illinois, USA, as a strategy for empowering marginalized groups and neighborhoods in the inner cities of the United States. They have continued to lead the global conversation on ABCD through the ABCD Institute, established at Northwestern University in 1995 and consolidated at DePaul University in Chicago in 2016(e.g., McKnight, 2014; McKnight and Block, 2012; McKnight, 2009; McKnight and Russell, 2018; McKnight and Russell, 2022). In the early 2000s, the Coady Institute at St. Francis Xavier University in Antigonish, Nova Scotia, Canada, adapted ABCD to international development contexts (Cunningham et al., 2018; Ghore, 2015; Mathie et al., 2017; Mathie and Cunningham, 2003, 2008; Mathie and Peters, 2014; Peters et al., 2011; Peters and Eliasov, 2013), and it has been adopted by many institutions and actors around the world. ABCD draws on and aligns with numerous theoretical and conceptual sources, including the field of appreciative inquiry (Ashford and Patkar, 2001; Elliott, 1999), "positive deviance" (Tufts University, P. D. I, 2010), the sustainable livelihoods approach (DfID, 1999), the theory and practice associated with community economic development and endogenous development (Diochon, 1997), as well as the large body of participatory rural appraisal (PRA) and other self-mobilizing techniques (Chambers and Conway, 1991; Chambers, 1994) associated with participatory action research.

ABCD is not that new, but its innovation lies in providing a conceptual and operational framework for recognizing that communities have driven their own development since time immemorial, and that they have done so in the absence of usually well-meaning external actors. Its second major innovative aspect lies in its ability to frame and guide a structured co-creation process that fosters responsive external action. ABCD falls within the broader spectrum of community-driven development approaches that have received increasing global attention since the 1990s, particularly in the context of the rise of the sustainable development paradigm as the international development leitmotif (Guyer and Richards, 1996; Okidi et al., 2008). Drawing on Russell (2017), different perspectives and approaches to community development have been proposed (Table 1).

While there is important internal ontological coherence and conceptual congruence, ABCD is operationalized in different ways by individuals and groups around the world.[1] ABCD is sometimes facilitated by external actors, or adopted by organic collectives, networks, and groups to structure their own collective action. In line with the diversity of voices in the ABCD space, there have been considerable differences between the specific ABCD practices and related research approaches implemented by the CIFOR-ICRAF ABCD team over the past decade, despite drawing on the same sources and tools (Fuchs, 2018; Fuchs et al., 2019a,b, 2020, 2021a,b, 2022). Typically, we have used ABCD to initiate and structure engagement with communities to foster the co-design of specific socio-technical support modules, which we implemented *in response* to the

1 Some of the very active ABCD networks include ABCD Institute institutional partners around the world, including Nurture Development led by Cormac Russel, the ABCD Institute's lead partner in Europe (https://www.nurturedevelopment.org/); the Bank of IDEAS, the lead partner in Australia (http://bankofideas.com.au/); the Jeder Institute (https://www.jeder.com.au) also in Australia; and the Tamarack Institute (https://www.tamarackcommunity.ca/) in Canada. The global ABCD community also organizes under the label of 'ABCD in Action' (https://abcdinaction.org/), and is strongly represented in the International Association for Community Development (https://www.iacdglobal.org/) and its journal *Practice Insights*.

TABLE 1 Different perspectives and approaches in community development.

	Type 1	Type 2	Type 3	Type 4
Type of approach	Deficit model; medical model	Charity model	Social model; Coproduction; Externally facilitated ABCD	Fully community-driven ABCD
Localization of power and agency	Top-down	Top-down	Top-down + Bottom-up	Bottom-up
The role of the people	Everything is done *to* and *without* the people	Everything is done *for* and *without* the people	Everything done is *for* and *with* the people	Everything done is *for* and *by* the people

Source: Adapted from Russell (2017).

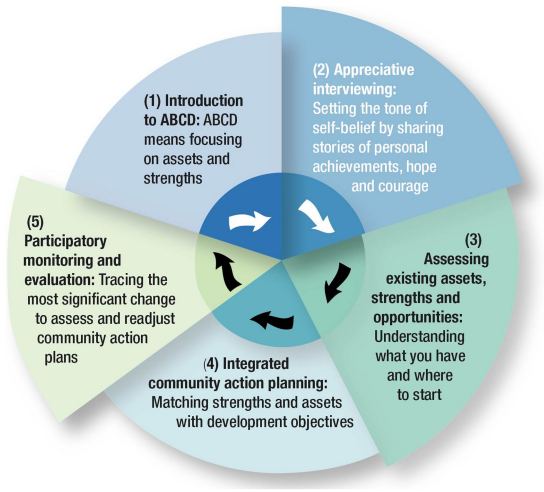

FIGURE 1
The five steps of the "ABCD practice wheel" used in "ABCD in Regreening" project. Source: adapted from Fuchs et al. (2020, pp. 35–36).

TABLE 2 The five general contribution claims for ABCD.

Category	Label	Summary description
Attitudinal changes	Asset mindset	People realize and appreciate what they have
	Sense of agency	People believe in their ability to influence their lives positively
Behavioral changes	Individual action	People decide to start with what they have and use it better, and in a more coordinated way, at an individual level
	Collective action	People come together and start with what they have collectively within their social networks to achieve joint objectives
	Strategic collaborations	People use their social networks to find solutions through strategic collaborations and partnerships with external actors

Source: Authors.

asset-based and agency-focused community action plans developed through the ABCD process. Unlike in other projects where ABCD was embedded in this broader research-in-development process, the "ABCD in Regreening" project explicitly focused on the *intrinsic* contribution that ABCD can make to supporting sustainable scaling. In terms of specific practice, the "ABCD in Regreening" project adopted a condensed and highly integrated "pure" ABCD process[2] that included 5 main steps (see Figure 1). Through these five steps, participants are encouraged to first focus on opportunities, the "glass half full," to be able to face challenges (Step 1); share stories of success to generate a sense of pride and hope (Step 2), discover, assess, and value what they already have (Step 3); link what they have with their objectives to mobilize their assets for concrete action (Step 4); and engage in regular self-reflection and self-evaluation to strengthen their resolve and adapt their personal and community action plans (Step 5).

ABCD, as an approach, is content-neutral and does not explicitly promote specific farming practices or livelihood options. In line with this general applicability, the first objective of the "ABCD in Regreening" project was to demonstrate that "adding" an ABCD module to the Regreening Africa project in Kenya would contribute *intrinsically* to strengthening the targeted farmers' adoption and sustainable engagement in "Regreening practices." Expected effects include both general and specific intrinsic effects. Based on extensive previous action research, the three underlying ABCD principles, and the five steps of the ABCD practice wheel, we developed five *general* intrinsic contribution claims for ABCD (Table 2; Supplementary Table S1 for additional information). In addition, the

2 After identifying two core opportunities for responsive support, we carried out two technical support trainings. In the first, a subset of ABCD group members (details of group selection and sampling are presented in Section 2.2 of the paper) were invited to participate in a training in agroecological soil, water, and integrated pest management techniques that held on a Regreening Africa lead-farmer's farm and that brought together experts from research, extension, NGOs and the government in a co-learning process. The second was in small-scale business tools and record keeping, drawing on specific participatory value chain analysis and business tools used in other ABCD projects (Fuchs et al., 2019a,b).

specific intrinsic effects of implementing ABCD in the context of Regreening Africa include empowered ABCD participants seeking strategic collaboration opportunities with the Regreening Africa project and engaging with the local Regreening model farmers for co-learning and collective action. To provide robust evidence on the specific processes, sequencing, and mechanisms, the ABCD team developed a detailed theory-based contribution analysis framework, and an associated mixed-methods research design, which are published together with the results in Fuchs et al. (2024).

In the context of growing recognition of agroecology's potential role in addressing the key crises of our time (HLPE, 2019; IPCC, 2023), and a significant increase in scientific interest and investment in agroecology (Geck et al., 2023), our second objective was to more specifically evidence ABCD's role in sustainable scaling by contextualizing its conceptual and practical contribution to agroecology. This research interest was warranted given the overlap between the regenerative focus of Regreening practices, ABCD's intrinsic focus on resource efficiency, and its overarching focus on assets and agency rather than deficits and needs.

Agroecology is a polysemic concept with various definitions that incorporates ecological and social considerations in the pursuit of improved interactions among plants, animals, humans, and the environment, with a focus on a sustainable and equitable food system. Based on the historical principles of agroecology defined by Alteri (1995), and further inspired by Gliessman's (2015) five levels of agroecological transitions and others, FAO (2018) proposed a consolidated set of 10 elements of agroecology. These elements combine the five ecology-centered elements of efficiency, recycling, diversity, synergies, and resilience, with five more human-centered elements, namely responsible governance, circular and solidarity economy, human and social values, and culture and food traditions. Barrios et al. (2020) developed this framework by drawing on existing analyses that have advanced agroecology as a science, a practice, and a social movement (Alteri, 1995; Gliessman, 2015; Tittonell, 2014; Tomich et al., 2011; Wezel et al., 2014), as well as efforts to address global sustainability challenges (Springmann et al., 2018; Steffen et al., 2015). In 2019, the High-Level Panel of Experts on Food Security and Nutrition (HLPE), the science-policy interface of the UN Committee on World Food Security (CFS), proposed an alternative list of 13 agroecological principles (HLPE, 2019). The principles, whose essence is succinctly summarized in Sinclair et al. (2019), were derived from combining and reformulating principles from three main sources, namely CIDSE (Coopération Internationale pour le Développement et la Solidarité) (2018), FAO (2018), and Nicholls et al. (2016). With the objective to "produce a minimum, non-repetitive but comprehensive set of agroecological principles" (HLPE, 2019, p. 39), the 13 principles are organized around three operational principles, that the HLPE says underpin sustainable food systems (Table 3). While individual principles have been assigned to the operational principle to which they most clearly contribute, interlinkages between the categories have been recognized.

While ABCD is a content-neutral engagement "vehicle," its focus on assets and their efficient and sustainable use aligns with CFS HLPE (2019) principles 1 to 7, which fall under the operational principles of resource efficiency and resilience. At the same time, its focus on agency, which includes considerations related to empowerment, inclusion, and participation, pairs particularly well with considerations subsumed under the operational principle of social equity. There are numerous specific ways in which the ABCD principles and practice can be mapped onto the 13 principles (Supplementary Table S2). Beyond this conceptual congruence, ABCD fundamentally provides a way to *enact* principle 8 on co-creation of knowledge (and action) and to ensure principle 13 on participation (related to agency).

In this paper, we focus on the importance of process in international development in general, and in large-scale land restoration projects in particular. For Regreening Africa, the primary interest of this collaborative research project was to identify and test sustainable scaling models to address anticipated and experienced challenges in achieving the project's ambitious targets in its intensification sites in western Kenya. While we developed a realist contribution analysis research design based on an actor-centered theory of change to identify the specific mechanisms underlying the contribution of ABCD to the identified attitudinal and behavioral changes (details in Fuchs et al., 2024), this paper focuses on the key outcome targets of the "ABCD in Regreening" project. The primary research question was therefore whether the adoption of an asset-based and agency-focused engagement approach—with its emphasis on self-assessment, self-realization, self-actualization, and self-evaluation—made an *intrinsic* positive contribution to impact of Regreening Africa on livelihoods and landscapes. This paper also provides insights into the methodical process we followed to first "define what matters," and then develop a specific tool that allowed to "measure what matters," and finally to "produce evidence on what matters" in response to this question. The process and results are presented, and their implications are discussed in the following sections.

TABLE 3 The 13 HLPE agroecological principles and their nesting under operational principles.

Improve resource efficiency		Strengthen resilience				
Principle 1	Principle 2	Principle 3	Principle 4	Principle 5	Principle 6	Principle 7
Recycling	Input reduction	Soil health	Animal health	Biodiversity	Synergy	Economic diversification
Secure social equity						
Principle 8	Principle 9	Principle 10	Principle 11	Principle 12	Principle 13	
Co-creation of knowledge	Social values and diets	Fairness	Connectivity	Land and NR governance	Participation	

Source: HLPE (2019).

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2 Methodology

2.1 Study location and background

As mentioned, the ABCD in Regreening project was implemented in the context of the wider Regreening Africa project, which aimed to restore large areas of land in eight African countries, including Senegal, Mali, Niger, and Ghana in West Africa, and Rwanda, Kenya, Somalia, and Ethiopia in East Africa from 2017 to 2023. The ABCD in Regreening project used a five-pronged ABCD approach to support sustainable individual and collective behavior change in support of the widespread adoption of and engagement in so-called Regreening practices. These include on-and off-farm practices that can be ranged under agroforestry, soil health, pasture management, household resource efficiency measures, alongside value chain development, and financial inclusion measures (see Table 4 for more details).

Therefore, this study was conducted in the Regreening Africa "intervention" site in Homa Bay County in the wider western region of Kenya. Homa Bay County, located between latitudes 0° 15'S and 0° 52'S and longitudes 34°E and 35°E (Figure 2), covers an area of 4,267 km^2 and comprises eight sub-counties (Regreening Africa, 2018).

As mentioned above, Regreening Africa aimed to directly engage with a total of 10,000 households, 3,500 of which were located in Homa Bay County. Through an in-depth inventory and assessment effort, Regreening Africa identified intervention and comparison sub-locations, which were also referred to as intensification and scale-out sites, respectively. Regreening Africa engaged households in both intensification and scale-out sub-locations, albeit at different points in the project implementation cycle, and with different activities (Regreening Africa, 2018).

2.2 Sampling framework

The overall targeting approach of "ABCD in Regreening" built on Regreening Africa's territorial intervention logic, which structured both the selection of ABCD project participants and the sampling of survey respondents. The study relied on Regreening Africa's distinction between so-called "intensification" and "scale-out" sub-locations in the Suba North and Suba South sub-counties.

TABLE 4 The nine key "Regreening practices" implemented in Kenya and their inductive categorization.

Category	Regreening practice
Agroforestry	(1) FMNR
	(2) Fruit tree farming
	(3) On-farm integration of indigenous trees
	(4) Enrichment planting
Soil health	(5) Soil and water conservation
Pasture management	(6) Reseeding with adaptable grass species
Household resource efficiency	(7) Energy saving options
Value chains	(8) Value chain development
Financial inclusion	(9) Financial inclusion

Source: Authors drawing on Odhiambo (2020).

We used a multi-stage sampling design. First, we defined three clusters within the two sub-counties, namely Lambwe, Ruma-Kaksingri East, and Kaksingri West (Figure 2). Each cluster contained several sub-locations, which were defined as so-called cluster cells. Second, based on Regreening Africa's sampling, we randomly designated one Regreening "intensification" sub-locations as an ABCD cluster cell, and another Regreening "intensification" as a Pure Regreening cell within each cluster. The selection of both the ABCD and the Regreening cells among the intensification sub-locations was to ensure that all had been involved with Regreening Africa, while only those in ABCD cells would also be involved with the ABCD team. This would allow us to compare the treatment effects between those who had participated in the "ABCD in Regreening" project and those who did not. Third, we randomly designated one "scale-out" sub-location as a Comparison cell within each cluster. These had previously served as controls in Regreening Africa. In total, we designated three ABCD cells, three pure Regreening cells, and three Comparison cells, one in each of the three clusters.

Following Fuchs et al. (2021b), we identified 30 ABCD groups from within the ABCD cells using a structured and purposive selection process. The approach allows identifying community groups that are contextually suitable for projects implemented by external actors. The tool is structured around two attributes: a group wellbeing index (material assets), and a group capacity and agency index (social capital). Each index consists of seven indicators. We administered the tool through a questionnaire containing 14 questions, each of which was linked to a pre-set 5-point Likert-type items. The survey forms were distributed during community entry after introducing the proposed project during local *barazas* held by the respective local authorities. Registered local community groups within the selected sub-locations, including self-help, women, and youth were invited and mobilized to collect and complete the survey form. Submissions were made either directly or through the local authorities.

We received completed questionnaires from 163 community groups in the nine pre-identified cells. After reviewing all the submissions, we used statistical analysis to classify all complete and legitimate submissions in the different group types (Type 1 through Type 4). Following the purposive selection method, we then randomly selected groups falling into different group types within each individual cluster cell to identify the 30 ABCD groups, 10 from each cell. We used the same approach to identify 15 groups from the Regreening cells, and 15 from the Comparison cells. We aimed to keep the distribution of group types constant in each sample.[3] Finally, from the 60 groups, we identified 10 households per group within the respective cluster cells using stratified randomized sampling to arrive at a total sample size of 600 households.

3 To further investigate the hypothesis that emerged from previous research see (Fuchs et al., 2021a,b) that types 1 and 3 are more likely to perform well, we targeted an equal distribution of group types during ABCD group selection. However, ground-proofing of the recruited groups led to a slightly skewed distribution, and more type 3 groups (28%) than type 4 (25%), type 1 (23%), or type 2 groups (23%). Similarly, while we targeted a similar group type distribution within each sample, and ideally within each cluster, but ended up with considerable differences in group type composition between the samples as indicted in Table 10.

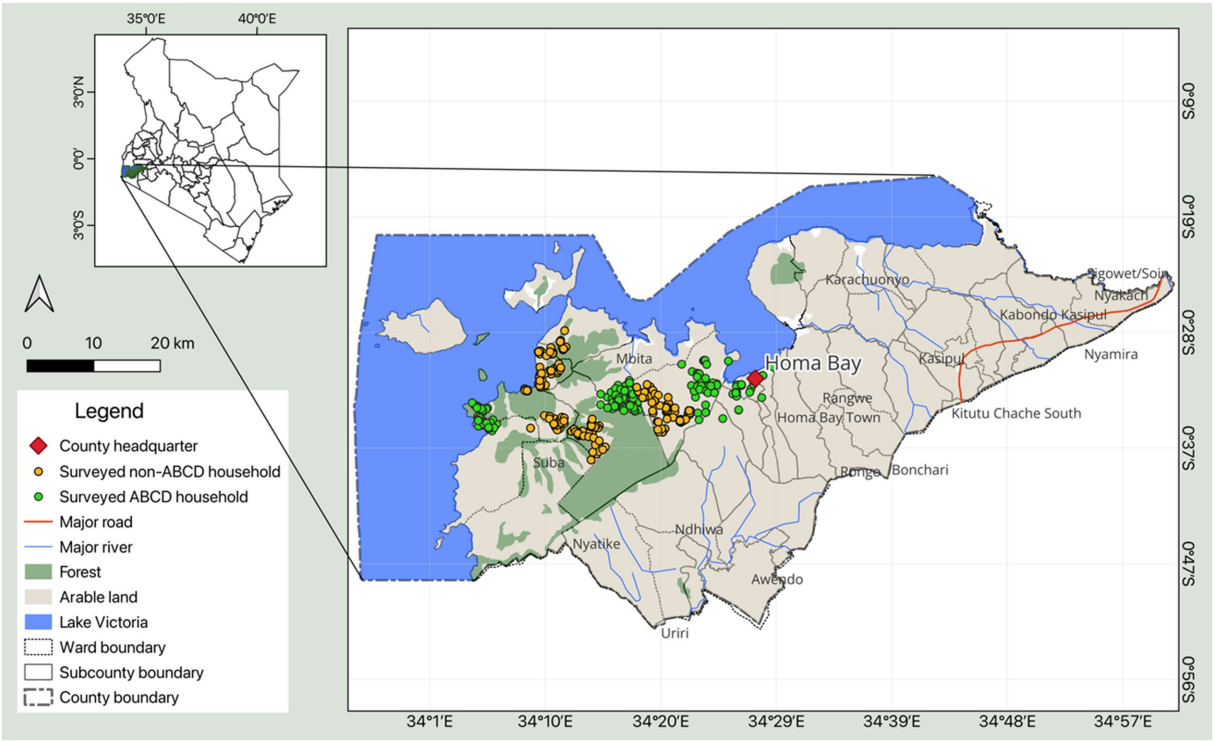

FIGURE 2
ABCD and non-ABCD households sampled in Homa Bay County in western Kenya. Source: Authors.

2.3 Data collection

We conducted baseline and endline surveys using a pre-tested questionnaire in Kobo Toolbox to capture demographic and farm system characteristics, as well as involvement with Regreening Africa. While we rolled out the "ABCD in Regreening" project to all members of the 30 ABCD groups, which included approximately 750 individuals, only 300 of them were included in the survey. The endline survey was conducted in September 2023 using the same questionnaire as the baseline, with 524 of the original 600 respondents re-interviewed. The attrition rate was 12.67%, and 48 outliers were omitted to ensure data accuracy. Of the final total sample of 476 respondents, 248 belonged to the ABCD sample, and 228 to the non-ABCD sample, with 67 being Regreening, and 161 being Comparison households.

2.4 Analytical framework

2.4.1 Introduction to the conceptual and empirical framework

As discussed, the investigation of the interaction of ABCD with agroecology was embedded in the broader ABCD contribution analysis (Fuchs et al., 2024). As part of the overall research design, and to ensure that the research approach and methods were indeed "measuring what matters" (Geck et al., 2023; Lamanna et al., 2024), we engaged in and documented an in-depth reflection process that interrogated and confirmed the overall research framing and ontology, the conceptual congruence between core project and analysis activities and objectives, and the specific and comprehensive research design. Since the main objective of the "ABCD in Regreening" project was to support the outcomes of the Regreening Africa project, we first analyzed the nature and assessment methods associated with Regreening Africa, as well as the assessment methods associated with agroecology, and then looked at the overlaps between Regreening and agroecological practices, as well as between Regreening, agroecology, and ABCD altogether.

We adopted this methodical and stepwise approach to analyzing the three core concepts and assessment frameworks to first ensure that an agroecological framing would be applicable to the goals of the Regreening Africa project that the "ABCD in Regreening" project aimed to strengthen. Consequently, the first aim was to clearly "define what matters." In addition, this approach aimed to lead to the adoption of a relevant assessment framework that would allow us to assess the targeted behavioral changes among the "ABCD in Regreening" project participants in a relevant manner. The second aim hence was to develop an assessment tool that would allow us to "measure what matters," and the third was to develop an empirical framework for data analysis to "produce evidence on what matters."

2.4.2 Defining what matters: what are Regreening and agroecology practices and how are they assessed?

As a first step, we examined how Regreening practices were defined and assessed. Based on the Regreening Africa country implementation plan for Kenya (Regreening Africa, 2018), Regreening Africa combined biophysical and socio-economic assessments to develop combinations of restoration options that deemed appropriate at the respective local level.

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TABLE 5 Focus on the F-ACT criteria for which the strongest positive effect is projected.

System component	Agroecological principle	Question	Consideration (ABCD promotes)
Household	Economic diversification (7)	Does your farm activity provide you with sufficient income to meet your goals and invest in further development?	Households are encouraged to use existing skills and assets more efficiently in various income-generating activities; and intrinsically focuses on diversification.
	Co-creation of knowledge (8)	Do you keep farm records?	Self-assessment, self realization, self-actualization, and self-evaluation—including by promoting on-farm record keeping with Commodity and Integrated Household Leaky Bucket.
	Fairness (10)	Do men and women have equal power in decision making processes relating to farm management?	Intra-household relationship improvement in line with "everyone has gifts" and "start with what you have" principles, as well as the Integrated Household Leaky Bucket.
Community	Economic diversification (7)	Are you a member of any farmers' organizations for collective sales of produce?	People value each other, identify joint interests, and act collectively; farmer organizations, including cooperatives, are core to these undertakings
	Co-creation of knowledge (8)	Are you involved in any platforms for knowledge sharing or co-creation?	Mutual respect and recognition in line with the "relationships build community" principle and social capital and network assessment, which foster planning for collective action and strategic collaborations.
	Participation (13)	How much do you participate in collective farming activities or landscape management?	Core principles focus on relationship building, strategic partnerships, and the development of joint visions for collective action for the individual and communal good.

Source: Authors.

Koech et al. (2020) note that "[p]roject learning and evidence have helped refine and diversify the recommended options, including FMNR and enrichment planting with multipurpose timber and non-timber trees; soil and water conservation with agroforestry trees and grasses (contour bunding, sand dune stabilization, halfmoon catchments and zaï pits); exclosures; *in-situ* grafting and direct sowing; and fire management" (p. 4). The Regreening Africa Baseline Report provided additional qualitative research results on the identification and prioritization of tree-based value chains, particularly timber and fuelwood. Three value chains were prioritized for Kenya based on a gender-differentiated preference assessment combined with other considerations such as income generation potential, as well as market access and demand: Honey, mango and pawpaw. Key challenges for these value chains were identified as being (a) limited access to quality germplasm (mango and pawpaw), (b) inadequate harvesting and post-harvest handling skills, (c) equipment, and (d) financial management skills (Hughes et al., 2020).

While the restoration options presented focused primarily on land-based practices, the Regreening Africa team also included broader socio-economic enhancement practices as well. These include further development of the selected value chains, as well as a focus on energy saving options and financial inclusion. According to a presentation given by World Vision Kenya in November 2020 (Odhiambo, 2020), the key Regreening practices implemented in the direct intervention sites in Kenya included both on-farm and/or environmental, as well as on off-farm concerns (Table 4).

Although the Regreening team initially developed a household adoption survey to monitor its two key performance indicators, the Regreening team soon focused more specifically on its Regreening Africa Index (RAI), a multi-dimensional index that combines an analysis of the extent, intensity, and diversity of practices with intra-household equity. The RAI is modeled on the Agroforestry Adoption Index, whose measurement approach is similar to that underlying the Multidimensional Poverty Index (MPI) and the Women's Empowerment in Agriculture Index (WEAI; Hughes et al., 2020).

In the second step, we specifically examined ways to assess agroecology and compared existing frameworks for their suitability to our context. Using similar information sources, Geck et al. (2023) recently inventoried 11 assessment frameworks and methodologies, which were developed by different actors, based on different conceptual frameworks, and differed in their focus in terms of scale.

In a third step, we used Biovision's ACT tool (Biovision Foundation, n.d.) to explore an initial congruence between Regreening Africa and agroecology. Based on the FAO 10 Elements and Gliessman's five levels, ACT assesses how agroecological a given

project, policy or initiative is; and/or the extent to which these projects are likely to deepen the level of agroecological integration of targeted households, communities, or landscapes. In order to analyze the Regreening practices implemented in the intensification sites of the Regreening Africa project in Kenya, we used the nine key Regreening practices introduced in Table 4 as a basis for evaluation, rather than conducting a more in-depth secondary data analysis and/or collecting primary data. To address the indicators ranged under the food system-focused elements, we also considered additional complementary information on Regreening communication channels and implementation processes [also presented in Odhiambo (2020)]. The results of this initial rapid assessment showed a positive engagement between Regreening practices and almost all of the agroecosystem-focused elements, especially in recycling (83%) and synergies (75%), but also efficiency (57%), diversity (56%), and regulation and balance (50%). Looking at the food system-focused elements, the results for only two exceeded the 50% mark, namely human and social values (67%) and culture and food traditions (50%). Responsible governance, on the other hand, registered no engagement. Despite methodological shortcomings, such as the use of the summary presentation given by the lead project manager rather than on the project proposal and document as a data source, and despite noting several critical observations about the tool itself,[4] we interpreted the positive summary performance score[5] of 49% as sufficient grounds to confirm beyond reasonable doubt the relevance of agroecology concepts to the activities and outcomes of the Regreening Africa project.

2.4.3 Measuring what matters: developing an agroecology-based tool to assess the "ABCD in Regreening" contribution to Regreening Africa objectives

While the main project purpose of the ABCD in Regreening project was based on the objectives of the Regreening project and was defined as "improved adoption of context-specific sustainable and agroecological land restoration options," after confirming sufficient conceptual overlap between Regreening and agroecology, we explored the benefits of using the F-ACT tool to actually monitor changes among project participants. F-ACT is an adaptation of the ACT tool that uses the HLPE principles as conceptual basis, captures behavioral changes at the farm-and household level, and focuses on collecting data on respondents' actual knowledge and practices within their farms and households. We specifically analyzed the suitability of F-ACT to ensure that it can actually measure what matters. According to the developers, the purpose of the tool was to "to assess the agroecological status of a farm in order to highlight how a farmer could further develop their farm" (Biovision Foundation, 2020).

The F-ACT tool consists of a questionnaire with several questions for each of the 13 principles, with pre-set answers corresponding to a 4-level Likert scale. The tool includes 58 criteria or indicators. Analytically, F-ACT proposes aggregated data outputs and interpretations at two levels (on a scale from zero to three). First, the "Agroecology Principle Indicators" overview shows the level of engagement of a respondent with the 13 individual agroecology principles. Second, the so-called "Agroecosystem Component Indicators" overview, which calculates the depth of agroecological integration in the different identified system components. The latter are divided into nine on-farm and three off-farm agroecosystem components. According to the authors, the bar graphs illustrating the data from these two levels, together with the contextualization questions on goals and challenges, are intended to inspire respondents to foster practical action planning. Mathematically, both aggregate indicators can be defined for the F-ACT tool as:

$$Score_{ijt}^{FACT} = N^{-1}\sum_{i=1}^{13}\sum_{j=1}^{n_i} S_{ijt} \quad (1)$$

where S_{ijt} is the household's score for question j in outcome category (agroecological principle or system component) i at time t, n_i is the number of questions gauging performance in outcome category i.

To assess compatibility, we first reviewed all 58 criteria and mapped the expected *intrinsic* effects of taking an ABCD approach on a 3-point Likert scale to confirm a basic match between the expected project outcomes and the outcomes captured by F-ACT. At the same time, we also looked for criteria that might not be applicable in the Kenyan context and identified five that could be excluded from the analysis.[6] We projected that 46 (79%) of the 58 criteria were likely to

4 Some negative aspects include the lacking clarity about the boundaries of some criteria leading to overlaps; grossly simplified answer options (yes/no; no levelling of answers); absence of information translated in the absence of positive observations (does not allow to discount indicators that might not be relevant in a given context); amalgamation of household and system level observations; deliberate interpretation of observed situations or behaviour as project effects equals farmers' practice and wider systemic changes being treated as a black box with little history and agency; considers project's intention/mission rather than actual implementation (and if so, by whom, how many, which surface area?).

5 The summary score is not included in the original tool, but was developed by us for the F-ACT tool later. The summary score is a simple average score of all individual Element percentages.

6 Despite the F-ACT tool having been developed and tested in Kenya, some questions and pre-set answer options are hardly pertinent in the Kenyan context. These include: (1) Since most of the regular electricity in the grid is renewable (geothermal, water), the focus on 'switching' to renewable energy sources is not necessarily pertinent in terms of an environmental sustainability argument. Although some value solar for self-sufficiency reasons, households might rather aspire to being connected to the grid than deliberately avoiding the grid to focus on self-produced renewable energy alone. (2) The negative evaluation of zero-grazing in relation to animal health is not contextually pertinent. Zero-grazing is often preferred option to allow for mixed farming and is rendered animal-friendly and sustainable through cut-and-carry etc. (3) Organic markets are not well developed in Kenya, especially in rural areas. Farmers aspiring to target organic markets is hence rather unlikely in our context. If they do, it is typically for export rather than to feed the local economy. (4) Farmers sell much of their non-cereal produce in local markets, and 'going local' is typically neither part of farmers' aspirations, nor progress towards agroecology, but rather a status quo. (5) While land tenure and ownership are fundamental, this is a rather static component that is not likely to change. It is hence disputable whether it should be captured in a tool geared towards monitoring changes observed over time.

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TABLE 6 Overview of ABCD-centered questions and related considerations to complement F-ACT tool.

System component	Agroecological principle	Question	Consideration (ABCD promotes)
Value chains	Co-creation of knowledge (8)	How do you access and share information about market prices?	Active identification of information channels for market prices and information sharing
	Social values & diets (9)	Do you consider the potential benefits of buyers who might buy your produce before choosing where to sell it?	Safeguarding of produce to improve selected people's access to nutritional foods.
	Fairness (10)	Are you able to access different markets of your choice in search of good prices?	Fair and equal access to markets and/or fair prices for own produce.
	Participation (13)	Do you actively work with other members of your farmer and/or informal producer group to improve your economic opportunities?	Participation in a farmer group and/or informal producer group to jointly identify and pursue opportunities in the local economy
Household	Social values & diets (9)	Who is responsible for the wellbeing and advancement of your household?	Positive self-valuation, self-efficacy, autonomy, and belief in own agency and capabilities.
	Participation (13)	Do you actively participate in a group savings and loaning group?	Membership and/or active participation in joint savings and loaning schemes.
Community	Social values & diets (9)	How well do you know, appreciate, and work with your neighbors, and how well do they know, appreciate, and work with you?	Enhanced sense of people's identities, interests and preferences (IIP).
	Participation (13)	Do you, individually or collectively with other members from your community group, collaborate with external actors (i.e., extension service, NGOs, government funding schemes etc.)?	Engagement in strategic collaboration with external actors from whom support can be leveraged.

While the first three additions under the "value chains" component easily suit their localization, the alignment of the other additional criteria with the existing framework is defendable, but less obvious. Source: Authors.

be positively influenced, of which 22 (38%) directly. In terms of principles, we projected the strongest effects (defined as the total percentage of direct positive effect predicted by the original F-ACT per principle or system component being equal to or greater than 50%; see in Table 7) in co-creation (100%), economic diversification (71%), connectivity (50%), and participation (50%), and for the trees (100%), as well as for the household (60%), community (57%), and value chain (50%) system components. Looking at individual criteria, we projected particularly strong effects in six criteria (Table 8).

In a second step, we considered whether the tool itself had gaps that could be addressed to avoid under-reporting of the expected effects of taking an ABCD approach. First, we found that the tool was clearly biased towards on-farm and resource efficiency and (technical) resilience strengthening. Despite proposing a few relevant criteria within the "lower right" where human-centered on-farm and off-farm system components meet with social equity principles (Table 7), explicit questions assessing social-cultural and socio-economic dynamics that contribute to deepening the level of agroecological integration remained rather few. In detail, we found that of the 58 proposed criteria, 44 criteria (76%) fell under the operational principles of resource efficiency and resilience, while only 14 (24%) fell under the operational principle of social equity; 47 criteria (81%) addressed on-farm system components, and only 11 (19%) addressed off-farm components; 37 criteria (64%) were allocated in the "upper left" section of the table and aligned with principles 1 to 6, and exclusively related to on-farm system components; 7 criteria (12%) fell under principle 7, the only principle that addressed both on-and off-farm system components; and 14 criteria (24%) fell within the "lower right" section of the Social equity operational principle, of which only 11 (19%) related to off-farm livelihood components.

In a third step, we adapted the F-ACT tool was to include additional criteria relevant to the Kenyan context, creating the F-ACT+ tool, which better captures the social and economic dynamics targeted by the ABCD approach Table 7. The F-ACT+ aggregate principle and system component scores can be defined as:

$$Score_{ijt}^{FACT+} = N^{-1}\sum_{i=1}^{13}\left(\sum_{j=1}^{n_i} S_{ijt} + \sum_{j=1}^{8} P_{ijt}\right) \quad (2)$$

TABLE 7 Projected areas that taking an ABCD approach is likely to influence within the F-ACT+ matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Soil (1)													
Water (2)													
Crops (3)													
Livestock (4)			*										
Trees (5)													
Pests (6)													
Energy (7)	°												
Household (8)												^	
Workers (9)													
Community (10)											‡		
Value chain (11)							†						
Policy (12)													

The 13 Principles of Agroecology are listed in the columns, and the 12 system components in the lines.
Green denotes a likely direct positive effect; yellow a likely indirect positive effect; blue likely no effect; dark green the projected strongest positive effect among original F-ACT criteria, and marron the new ABCD criteria with likely direct positive effects as well.
Symbols were placed in the criteria that are not applicable in the western Kenyan context: ° Switching to renewable energy. * Negative evaluation of zero-grazing. † Accessing organic markets. ‡ Targeting local markets. ^Land tenure change.
Source: Authors.

where P_{ijt} is a household score in an additional question deemed necessary to the original F-ACT tool after the adjustment.

In developing these additional criteria, we drew on prior work on empowerment and agency, including the project-level adaptation of the Women in Agriculture Index (pro-WEIA), and the distinction between intrinsic, instrumental, and collective agency (Malapit et al., 2019), which aligns neatly with our "sense of agency," "individual action," and "collective action" outcomes. Our indicators were also inspired by practical and context-specific insights from our more than 10 years of experience, and focus on assessing the crucial social-cultural and socio-economic dynamics targeted by ABCD, which were under-represented in the original F-ACT tool. Because of their clear alignment with agroecology, they can also be positioned as likely contributors to deepening agroecological integration (Table 6; the full details can be found in Supplementary Table S3).

Increasing the number of criteria by eight (see maroon additions Table 7) to 66 made it possible to balance the proportion of criteria located under the social equity operational principle from 24 to 33%. Looking at the sub-systems, the balance shifted from 19 to 29% of off-farm criteria. Based on this adjustment, we projected direct positive effects on 30 (45%) and indirect positive effects on 24 (36%) criteria, for a total positive effect on 54 (82%) of the captured criteria. In F-ACT+, we expected the strongest effects of the project in six principles and included co-creation (100%), participation (80%), economic diversification (71%), social values and diets (60%), fairness (50%), connectivity (50%). At the system component level, we expect the strongest effects in trees (100%), as well as value chain (83%), household (71%), and community (67%).

As mentioned above, we also eliminated five specific criteria that were not applicable in the western Kenyan context. This adaptation resulted in the F-ACT Minus 5 and F-ACT+ Minus 5 variants of the original F-ACT tool, and are defined as follows:

$$Score_{ijt}^{FACT\ Minus\,5} = N^{-1}\sum_{i=1}^{13}\left(\sum_{j=1}^{n_i} S_{ijt} - \sum_{j=1}^{5} M_{ijt}\right) \quad (3)$$

$$Score_{ijt}^{FACT+Minus\,5} = N^{-1}\sum_{i=1}^{13}\left(\sum_{j=1}^{n_i} S_{ijt} + \sum_{j=1}^{8} P_{ijt} - \sum_{j=1}^{5} M_{ijt}\right) \quad (4)$$

where M_{ijt} represent a household score in a question deemed irrelevant during the localization process.

Excluding the five inapplicable criteria, the percentage of expected positive change increased to 89%, including 49% for expected direct positive change. In the adapted version of the tool, the number of principles we predicted to be most positively affected increased to seven, and included governance (50%), with some values increasing. At the system component level, the number remained at four, with values increasing for the three off-farm components.

2.4.4 Producing evidence On what matters: empirical framework

To estimate the evolution of the ABCD group in terms of agroecological integration (1), system components (2), and overall agroecology performance (3) and hence the so-called average treatment effect on the treated (ATT), we used the doubly robust difference-in-differences (DRDID) estimator proposed by Sant'Anna and Zhao (2020). Rather than comparing the performance of different samples in absolute terms, the DRDID approach compares the degree of improvement within each sample to the degree of improvement in another sample. It thus provides relative comparisons that acknowledge differences in initial performance, and focus on the trajectories and trends rather than absolute values. The DRDID approach is attractive for a number of reasons. First, because our panel data have only two periods namely baseline (pre-treatment period, $t=0$) and endline (post-treatment period, $t=1$), it is impossible to "test" whether or not the parallel trends assumption

holds—an identification strategy for the ATT. In essence, this assumption requires that, in the absence of the treatment, both the ABCD and non-ABCD groups would have experienced a similar evolutionary trend (or simply, average variance over time). However, it is well known that conditional parallel trends can be recovered through the inclusion of the pre-treatment covariates (Abadie, 2005; Heckman et al., 1997). Second, the ATT from the DRDID is consistent provided that either the propensity score or the outcome model is correctly specified, but not necessarily both. Third, under panel settings, the DRDID is locally efficient for the semiparametric bound (Sant'Anna and Zhao, 2020). Finally, the approach is easy to implement, and its parametric nature evades the "curse of dimensionality."

Suppose our treatment assignment mechanism is given by a binary treatment variable D so that:

$$D_{it} = \begin{cases} 1, \textit{if a household } i \textit{ participates in ABCD program at time } t \\ 0, \textit{otherwise if a household } i \textit{ does not participate in ABCD program at time } t \end{cases} \tag{5}$$

Let Y_{ijt} be household i's score on outcome category j (which can be either agroecological integration, system components or overall agroecology performance) at time t, $\pi(X) = \Lambda(X'\varphi)$ to represent the true unknown propensity score model, and $m_{d,\Delta}$ be the true unknown outcome regression $m_{d,\Delta} \equiv m_{d1}(X) - m_{d0}(X) \equiv \mathbb{E}[Y_t | D = d, X = x]$. Following Sant'Anna and Zhao (2020) and Callaway and Sant'Anna (2021), the DRDID for panel data was estimable in three steps. In the initial step, we estimated the probability of participating in ABCD conditional on covariates using an inverse probability tilting (IPW) estimator proposed by Graham et al. (2012) as:

$$\hat{\varphi} = \underset{\varphi \in \Gamma}{\arg\max}\, \mathbb{E}_n\left[DX'\varphi - (1-D)\exp(X'\varphi) \right] \tag{6}$$

where $\mathbb{E}[\cdot]$ is the expectations operator, $\hat{\varphi}$ is the IPW estimate of the pseudo-true φ, Γ is the parameter space, and X is a set of pre-treatment covariates that are thought of influencing the probability of exposure to the ABCD treatment. A description of the covariates used in the IPW models is outlined in Table 6.

Next, we estimated an outcome regression by weighted least squares approach, where we imputed the potential outcome evolution for the ABCD group with a regression based only on the covariates of the control group (either non-ABCD, or its subsets: Comparison or Regreening) following Heckman et al. (1997):

$$\hat{\beta}_{0,\Delta} = \underset{\beta \in \Theta}{\arg\min}\, \mathbb{E}_n\left[\frac{\Lambda\left(X'\hat{\varphi}\right)}{1 - \Lambda\left(X'\hat{\varphi}\right)} \left((Y_1 - Y_0) - X'\beta \right)^2 \middle| D = 0 \right] \tag{7}$$

where $\hat{\beta}_{0,\Delta}$ is the weighted least squares estimator of the pseudo-true $\beta_{0,\Delta}$, Θ is the parameter space, $\Lambda(X'\varphi)$ follows a logistic specification for the nuisance function, hence $\frac{\exp(X'\varphi)}{1+\exp(X'\varphi)}$, Y_1 represents the outcome for a household in the treatment group at post-treatment period, and Y_0 is the outcome for the same household at the baseline period.

Finally, plugging φ and $\hat{\beta}_{0,\Delta}$ into the Equation 8, we obtained the ATT, ϑ, via the DRDID (Sant'Anna and Zhao, 2020) as:

$$\vartheta = \mathbb{E}\left[\left(\hat{r}_1(D) - \hat{r}_0\left(D, X; \hat{\varphi}\right) \right) \left(\Delta Y - m_{0,\Delta}\left(X; \hat{\beta}_{0,\Delta}\right) \right) \right] \tag{8}$$

where $\hat{r}_1(D) = \frac{D}{\mathbb{E}_n[D]}$, $\hat{r}_0(D,X,\varphi) = \left(\frac{\left[\frac{\pi(X;\varphi)(1-D)}{1-\pi(X;\varphi)} \right]}{\mathbb{E}_n\left[\frac{\pi(X;\varphi)(1-D)}{1-\pi(X;\varphi)} \right]} \right)$,

$\Delta Y = Y_1 - Y_0$, and $m_{0,\Delta}(X;\beta_{0,1}) \equiv m_{0,\Delta}(X'\beta_{0,\Delta})$.

Thus, the DRDID estimand becomes:

$$\vartheta = \mathbb{E}\left[\left(\frac{D}{\mathbb{E}_n[D]} - \left(\frac{\left[\frac{\pi(X;\varphi)(1-D)}{1-\pi(X;\varphi)} \right]}{\mathbb{E}_n\left[\frac{\pi(X;\varphi)(1-D)}{1-\pi(X;\varphi)} \right]} \right) \right) \left(\Delta Y - m_{0,\Delta}\left(X; \hat{\beta}_{0,\Delta}\right) \right) \right]$$

All analyses were performed in R (R Core Team, 2023) and Stata version 17.

3 Results

3.1 Descriptive statistics

The demographic and socio-economic characteristics (Table 8) of the ABCD and the non-ABCD samples were similar, but masked important within-sample differences between respondents from the different clusters, with land size, crop diversity, and the importance of farming being significantly higher in the Ruma Kaksigiri East cluster than in the others. Overall, however, the respondents had an average age of 44–45 years. Just over a quarter of the households were headed by men, with an average household size of about 7 people. The main income-generating activity of the respondents was farming. On average, a household was food self-sufficient for 6 months in a typical year. Notable differences include the size of land owned and farmed, both of which were significantly higher among non-ABCD households. One-third of the ABCD sample fell into Group Type 4 characterization, which was significantly higher than their proportion in the non-ABCD sample. While prior exposure to Regreening Africa was significantly higher among the ABCD sample, this was not as significant as expected.[7]

7 According to our sampling strategy that directly drew on Regreening Africa's sampling strategy, all ABCD households were sampled from Regreening 'intensification' sub-locations, and the Regreening households were also

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TABLE 8 Socio-demographic characteristics of ABCD and non-ABCD households.

Variable	Description	Pooled	ABCD (a)	Non-ABCD (b)	Test of difference (a)–(b)	
		Mean (SD)	Mean (SD)	Mean (SD)	Diff.	*t*-test
Continuous variables						
Age (years)	Age of the household head	44.590 (13.495)	43.968 (13.835)	45.268 (13.112)	−1.300	−1.052
Household size (count)	Number of individuals in the household	6.765 (2.780)	6.657 (3.070)	6.881 (2.428)	−0.224	−0.888
Land owned (acres)	Land owned by the household	0.942 (1.831)	0.536 (1.504)	1.382 (2.045)	−0.845	−5.103***
Land farmed (acres)	Land under agricultural activities	0.630 (1.221)	0.406 (1.151)	0.873 (1.252)	−0.466	−4.235***
Food sufficiency months (count)	Number of months in a typical year when the household has access to sufficient food	6.118 (3.152)	6.266 (3.287)	5.956 (2.997)	0.310	1.072
Categorical variables		Proportions				χ^2 test
Gender	Respondent is a male (%)	28.2 (45.0)	27.4 (44.7)	28.9 (45.5)	−1.5	−0.137
Prior exposure	A household member has ever been exposed to Regreening activities (%)	39.5 (48.9)	43.1 (49.6)	35.5 (48.0)	7.6	2.886*
Group-type§	Type 1: Group has high WB and high CA (%)	26.5	29.4	23.2	5.2	3.174
	Type 2: Group has high WB and low CA (%)	25.6	19.8	32.0	−12.2	−4.721
	Type 3: Group has low WB and high CA (%)	22.9	18.1	28.1	−10.0	−3.311
	Type 4: Group has low WB and low CA (%)	25.0	32.7	16.7	16.0	15.538***
Main income activity§	Farming (%)	73.3	66.5	80.7	−14.0	−1.034
	Business (%)	21.2	25.4	16.7	8.7	6.188*
	Salaried (%)	1.7	2.0	1.3	0.7	0.500
	Other (%)	3.8	6.0	1.3	4.7	8.000**
N		476	248	228		

*, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively. § denotes variables for which p values were adjusted by Bonferroni method. Values in parentheses are standard deviations. WB, Wellbeing; CA, Capacity and Agency. Source: Survey data (2023).

3.2 Degree of agroecological integration and system components scores

There were clear differences between baseline and endline performance in agroecological integration and components addressed in the overall sample (see Supplementary Figure S1). Comparing the results from the different tool variants, the principles, systems and overall agroecology scores of the F-ACT and F-ACT+ tools were higher than those of their variants from which five performance criteria were excluded. This trend was particularly evident in the baseline data. Across the sample, F-ACT+ scores were the highest at baseline and at endline, while F-ACT+ Minus 5 values overtook F-ACT values at endline. Although we had four variants of the F-ACT tool, we opted to use the F-ACT+ Minus 5 results for further data analysis because they are localized and therefore more representative of the local context (see detailed results for the other variations in the appendix of this paper).

Comparing the overall performance based on F-ACT+ Minus 5 for the ABCD and non-ABCD samples (Figure 3), it is apparent that the ABCD sample had considerably lower values at baseline, but

sampled from other Regreening 'intensification, sub-locations, while the Comparison households were sampled from Regreening 'scale-out' sub-locations. We hence expected prior exposure to Regreening to be twice as high among ABCD households.

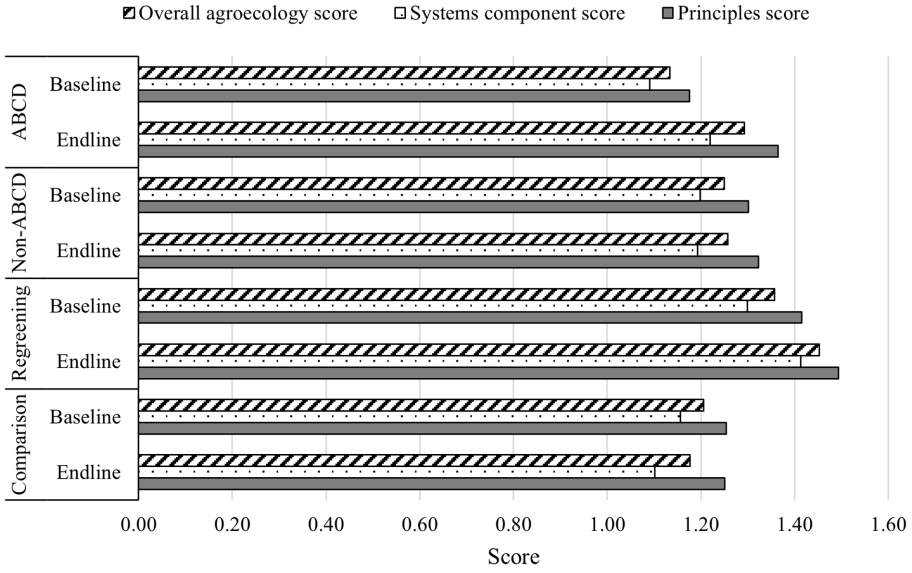

FIGURE 3
Summary performance of samples at baseline and endline based on F-ACT+ Minus 5. Source: Survey data (2023).

slightly higher values at endline. However, when looking at the non-ABCD sub-samples, namely the Regreening and the Comparison sub-samples, there is a strong difference at both baseline and endline, with Regreening continuing to progress further from previous considerably higher values, while Comparison values regressed slightly.

Considering the agroecology principles indicators scores using F-ACT+ Minus 5 (Table 9), the ABCD and non-ABCD samples followed similar overall trends. For both samples, the highest scores at baseline were for recycling (principle 1), input reduction (2), governance (12), (and input reduction, 2, for non-ABCD). At endline, the values for governance (12) and recycling (1) remained high, while social values and diets (9), as well as connectivity (11) improved considerably. However, there are clear differences between the samples. The ABCD sample showed improvements in 11 of the 13 principles, nine of which were significant, including six of the seven principles that fall under the operational principle of social equity, as well as input reduction (2), biodiversity (5), synergies (6), and economic diversification (7). The strongest improvement was observed in economic diversification (7), followed by social values and diets (9) and co-creation (8). A significant negative change was observed in input reduction (2). In the non-ABCD sample, improvements were recorded in only seven principles. Significant positive changes were observed in social values and diets (9) and connectivity (11), while significant negative trends were seen in recycling (1), input reduction (2), and fairness (10).

Looking at the scores for the agroecosystem component indicators using F-ACT+ Minus 5 (Table 9), the trends were similar in both samples as well. At baseline, the soil (1) system component was addressed most, followed by livestock (4), household (8), pest and disease (6), and community (10), while workers (9) and energy (7) were addressed least. At endline, soil (1), livestock (4), and household (8) continued to dominate, while there was considerable variance between the samples in other components. Again, baseline scores were higher for the non-ABCD sample than among the ABCD sample, except in the policy (12), value chain (11), and "other" (13) components. Looking at the difference in performance for the ABCD sample, there were significant positive changes in a nine of the 13 system components, including all three non-farm components (10–12) and the "other" (13) component, as well as significant negative trends in livestock (4) and workers (9). The strongest positive trends were in pest and disease (6), household (8), and value chain (11). In the non-ABCD sample, there were four significant positive changes in soil (1), pest and disease (6), policy (12), and value chain (11), while there were significant negative trends in four components, including livestock (4), trees (5), and workers (9).

3.3 Average treatment effect on the treated of the ABCD in Regreening project

Considering the treatment effect on the treated for the ABCD project using F-ACT+ Minus 5 (Table 10; details for the other tool variants are in Supplementary Table S4), the scores were significantly higher in the ABCD than in the non-ABCD sample for 10 of the 13 principles—that is all but animal health (4), social values (9) and connectivity (11). Comparing ABCD with the Regreening and Comparison samples, the difference between ABCD and Comparison was considerably greater than between ABCD and Regreening. Differences in ATT between ABCD and Regreening were more nuanced and significant in only six principles, namely input reduction (2), soil health (3), biodiversity (5), synergies (6) economic diversification (7), and co-creation of knowledge (8). At the same

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TABLE 9 Comparison of performance between ABCD and non-ABCD based on change in principle and component scores between baseline and endline according to F-ACT+ Minus 5 tool.

Principle	ABCD				Non-ABCD			
	Baseline	Endline	Test of difference		Baseline	Endline	Test of difference	
			Difference	*t*-test			Difference	*t*-test
Recycling (1)	1.887	1.833	−0.054	−1.401	1.926	1.808	−0.118	−2.801***
Input reduction (2)	1.476	1.406	−0.070	−1.795*	1.649	1.374	−0.275	−7.331***
Soil health (3)	0.950	1.134	0.184	4.020***	1.058	1.120	0.062	1.184
Animal health (4)	1.186	1.192	0.006	0.105	1.252	1.274	0.022	0.376
Biodiversity (5)	1.016	1.148	0.132	3.343***	1.194	1.167	−0.027	−0.673
Synergies (6)	0.742	0.979	0.237	4.779***	0.972	0.953	−0.019	−0.348
Economic diversification (7)	0.793	1.215	0.422	11.448***	1.050	1.099	0.049	1.173
Co-creation of knowledge (8)	0.874	1.276	0.402	7.451***	1.057	1.054	−0.003	−0.048
Social values and diets (9)	1.314	1.606	0.292	7.674***	1.359	1.635	0.276	6.039***
Fairness (10)	1.181	1.418	0.237	3.807***	1.405	1.203	−0.202	−3.078***
Connectivity (11)	1.232	1.587	0.355	3.052***	1.217	1.682	0.465	3.816***
Land and natural resource governance (12)	1.423	1.655	0.232	3.535***	1.550	1.542	−0.008	−0.115
Participation (13)	1.216	1.301	0.085	1.442	1.233	1.280	0.047	0.760
Component								
Soil (1)	1.862	1.981	0.119	3.254***	1.903	1.985	0.082	1.859*
Water (2)	0.907	1.004	0.097	2.528**	1.034	1.031	−0.003	−0.074
Crops (3)	1.110	1.071	−0.039	−0.843	1.250	1.177	−0.073	−1.460
Livestock (4)	1.455	1.291	−0.164	−2.546**	1.576	1.242	−0.334	−5.696***
Trees and woody species (5)	1.092	1.124	0.032	0.722	1.291	1.138	−0.153	−2.852***
Pest and disease (6)	1.248	1.560	0.312	8.847***	1.380	1.464	0.084	2.631***
Energy (7)	0.423	0.645	0.222	4.145***	0.654	0.667	0.013	0.219
Household (8)	1.325	1.654	0.329	7.652***	1.504	1.473	−0.031	−0.766
Workers (9)	0.601	0.460	−0.141	−1.727*	0.890	0.509	−0.381	−4.007***
Community (10)	1.224	1.426	0.202	4.137***	1.319	1.321	0.002	0.033
Value chain (11)	1.011	1.346	0.335	6.313***	0.931	1.340	0.409	6.869***
Policy (12)	1.226	1.419	0.193	2.327**	1.186	1.463	0.277	2.967***
Other (13)	0.700	0.880	0.180	3.256***	0.663	0.706	0.043	0.649
N	248				228			

*, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively. Source: Survey data (2023).

time, the improvement in governance was significantly (10%) higher in the Regreening sample. All the significant differences between the ABCD and non-ABCD samples were also evident between the ABCD and Comparison samples, except for biodiversity (5), while the Comparison sample had a significantly (10%) higher improvement in connectivity (11).

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TABLE 10 Comparison of estimates of the ATT on agroecology principles and system components from the DRDID estimator based on F-ACT+ Minus 5 tool variation.

Principle	ABCD vs. non-ABCD	ABCD vs. Comparison	ABCD vs. Regreening
	ATT (Std.Err.)	ATT (Std.Err.)	ATT (Std.Err.)
Recycling (1)	0.113* (0.059)	0.152** (0.060)	−0.052 (0.074)
Input reduction (2)	0.214*** (0.058)	0.188*** (0.058)	0.199* (0.104)
Soil health (3)	0.210** (0.082)	0.121 (0.081)	0.372*** (0.122)
Animal health (4)	0.055 (0.089)	−0.010 (0.091)	0.100 (0.148)
Biodiversity (5)	0.176*** (0.061)	0.108 (0.069)	0.250*** (0.079)
Synergies (6)	0.341*** (0.089)	0.247*** (0.078)	0.372** (0.159)
Economic diversification (7)	0.396*** (0.058)	0.393*** (0.059)	0.306*** (0.094)
Co-creation of knowledge (8)	0.375*** (0.076)	0.393*** (0.084)	0.366*** (0.137)
Social values and diets (9)	0.090 (0.067)	0.069 (0.074)	0.039 (0.103)
Fairness (10)	0.328*** (0.098)	0.351*** (0.116)	0.158 (0.156)
Connectivity (11)	−0.150 (0.183)	−0.367* (0.211)	−0.074 (0.343)
Land and natural resource governance (12)	0.270*** (0.097)	0.438*** (0.116)	−0.339* (0.172)
Participation (13)	0.174** (0.085)	0.257*** (0.089)	−0.164 (0.236)
Component			
Soil (1)	0.078 (0.054)	0.010 (0.063)	0.172* (0.099)
Water (2)	0.189*** (0.069)	0.097 (0.060)	0.279*** (0.086)
Crops (3)	0.074 (0.077)	0.037 (0.073)	0.060 (0.146)
Livestock (4)	0.203** (0.080)	0.336*** (0.090)	−0.126 (0.117)
Trees and woody species (5)	0.218*** (0.080)	0.186** (0.075)	0.146 (0.134)
Pest and disease (6)	0.247*** (0.054)	0.150*** (0.052)	0.339*** (0.077)
Energy (7)	0.173** (0.085)	0.127 (0.097)	0.332** (0.147)
Household (8)	0.370*** (0.057)	0.450*** (0.066)	0.128 (0.105)
Workers (9)	0.228 (0.143)	0.518*** (0.135)	−0.393 (0.331)
Community (10)	0.226*** (0.068)	0.352*** (0.075)	−0.035 (0.132)
Value chain (11)	−0.048 (0.100)	−0.226** (0.103)	0.090 (0.113)
Policy (12)	0.107 (0.137)	0.333** (0.153)	−0.758** (0.362)
Other (13)	0.199** (0.090)	0.281*** (0.099)	−0.150 (0.182)
N	476	409	315

*, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively. Values in parentheses are standard errors. Source: Survey data (2023).

Looking at the performance of the agroecosystem components (Table 10; and Supplementary Table S4), the ABCD sample had significantly higher improvements than the non-ABCD sample in eight of the 13 system components, including in water (2), livestock (4), trees (5), energy (7), pest and disease (6), household (8), community (10), as well as "other" (13).There was a much stronger difference between ABCD and Comparison than between ABCD and Regreening. Comparing ABCD and Regreening, the ATT was significantly stronger in the ABCD sample in soil (1), water (2), household (8), and pest and disease (6), while it was stronger in the Regreening sample in policy (12). Comparing ABCD and Comparison, the ABCD sample's ATT was significantly higher in all but the soil (1), water (2), crops (3), energy (7), and value chain (11) components, and hence eight of the 13 system components. Interestingly, the Comparison sample's ATT was significantly (5%) higher in the value chain component.

Applying the same estimation strategy to the summary principles, system components, and overall agroecology scores (Supplementary Table S5), the positive changes were significantly higher for the ABCD sample than for the non-ABCD sample (at the 1% level). The highly significant difference in the positive change for all three estimates between the ABCD and non-ABCD was also observed between ABCD and Comparison samples, but not as comprehensively between the ABCD and Regreening samples. Here, while the ATT was stronger for all three scores in the ABCD sample, it was only significant (at the 10% level) for the principles score in the F-ACT+ tool variant.

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TABLE 11 Comparison of DRDID estimates of the ATT for the eight ABCD and six core F-ACT criteria.

Criteria	System component	Agroecological principle	Subsample comparison		
			ABCD vs. non-ABCD	ABCD vs. Comparison	ABCD vs, Regreening
			ATT (Std.Err.)	ATT (Std.Err.)	ATT (Std.Err.)
ABCD "plus" criteria	Value chains	Co-creation (8): Access and sharing of market prices	0.184 (0.122)	0.294** (0.137)	0.005 (0.141)
		Social values & diets (9): Care for benefit of local buyers	0.360*** (0.114)	0.464*** (0.122)	−0.006 (0.152)
		Fairness (10): Fair access to markets	0.388*** (0.147)	0.359** (0.165)	0.418 (0.256)
		Participation (13): Producer group participation	−0.080 (0.116)	−0.105 (0.120)	−0.031 (0.206)
	Household	Social values & diets (9): Self-efficacy	0.009 (0.078)	0.054 (0.092)	−0.139 (0.095)
		Participation (13): Group saving and loaning	−0.025 (0.118)	0.020 (0.129)	−0.271* (0.144)
	Community	Social values & diets (9): Community respect and action	0.545*** (0.140)	0.628*** (0.151)	0.389 (0.258)
		Participation (13): Strategic collaboration	0.334*** (0.127)	0.644*** (0.128)	−0.536*** (0.203)
Core F-ACT criteria	Value chains	Economic diversification (7): Sufficient and diverse farm income	1.168*** (0.109)	1.352*** (0.120)	0.906*** (0.139)
		Co-creation (8): Farm records	0.813*** (0.111)	0.912*** (0.130)	0.633*** (0.179)
		Fairness (10): Equal decision-making men and women	0.149 (0.131)	0.338** (0.148)	−0.290 (0.196)
	Community	Economic diversification (7): Farmer group for joint sales membership	0.296*** (0.074)	0.348*** (0.083)	0.155 (0.160)
		Co-creation (8): Co-creation platform participation	0.118 (0.122)	0.230* (0.138)	0.064 (0.198)
		Participation (13): Collective farming or landscape management action	0.429*** (0.148)	0.747*** (0.163)	−0.147 (0.310)
N			476	409	315

*, **, and *** denote statistical significance at the 10, 5, and 1% levels, respectively. Values in parentheses are standard errors. Source: Survey data (2023).

Isolating the eight ABCD-focused "plus" criteria, as well as the six individual F-ACT criteria for which we predicted particularly strong effects (Table 11), the ATT is highly significantly stronger in the ABCD sample than in the non-ABCD sample for eight of the 14 criteria. These include care for local customers, fair access to markets, community respect and action, and strategic collaboration, as well as sufficient and diverse farm income, keeping of farm records, farmer group membership, and collective farming or landscape management action. Again, the difference between the ABCD and Comparison samples is more pronounced, with a significant positive ATT in 11 of the 14 criteria. In addition to the eight mentioned, the positive trend in access to and sharing of market prices, equal decision-making, and participation in co-creation platforms was also significantly higher in the ABCD sample. The effect is much more nuanced with the Regreening sample performing significantly better in two ABCD criteria (group saving and loaning; strategic collaboration), and the ABCD sample in two highlighted regular F-ACT criteria (sufficient and diverse farm income, farm record keeping).

Finally, the DRDID estimates of the performance of the different group types between the ABCD and the non-ABCD samples showed clear differences (Figure 4; more details in Supplementary Table S6), with groups falling under Type 1 performing slightly better than Type 3, and both outperforming groups of Type 2 and 4 by far. While the differences between Type 1 and 3 and between Type 2 and 4 were not significant, the differences between the former two and the latter two were significant at the 10% level.

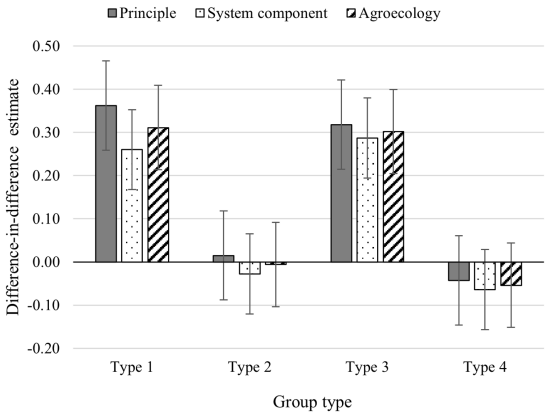

FIGURE 4
Difference-in-differences estimates in overall agroecological integration, system components, and agroecology scores by group type in the ABCD vs. non-ABCD samples using F-ACT+ Minus 5. Source: Survey data (2023).

4 Discussion

4.1 Key results confirm ABCD sample's accelerated agroecological integration

The results presented manifest accelerated agroecological integration among the ABCD participants. First, as expected, the ABCD sample improved significantly in nine of the 13 principles, including all principles nested under the social equity operational principle, as well as economic diversification (7), alongside biodiversity (5), synergies (6). The strongest improvements were observed in economic diversification (7), social values and diets (9) and co-creation (8), while the expected improvement in participation (13) was not as significant as expected, and a significant negative trend was observed in input reduction (2). Regarding the changes observed in the different system components, the expected positive effects were confirmed in value chain (11), household (8), and community (10), alongside highly significant changes in soil (1), water (2), pest and disease (6), policy (12), and "other" (13). At the same time, significant negative effects were observed for livestock (4) and workers (9). Of the nine significant positive trends, the strongest were in pest and disease (6), household (8), and value chain (11). These results were largely confirmed in the ATT analysis using the DRDID method, which directly compared the performance of the ABCD sample with that of the non-ABCD respondents. The ATT was significantly higher in the ABCD sample for 10 of the 13 principles, and in eight of the 13 system components. However, several principles that initially showed the greatest improvements did not have significant ATT scores, including in social values and diets (9) and connectivity (11). At the same time, they showed significantly higher improvements in recycling (1), input reduction (2), and participation (13) that were not reflected in the initial *t*-tests. Notable differences from the initial tests in the system components were significant positive ATT values in livestock (4) and biodiversity (5), while ATT values in soil (1), value chain (11), policy (12) were not significant. Looking specifically at the ABCD "plus" criteria, as well as the six highlighted individual "core" F-ACT criteria, the positive trends in the ABCD sample were significantly higher than among the non-ABCD sample in eight of the 14 specific criteria. Again, the difference with the Comparison sample was substantial, and significant in 11 criteria, while the difference with the Regreening sample was much more nuanced.

Consistent with our overall predictions, the improvements observed in the ABCD sample were generally significantly higher than those observed in the non-ABCD sample. Furthermore, there was a clear difference in performance between the ABCD sample and the Regreening sample, and an even clearer difference with the Comparison sample. This confirms our main hypothesis, although the significance varies depending on the group pairing. Looking more specifically at the performance of the different ABCD groups more specifically, as expected, the ABCD group types 1 and 3, characterized by high assets/ high agency, and by low assets/high agency, respectively, performed statistically significantly better than types 2 and 4. This is in line with the core argument made in Fuchs et al. (2021b) that a purposive participant selection process, which *ex ante* screens the suitability of for potential participants with regard to the specific project content in order to "establish a mutual match," can help" to eliminate procedural inefficiencies and considerably improve development effectiveness, efficiency, and sustainability.

4.2 How asset-based and agency-centered approaches and tools scale sustainable practice

While the detailed results of the contribution analysis are reported in Fuchs et al. (2024), two dominant underlying mechanisms that supported Regreening outcomes in our contexts can be highlighted. First, in line with the conceptual congruence between ABCD and agroecology, and the applicability of the agroecology framing for the promoted "Regreening practices," ABCD *intrinsically* supports agroecology through its focus on resource appreciation and peoples' self-mobilization to use their existing resources efficiently and sustainably. As discussed above, one of the key differences between ABCD and other approaches is that ABCD explicitly invites people to think about their own individual and collective contribution by starting with what they already have in terms of human, social, natural, economic, and other capital. On the other hand, while many other approaches engage people in conversations, visioning, and decision-making, they often do so without centering them and what *they* can do to make a positive contribution to their lives and landscapes. The second mechanism concerned ABCD project participants who, through the social asset assessment, gained a better understanding the identities, interests and preferences (IIP) of associations and institutions that are active in their community. This helped empowered and interested community members to seek targeted support from and strategic collaboration with existing external actors and their projects based on an alignment of their interests with IIPs of the respective external actors—in this case Regreening Africa. Similarly, the ABCD participants gained a better understanding of the IIP of other community members through the human asset assessment. This contributed to Regreening Africa lead-farmers being recognized and approached by other community members for exchange and learning opportunities. In turn, this community-driven demand helped Regreening Africa and its local lead-farmers to be more effective, efficient, and sustainable in their

Regreening capacity building, as this interaction was driven by the demand of empowered community members who differentiated between those change pathways that they could drive by themselves, and those that were pursued through targeted collaboration and external support.

Comparing the performance of the ABCD sample with that of the Regreening sample, the positive effect remained significant but nuanced. There are several possible explanations. One general observation relates to the fact that the Regreening sample started from a much higher level than the ABCD sample, whose baseline scores were even considerably lower than the ones of the Comparison sample. At the same time, although we adapted our sampling framework to Regreening's, which was designed to ensure a similar level of prior engagement with Regreening Africa among the ABCD and Regreening samples, the actual percentage was much higher among the Regreening sample. In addition, the non-ABCD sample held and operated significantly bigger land sizes, and the percentage of Type 4 groups (which we projected would do least well) was significantly lower among the non-ABCD sample, while the percentage of Type 3 groups (which we projected would do the best) was considerably, although not significantly, higher.

Furthermore, while not expected to be a significant *intrinsic* effect of ABCD, it is possible that the positive outcomes in soil, water, and pest and disease (management) were related to the fact that our team provided technical training in response to a demand for on-farm agroecological practices that focused specifically on these three areas. While the data used in this study did not provide insight into this matter, additional data collected and reported in Fuchs et al. (2024) allow for a case to be made that ABCD is an excellent approach to co-learning in the broader context of context-specific technical knowledge dissemination and co-creation. As introduced, we typically use ABCD to define responsive action plans. While the research design in the "ABCD in Regreening" project did not allow for much responsive action, this result allows a case to be made for its value as a synergistic approach to projects that aim to promote specific land-based practices, such as Regreening Africa, which has the potential to accelerate and deepen their impact and reach.

ABCD's clear positive contribution to principles that fall under the social equity operational principles and off-farm system components can be invoked in response to critiques that argue that by focusing and building on existing assets and strengths, community-driven development allegedly fails to challenge the political, economic, and social context and thus perpetuates rather than challenges existing structures and injustices (Brooks and Kendall, 2013; Ennis and West, 2013; Friedli, 2013; McConnell, 2021). Our findings contribute to others that show that ABCD allows for addressing situations in which the "strengths and assets of people in communities have been undervalued, weakening the potential for citizens to engage as active partners in social change" (Peters et al., 2021, p. 14). Instead, ABCD "combines different forms of active citizenship where people bring about change at their own pace, on their own terms. Structural change may not be the starting point, but the collective agency built through identifying and mobilizing local assets (…)" (*ibid.*, p. 15) is an important ingredient for self-actualization and collective mobilization that enables communities to advocate for social change. While power imbalances between external actors and project participants, as well as among community members themselves, can, of course, not be avoided or solved by asset-based and agency-focused engagement approaches, ABCD is an approach that supports transformation through intrinsic bottom-up empowerment, and provides guidelines for purposive, reflexive, and methodical engagement methods and modalities that (e.g., Fuchs et al., 2021b).

The study found significant positive changes in the level of agroecological integration among the ABCD sample, and significantly higher improvements than among the non-ABCD sample. This makes it possible to argue for the overall intrinsic positive effect of ABCD, and its promise as a synergistic approach to support projects aiming at sustainable behavior change at the individual and collective levels. Adopting an ABCD approach allows an external actor to play a facilitating and supportive role, from which communities can seek targeted support. Providing external support in a *responsive* rather than prescriptive manner allows communities' control and dignity to be maintained and respected, thus avoiding top-down dissemination approaches. It also allows external actors to understand which entry points and framings to use in their work. This makes it more likely that communities implement and adopt knowledge that is co-created with external actors through community-demand-driven co-learning processes. Ultimately, it allows external actors and their local partners to work together in those areas and domains where there is a "mutual match," and where they are most likely to benefit from each other, rather than imposing from the outside a singular development model designed by a particular external partner that is likely to oversimplify the complexity of local realities and therefore risks being rejected outright. It also helps external actors identify and engage with community members who are interested in what they are proposing. This helps to build sustainable relationships based on mutual recognition and dignity, which helps to manage mutual expectations. The proposed process aligns with the core hypothesis that many facets of development, such as adaptation, adoption, livelihood diversification etc., happen only when they are driven by empowered and enabled individuals and communities themselves, and that their sustainability may be compromised if fostered and facilitated through top-down processes (Fuchs et al., 2021b).

4.3 Usefulness of the F-ACT+ tool for assessing engagement in sustainable land management practices

Considering the usefulness of the F-ACT+ tool in the context of evaluating the contribution of the "ABCD in Regreening" project to strengthening the results of Regreening Africa, several observations can be made. First, the structured and methodical process to first of first defining what matters, then measuring what matters, and generating data on what matters, ine line with the proceeding proposed in (Lamanna et al., 2024), was very useful and confirms the suitability of the F-ACT+ tool. The tool proposes a systemic approach to evaluation that embraces complexity and includes many of "social" outcomes emphasized by ABCD. It also embeds the assessment part in other activities including visioning and action planning for sustainable development at the household level—much like ABCD itself as well. In general, the tool itself is easy to use, the questions are usually clear, and the response options are mostly well structured in 4-point response formats that allow for the levelling of answers. The data representation options are interesting, and the overall embedding of the quantitative assessment part in a contextualization, an

inspiration, and a planning part demonstrates the tool's appropriateness for a research-in-development setting.

However, we found several weaknesses in the original F-ACT tool. In general, answer options for some criteria are not equidistant (i.e., the difference between answer options 3 and 4 is often greater than between 1 and 2, or between 2 and 3), and answer options across criteria sometimes appear unbalanced (i.e., an answer option that is associated with the numerical number 1 in one question would receive a 3 in a similar question). The spacing of response options sometimes reveals a potential underlying conceptual bias: some response options appear to be biased toward diversification, with the highest scores given for the greatest diversity of practices, tree species, crop species etc., without explicit consideration of their contextual suitability. While general diversification is certainly an underlying agroecological principle, the diversification imperative implicit in the tool sometimes seems to contradict the options by context paradigm (Coe et al., 2014). In addition, as discussed in the context of the "Minus 5" variations of the tool, some questions and response options seem Eurocentric and not adapted and relevant to the Kenyan context. Because the tool is designed as a questionnaire that can be used to collect primary data from households at the farm level, it is suitable for monitoring change over time, and can therefore be used for baseline, midline and endline data collection. However, because of its broader objectives, it is however not as extractive as other monitoring and evaluation approaches. Yet, the tool also includes several indicators that are rather unlikely to change over short periods of time, which may require adaptation if the tool is to be used to monitor changes over time rather than for point-in-time insights. Furthermore, despite the inclusion of off-farm system components (albeit few compared to on-farm components) and at least six principles directly related to social characteristics that support social equity, explicit questions to assess the social-cultural and socio-economic dynamics that contribute to deepening the level of agroecological integration remain rather few. While our team's efforts to supplement the tool have helped to address this imbalance, the official version of the tool could benefit from further related adaptations.

4.4 Sustainable scaling requires tools and processes that foster *responsive* external support for community empowerment, agency, and action

The Regreening Africa project team sought support from the ABCD team with an explicit interest in identifying sustainable scaling mechanisms that would help them achieve their "ambitious" land restoration targets, and reach more people more quickly and more sustainably. We developed a methodical and stepwise conceptual and analytical framework to demonstrate in detail that the adoption of an asset-based and agency focused engagement approach made an intrinsic positive contribution through community-driven scaling of Regreening practices. The Regreening team also introduced several other knowledge dissemination and scaling practices in Kenya, including media engagement in radio and television, road shows, soccer tournaments, farmer field days, and participatory videography (Regreening Africa, 2020). In addition, the ABCD team also collaborated with Regreening Africa to develop a Sustainability Planning approach that combines previous ABCD and SHARED work (Fuchs et al., 2021a), which was rolled out in all eight project countries. Regreening Africa celebrated ABCD as one of its "success stories" in light of the positive evaluation by implementing staff and project participants (Regreening Africa, 2022a, 2022b).

ABCD is being used by communities around the world to self-organize. In contexts such as the "ABCD in Regreening" project, external actors use ABCD as an intentional co-design approach that allows them to "bridge the divide in community development… [and link] community demands and responsive external support" (Fuchs, 2018, title) to promote sustainable behavioral change in a research-in-development context. While there are many interesting participatory engagement approaches being used in similar contexts, ABCD's approach and practice differ from others in that it proposes a combination of a particular set of framings, methods and mechanisms, and processes. ABCD's framing includes an inclusive and comprehensive focus on existing assets (what *you* already *have*) and agency (what *you* can *do* with it). The ABCD methods and mechanisms emphasize self-assessment, self-realization, self-actualization, and self-evaluation. Finally, the ABCD processes focus on attitudes about assets and agency before addressing behaviors.

Agroecology is fundamentally focused on the co-creation and co-design of knowledge and contextualized solutions. It is committed to transdisciplinary approaches that are problem-focused, solution-oriented, inclusive, and reflexive (HLPE, 2019; Sinclair, 2021). Our study affirms the importance of engagement processes that, first, promote self-reflection, self-belief, and self-mobilization among communities to sustainably mobilize their assets for individual and collective action, and, second, promote critical self-reflection among implementing external actors to ensure that they focus on sustainable relationship building and responsive action that aligns with their IIP while being scientifically sound. Due to its outcome focus, our study provided limited insights into these and other specific mechanisms and what, if any, specific contribution claims could be verified. Our separate work on theory-based contribution analysis (Fuchs et al., 2024) meaningfully enriches this study. The land restoration agenda must be driven by local communities to build climate-resilient livelihoods and landscapes, the sustainability of which depends on communities around the world individually and collectively defining, co-creating, and implementing context-specific land restoration options. By adopting an asset-based and agency-focused approach to engagement, external actors can accompany community-driven change and support broad agroecological transitions. Further research on the impact of specific co-design tools and methods, as well as on the processes and behaviors of external actors, will allow to strengthen their capacity to develop and implement sustainability-promoting approaches that help to address the pressing crises of our time in a transdisciplinary manner.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/TQJ2PJ.

Ethics statement

Ethical approval was obtained in accordance with the legal legislation and institutional requirements. The participants provided their informed consent as part of the surveys.

Author contributions

LF: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. LO: Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. LK: Investigation, Writing – original draft, Writing – review & editing, Conceptualization. VA: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. SO: Data curation, Formal analysis, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1449615/full#supplementary-material

References

Abadie, A. (2005). Semiparametric difference-in-differences estimators. *Rev. Econ. Stud.* 72, 1–19. doi: 10.1111/0034-6527.00321

Alteri, M. A. (1995). Agroecology: The science of sustainable agriculture. *2nd* Edn. Boulder and London: Westview Press.

Arslan, A., Floress, K., Lamanna, C., Lipper, L., and Rosenstock, T. S. (2022). A meta-analysis of the adoption of agricultural technology in sub-Saharan Africa. *PLoS Sustain. Trans.* 1:e0000018. doi: 10.1371/journal.pstr.0000018

Ashford, G., and Patkar, S. (2001). Beyond problems analysis: Using appreciative inquiry to design and deliver environmental, Gender Equity and Private Sector Development Projects. Final Progress Report (Issue December).

Barrios, E., Gemmill-Herren, B., Bicksler, A., Siliprandi, E., Brathwaite, R., Moller, S., et al. (2020). The 10 elements of agroecology: enabling transitions towards sustainable agriculture and food systems through visual narratives. In Ecosystems and people (Vol. 16, Issue 1, pp. 230–247).

Biovision Foundation (2020). Farm-level agroecology criteria tool (FACT) excel sheet. Preliminary Version Shared by Authors Directly. Available at: https://www.agroecology-pool.org/wp-content/uploads/2021/09/Farm-Level-Agroecology-Criteria-Tool_v1.10.zip

Biovision Foundation (n.d.). Agroecology criteria tool (ACT) excel sheet. Available at: https://www.agroecology-pool.org/methodology/

Bourne, M. (2024). Communities and evidence at the Centre of Africa restoration success. "Regreening Africa" programme recognized as world restoration flagship. Forests News. Available at: https://forestsnews.cifor.org/86301/communities-and-evidence-at-the-centre-of-africa-restoration-success?fnl=en

Brooks, F., and Kendall, S. (2013). Making sense of assets: what can an assets based approach offer public health? *Crit. Public Health* 23:2. doi: 10.1080/09581596.2013.783687

Callaway, B., and Sant'Anna, P. H. C. (2021). Difference-in-differences with multiple time periods. *J. Econ.* 225, 200–230. doi: 10.1016/J.JECONOM.2020.12.001

Chambers, R. (1994). Participatory rural appraisal (PRA): challenges, potentials and paradigm. *World Dev.* 22, 1437–1454. doi: 10.1016/0305-750X(94)90030-2

Chambers, Robert, and Conway, G. R. (1991). Robert Chambers and Gordon R. Conway. In IDS discussion paper 296 (Vol. 296, Issue Brighton: Institute of Development Studies, University of Sussex).

CIDSE (Coopération Internationale pour le Développement et la Solidarité). (2018). The principles of agroecology. Towards just, resilient and sustainable food systems.

Coe, R., Sinclair, F., and Barrios, E. (2014). Scaling up agroforestry requires research 'in' rather than 'for' development. *Curr. Opin. Environ. Sustain.* 6, 73–77. doi: 10.1016/j.cosust.2013.10.013

Cunningham, G., Fuchs, L. E., Orero, L., Apondi, V. A., and Kipkorir, L. (2018). The integrated household leaky bucket: building financial and economic literacy by doing: a simple guide to help smallholder farmers separate their farm and household revenues and expenses. Coady Innovation Series, 14 (December).

DfID (1999). Sustainable livelihoods guidance sheets introduction: overview. *Sustain. Livelihoods Guid. Sheets* DFID, London, UK. 10.

Diochon, M. (1997). Entrepreneurship and community economic development: Exploring the link. Durham, UK: Durham University.

Elliott, C. (1999). Locating the energy for change: an introduction to appreciative inquiry. International Institute For Sustainable Development.

Ennis, G., and West, D. (2013). Using social network analysis in community development practice and research: a case study. *Commun. Dev. J.* 48, 40–57. doi: 10.1093/cdj/bss013

Ewert, F., Baatz, R., and Finger, R. (2023). "Agroecology for a sustainable agriculture and food system: from local solutions to large-scale adoption" in *Annual review of resource economics*, vol. *15* (Annual Reviews Inc), 351–381.

FAO. (2018). The 10 elements of agroecology: Guiding the transition to sustainable food and agricultural systems.

Friedli, L. (2013). "What we've tried, hasn't worked": the politics of assets based public health. *Crit. Public Health* 23, 131–145. doi: 10.1080/09581596.2012.748882

Fuchs, L. E. (2018). Bridging the divide in community development: the importance of process in linking community demands and responsive external support. Coady Innovation. Series, 8, 12.

Fuchs, L. E., Bourne, M., Achieng, W., and Neely, C. (2021a). Sustainability planning with community and local stakeholders. World Agroforestry, ICRAF.

Fuchs, L. E., Kipkorir, L., Apondi, V., and Orero, L. (2020). Facilitating an asset-based community-driven (ABCD) approach for holistic community development: A manual for community Organising. World Agroforestry, ICRAF. http://www.worldagroforestry.org/downloads/Publications/PDFS/MN20057.pdf

Fuchs, L. E., Orero, L., Apondi, V. A., and Kipkorir, L. (2021b). How to stop wasting money in international development: using a structured group selection approach to counter procedural inefficiency. *World Dev. Persp.* 24:100364. doi: 10.1016/j.wdp.2021.100364

Fuchs, L. E., Orero, L., Namoi, N., and Neufeldt, H. (2019a). How to effectively enhance sustainable livelihoods in smallholder systems: a comparative study from Western Kenya. *Sustain. For.* 11:1564. doi: 10.3390/su11061564

Fuchs, L. E., Orero, L., Ngoima, S., Kuyah, S., and Neufeldt, H. (2022). Asset-based adaptation project promotes tree and shrub diversity and above-ground carbon stocks in smallholder agroforestry Systems in Western Kenya. *Front. Forests Glob. Change* 4:773170. doi: 10.3389/ffgc.2021.773170

Fuchs, L. E., Orero, L., van Dien, L. C., Apondi, V., Kipkorir, L., Kamau, A., et al. (2024). Evidencing that process matters: Conceptualising and evaluating the contribution of an asset-based and agency-focused engagement approach on strengthening Regreening Africa outcomes in Kenya. [Forthcoming].

Fuchs, L. E., Peters, B., and Neufeldt, H. (2019b). Identities, interests, and preferences matter: fostering sustainable community development by building assets and agency in Western Kenya. *Sustain. Dev.* 27, 704–712. doi: 10.1002/sd.1934

Geck, M. S., Crossland, M., and Lamanna, C. (2023). Measuring agroecology and its performance: an overview and critical discussion of existing tools and approaches. *Outlook Agric.* 52, 349–359. doi: 10.1177/00307270231196309

Ghore, Y. (2015). Producer-led value chain analysis: the missing link in value chain development a tool for effective engagement of small producers.

Gliessman, S. R. (2015). Agroecology: The ecology of sustainable food systems (3rd edition). Boca Raton, FL: CRC Press/Taylor&Francis.

Glover, D., Sumberg, J., Ton, G., Andersson, J., and Badstue, L. (2019). "Rethinking technological change in smallholder agriculture" in *Outlook on agriculture*, 48, 169–180.

Gonsalves, J. (2000). Going to scale: can we bring more benefits to more people more quickly. In Workshop highlights presented by the CGIAR-NGO committee and the global forum for agricultural research with BMZ, MISEREOR, Rockefeller Foundation, IRRI and IIRR. Silang, Philippines: International Institute of Rural Reconstruction. Available at: http://www.fao.org/docs/eims/upload/207909/gfar0086.PDF

Graham, B. S., De Xavier, C., Pinto, C., and Egel, D. (2012). Inverse probability tilting for moment condition models with missing data. *Rev. Econ. Stud.* 79, 1053–1079. doi: 10.1093/restud/rdr047

Guyer, J., and Richards, P. (1996). The invention of biodiversity: social perspectives on the management of biological variety in Africa. *Africa* 66, 1–13. doi: 10.2307/1161508

Heckman, J. J., Ichimura, H., and Todd, P. E. (1997). Matching as an econometric evaluation estimator: evidence from evaluating a job training Programme. *Rev. Econ. Stud.* 64, 605–654. doi: 10.2307/2971733

HLPE (2019). Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, July.

Hughes, K., Oduol, J., Kegode, H., Ouattara, I., Vagen, T., Winowiecki, L. A., et al. (2020). Regreening Africa consolidated baseline survey report. Nairobi, Kenya: Regreening Africa.

IPCC (2023). Summary for Policymakers. In Climate Change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Knowler, D., and Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: a review and synthesis of recent research. *Food Policy* 32, 25–48. doi: 10.1016/j.foodpol.2006.01.003

Koech, G., Winowiecki, L. A., Westermann, O., Bourne, M., Wamawungo, D., Carsan, S., et al. (2020). Regreening Africa: a bottom-up transformation of degraded lands. ETFRN News 60 – Restoring African Drylands, pp. 219–226.

Kretzmann, J. P., and McKnight, J. L. (1993). Building communities from the inside out: A path toward finding and mobilizing a community's assets: The Asset-Based Community Development Institute.

Kretzmann, J. P., and McKnight, J. L. (2005). Discovering community power: A guide to mobilizing local assets and your organization's capacity. In Asset-Based Community Development Institute, Northwest University. Chicago.

Lamanna, C., Coe, R., Crossland, M., Fuchs, L. E., Barahona, C., Chiputwa, B., et al. (2024). Developing holistic assessments of food and agricultural systems: a meta-framework for metrics users. In Agroecology TPP working paper no. 4 (issue February).

Lukuyu, B., Place, F., Franzel, S., and Kiptot, E. (2012). Disseminating improved practices: are volunteer farmer trainers effective? *J. Agric. Educ. Ext.* 18, 525–540. doi: 10.1080/1389224X.2012.707066

Malapit, H., Quisumbing, A., Meinzen-Dick, R., Seymour, G., Martinez, E. M., Heckert, J., et al. (2019). Development of the project-level Women's empowerment in agriculture index (pro-WEAI). *World Dev.* 122, 675–692. doi: 10.1016/j.worlddev.2019.06.018

Mathie, A., Cameron, J., and Gibson, K. (2017). Asset-based and citizen-led development: using a diffracted power lens to analyze the possibilities and challenges. *Prog. Dev. Stud.* 17, 54–66. doi: 10.1177/1464993416674302

Mathie, A., and Cunningham, G. (2003). Who is driving development? Reflections on the transformative potential of asset-based community development. Coady International Institute Ocassional Paper Series, 5, 14.

Mathie, A., and Cunningham, G. (2008). From clients to citizens: communities changing the course of their own development. Rugby, UK: Practical Action are the publishing house. 400.

Mathie, A., and Peters, B. (2014). Joint (ad)ventures and (in)credible journeys evaluating innovation: asset-based community development in Ethiopia. *Dev. Pract.* 24, 405–419. doi: 10.1080/09614524.2014.899560

McConnell, C. (2021). Asset based community development in the UK: an opinion piece. *Pract. Insights Mag.* Glasgow: International Association for Community Development (IACD). 18, 16–17. Available at: https://www.iacdglobal.org/practice-insights-magazine/

McKnight, J. L. (2009). Community Capacities and Community Necessities. In Opening remarks, July 8, 2009, At the "from clients to citizens forum", Coady International Institute, St. Francis Xavier University, Antigonish, Nova Scotia.

McKnight, J. (2014). A basic guide to ABCD Community organizing. *Asset-Based Commun. Dev. Inst.* 37, 736–742. doi: 10.1111/j.1440-1681.2010.05387.x

McKnight, J., and Block, P. (2012). "The abundant community" in Awakening the Power of Families and Neighborhoods. (Oakland: Berrett-Koehler Publishers).

McKnight, J. L., and Russell, C. (2018). Asset-based community development process what is distinctive about an asset-based. 1–15.

McKnight, J., and Russell, C. (2022). The connected community: Discovering the health, wealth, and power of Neighbourhoods. Oakland: Berrett-Koehler Publishers.

Nicholls, C., Altieri, M., and Vázquez, L. (2016). Agroecology: principles for the conversion and redesign of farming systems. *J. Ecosyst. Ecography*. 1, 1–8. doi: 10.4172/2157-7625.s5-010

Nikiema, T., Ezin, E. C., and Kpenavoun Chogou, S. (2023). Bibliometric analysis of the state of research on agroecology adoption and methods used for its assessment. *Sustain. For.* 15616, 1–18. doi: 10.3390/su152115616

Odhiambo, C. (2020). Regreening Africa project overview. In Powerpoint presentation given by World Vision Project Manager. pp. 1–6.

Okidi, C., Kameri-Mbote, P., and Akech, M. (2008). Environmental governance in Kenya. Implementing the framework law. Nairobi, Kenya: East African Educational Publishers.

Pannell, D. J., Marshall, G. R., Barr, N., Curtis, A., Vanclay, F., and Wilkinson, R. (2006). Understanding and promoting adoption of conservation practices by rural landholders. In. *Aust. J. Exp. Agric.* 46:1407. doi: 10.1071/EA05037

Peters, B., and Eliasov, E. (2013). Compendium of tools for asset-based community-driven development facilitators. Coady International Institute, St. Francis Xavier University, Antigonish, Nova Scotia.

Peters, B., Gonsamo, M., and Molla, S. (2011). Capturing unpredictable and intangible change: evaluating an asset-based community development (ABCD) approach in Ethiopia. Coady International Institute Occasional Paper Series, 10, 1–28.

Peters, B., Mathie, A., and Cunningham, G. (2021). Does ABCD do justice to systems and structures? *Practice Insights Magazine*. Glasgow: International Association for

Community Development (IACD). 8, 14–15. Available at: https://www.iacdglobal.org/practice-insights-magazine/

Prokopy, L. S., Floress, K., Klotthor-Weinkauf, D., and Baumgart-Getz, A. (2008). Determinants of agricultural best management practice adoption: evidence from the literature. *J. Soil Water Conserv.* 63, 300–311. doi: 10.2489/jswc.63.5.300

R Core Team (2023). R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: https://www.R-project.org/

Regreening Africa. (2018). Evergreening Africa with trees. Kenya Country Implementation Plan 2017–2022. Nairobi, Kenya.

Regreening Africa. (2020). Regreening Africa. A Glimpse of Kenya. Newsletter Issue 1. Nairobi, Kenya.

Regreening Africa. (2022a). Regreening Africa. Inclusive and evidence-based approaches to accelerating land restoration in Kenya. Stakeholder workshop November 22–23, 2022, Nairobi, Kenya. Available at: https://regreeningafrica.org/wp-content/uploads/2023/02/2022_Regreening-Africa-Kenya-Report_27_02_23.pdf

Regreening Africa. (2022b). Regreening Africa. Kenya Country Overview. Available at: https://regreeningafrica.org/wp-content/uploads/2022/12/Regreening-Africa-Kenya-Brief_18_11_22.pdf

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., et al. (2023). Earth beyond six of nine planetary boundaries. *Sci. Adv.* 9, 1–16. doi: 10.1126/sciadv.adh2458

Russell, C. (2017). By the people for the people. *Nurt. Dev. Blog.* Available at: https://www.nurturedevelopment.org/blog/abcd-approach/by-the-people/

Sant'Anna, P. H. C., and Zhao, J. (2020). Doubly robust difference-in-differences estimators. *J. Econ.* 219, 101–122. doi: 10.1016/J.JECONOM.2020.06.003

Sinclair, F. (2021). Wind of change – the growing momentum for agroecological transitions. In Rural 21 (pp. 30–32). Available at: https://www.rural21.com/english/news/detail/article/wind-of-change-the-growing-momentum-for-agroecological-transitions.html

Sinclair, F., Wezel, A., Mbow, C., Chomba, S., Robiglio, V., and Harrison, R. (2019). The contribution of Agroecological approaches to realizing climate-resilient agriculture. Global commission on adaptation to inform its 2019 flagship report.

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., et al. (2018). Options for keeping the food system within environmental limits. *Nature* 562, 519–525. doi: 10.1038/s41586-018-0594-0

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., et al. (2015). Planetary boundaries: guiding human development on a changing planet. *Science* 347, 1–10. doi: 10.1126/science.1259855

Tittonell, P. (2014). Ecological intensification of agriculture-sustainable by nature. *Curr. Opin. Environ. Sustain.* 8, 53–61. doi: 10.1016/j.cosust.2014.08.006

Tomich, T. P., Brodt, S., Ferris, H., Galt, R., Horwath, W. R., Kebreab, E., et al. (2011). Agroecology: a review from a global-change perspective. In. *Annu. Rev. Environ. Resour.* 36, 193–222. doi: 10.1146/annurev-environ-012110-121302

Tufts University, P. D. I (2010). Basic field guide to the positive deviance approach: positive deviance initiative. In positive deviance initiative (issue September), 1–17.

Wezel, A., Casagrande, M., Celette, F., Vian, J. F., Ferrer, A., and Peigné, J. (2014). Agroecological practices for sustainable agriculture. A review. *Agron. Sustain. Dev.* 34, 1–13. doi: 10.1007/s13593-013-0180-7

Wossen, T., Abdoulaye, T., Alene, A., Haile, M. G., Feleke, S., Olanrewaju, A., et al. (2017). Impacts of extension access and cooperative membership on technology adoption and household welfare. *J. Rural. Stud.* 54, 223–233. doi: 10.1016/j.jrurstud.2017.06.022