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PRACTICE INSIGHTS

Co-Designed Projects in Ecological Research and Practice

Multi-stakeholder participation for successful implementation of applied research projects in Africa

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Abstract

1. Rainwater harvesting from Roads For Indigenous Pasture production and improved rural livelihoods in Kitui, Kenya (ROFIP) is an applied research project. It assessed the potential of combining multiple sustainable land management practices, for example native grass reseeding, rainwater harvesting from roads and in situ microcatchments to enhance vegetation cover in a semi-arid dryland in Kenya.
2. Rural earth roads were used as a catchment. Runoff generated from rainfall events was diverted into reseeded pastures with trenches established at intervals, across a slope. The ROFIP project also integrated microcatchments created using ox-driven ploughs, a traditional practice for seedbed preparation and harnessing in situ rainwater harvesting in African drylands.
3. Combining the diversion of runoff from roads and harvesting rainwater in situ improves and prolongs soil moisture availability in reseeded pastures. Consequently, this translated to higher biomass yields (i.e. forage for livestock) and vegetation cover (land degradation mitigation and enhanced soil health). This project clearly showed that combining rainwater harvesting and native pasture reseeding improves water retention and soil health, thus improving sustainable pasture production.
4. However, for this to be achieved, it is prudent to involve practitioners to co-design practical solutions that are socially, economically and environmentally sustainable. Multi-stakeholder engagement, effective knowledge sharing, and community involvement can be major enablers in the pursuit of environmental and socioeconomic relevant benefits in applied research projects in Africa. This approach enhances a sense of shared purpose among practitioners and empowers them to become points of reference to their peers.

KEYWORDS
applied research, co-creation, drylands, grasses, sustainability, traditional knowledge

1 | INTRODUCTION

African drylands cover approximately 65% of the continent's landmass and about one-third of the world's drylands (Darkoh, 2003). They are generally characterized by low and unreliable annual rainfall (300–600 mm), high temperatures and infertile soils (Sanchez, 2002). Extensive utilization of multiple grazing resources by livestock in drylands remains an important way of life among pastoral communities. Livestock are among the main assets in African drylands, helping improve the nutritional status of the community, contributing to economic growth and sustainable livelihoods (Homewood et al., 2012).

However, land degradation is widely recognized as a serious global environmental challenge affecting roughly 20% of the Earth's vegetated surface and livelihoods of more than 1.3 billion people (Cherlet et al., 2018; Pricope et al., 2023). More than 90% of the global land surface is estimated to continue to suffer from the land degradation crisis by 2050 unless measures are implemented to stop its rapid spread (Cherlet et al., 2018). Africa is particularly affected because land degradation affects approximately 46% of its total land surface and 73% of arid and semi-arid drylands (Gisladottir & Stocking, 2005; Mganga et al., 2018). Arid and semi-arid African drylands are particularly vulnerable as they have fragile soils, generally low input form of agriculture, scarce vegetation cover and weak soil structure (Lal, 2009). The decline in soil fertility, the loss of soil biodiversity and erosion exemplify environmental degradation in arid and semi-arid drylands in Africa (Visser et al., 2007). Long dry periods are followed by heavy, intense and concentrated downpours that wash away the fertile topsoil, depleting the land of nutrients to support a continuous perennial vegetation cover.

Environmental degradation is a key challenge in the arid and semi-arid drylands of Kenya. Previous studies have estimated that approximately 30%–40% of Kenya's drylands are rapidly degraded and an additional 2% have completely been denuded (Nyangito et al., 2008). The decline in soil productivity, the increasing rate of soil erosion, and depleted vegetation cover depict degradation in semi-arid lands in Africa. Specifically, vegetation degradation on these marginal lands is characterized by the depletion and disappearance of grass species preferred by grazing livestock (Mureithi et al., 2016). To address this environmental challenge, the Roads For Indigenous Pasture production and improved rural livelihoods in semi-arid Kitui, Kenya (ROFIP) applied project consortium https://www.nwo.nl/en/projects/w-08270348 was established. This consortium included individuals from South Eastern Kenya University (SEKU); Kitui County Government, Kenya; MetaMeta Research; and Rise Against Poverty, Kenya (RAP-K). To promote inclusion, the consortium engaged other stakeholders and practitioners (individual farmers, common interest groups [CIGs], Agricultural Training Center [ATC], Kitui, Kenya Agricultural and Livestock Research Organization [KALRO]) in co-designing and implementing the project in a semi-arid dryland in Kenya.

Specifically, the ROFIP project aimed to assess the potential of combining sustainable land management (SLM) practices, namely: (1) native grass reseeding, (2) harvesting rainwater from roads and diverting runoff into reseeded areas and (3) in situ rainwater harvesting using trenches and microcatchments, for ecological restoration and rehabilitation, native pasture production, and improving livelihoods of pastoralists in semi-arid drylands. The selected perennial native grasses were *Cenchrus ciliaris* (African foxtail grass), *Enteropogon macrostachyus* (Bush rye grass), *Eragrostis superba* (Maasai love grass), *Chloris roxburghiana* (Horsetail grass) and *Chloris gayana* cv. Boma (Rhodes grass). The selection process was informed by the knowledge of the grasses by practitioners (Table 1). The choice of grasses was largely influenced by their forage value for livestock production (Mganga et al., 2015). Here, we explicitly aim at sharing our insights, observations, practical experiences, and lessons learned from implementing the ROFIP project. Moreover, we demonstrate how similar applied research projects involving multiple stakeholders can be executed more efficiently for successful outcomes in Africa.

2 | APPROACH TO PROJECT IMPLEMENTATION

Combining road water harvesting and native grass reseeding holds the key to ecosystem restoration and sustainable livestock production systems in arid and semi-arid African drylands. The consortium jointly set up nature laboratories and knowledge centres at the project sites: (1) South Eastern Kenya University (SEKU) (research and training), (2) the Agricultural Training Centre (ATC), Kitui (outreach and training) and (3) model farmers (practitioners and adoption). This approach was aimed at reaching a broad range of stakeholders and practitioners.

Plant morphoecological traits (e.g. biomass yields, vegetation cover, plant densities, frequencies, tiller densities, plant height, seed production) were measured and monitored. Moreover, farmer-to-farmer exchange visits and trainings (e.g. field visits and on-site demonstrations) were also organized. Exposing farmers to what other practitioners (success stories) were implementing on their individual farms was aimed at providing a platform for peer-to-peer knowledge exchange and contributing to adoption of the SLMs promoted. The ROFIP project impact pathway is shown in Table 2.

3 | OUTCOMES AND POTENTIALS FOR IMPACT

New knowledge and insights on (1) native perennial pasture production in drylands, (2) rainwater harvesting from roads and in situ (Figure 1) and (3) assessing forage value of selected grasses for livestock production using morphometric characteristics, were coproduced, shared, gained and applied. The number of practitioners and the land area covered by the selected grasses established during the project period are shown in Table 3.

TABLE 1 Characteristics of native grasses used for restoring degraded African drylands based on practitioners knowledge.

Species	Local name	Characteristics
Cenchrus ciliaris (African foxtail grass)	*Ndata kivumbu*	Soft and tender when young; drought tolerant; high biomass yields; soil erosion control; easy to cut and bulk as hay; quick to establish; fast growing; stays green for long time; easy to harvest seeds
Enteropogon macrostachyus (Bush rye grass)	*Nguu*	Good for soil and water conservation; high plant density and ground cover; good for rehabilitating degraded grazing lands; germinates readily; establishes very quickly
Eragrostis superba (Maasai love grass)	*Mbeetwa*	Good establishment; wide branching shoot architecture captures rainwater and covers soil; high biomass yields; preferred by free grazing livestock; good for stabilizing terraces; suitable for fattening livestock for sale; produces seeds in bulk; easy to harvest seed
Chloris roxburghiana (Horsetail grass)	*Kilili, Kiimbu*	Hardy and drought tolerant; readily grazed by livestock; highly palatable especially when young; good biomass yields; soil and water conservation; establishes well in different soil types
Chloris gayana (Boma Rhodes grass)	*Boma Rhodes*	High leafy biomass; easy to harvest and bale for storage; good nutritive value for grazing livestock; high seed production; very suitable as cover crop; quick establishment (within 3 months); enhances soil water holding capacity and stabilization

Consequently, this contributed to (1) increased uptake of native grass reseeding technology by individual practitioners and CIGs, (2) enhanced native pasture production and utilization by practitioners, (3) diversification of livelihood and income sources (hay and grass seeds), (4) change in mind set on the significance and potential of indigenous pasture farming and runoff harvesting for enhanced pasture farming (fallacy debunked), (5) skills and knowledge transfer (multidirectional between stakeholders), (6) uptake and customization of different rainwater harvesting technologies by practitioners, that is, diverting runoff from roads and in situ macro and micro-catchments, (7) increased level of knowledge and insights on pasture conservation (Figure 2) and (8) ranking forage grasses for livestock production. Subsequently, this increased the number of practitioners in the value chain of native pasture production.

The potential impact of the project includes: (1) improved sustainable native pasture production at the farm level, (2) increased herbaceous vegetation cover in reseeded pasture areas using selected grasses, which also contributes to combating land degradation and improving soil health and protection against soil erosion, (3) healthier livestock herds, especially during lean pasture yield periods, harvested hay cushions livestock keepers against forage scarcity especially during the dry season, (4) diversification of sources of rural livelihoods and increased household incomes, (5) improved human nutrition—milk and meat and purchase of other food products in local markets, for example, cereals and pulses, from income generated through sale of grass hay, seeds and healthier animals and (6) stronger integration between different practitioners, local and international NGO's, entrepreneurs, media, private companies, research institutions and local authorities. Thus, the project established and strengthened stakeholder linkages to explore subsequent opportunities that might be of mutual interest, for example agricultural research and development.

Additionally, local government authorities in the project area showed great interest in promoting and supporting native pasture production because it complements its own improved livestock (cattle, sheep and goat) breeding program. Subsequently, approximately 80 practitioners, two for each administrative ward, were identified to lead the native pasture production program for up-scaling and adoption among other livestock keepers (Table 3). Looking at the greater impact, the potential of the enhanced contribution of native pasture production to food and nutrition security is evident with great interest and support from local authorities and practitioners.

4 | CO-CREATION, RESEARCH UPTAKE AND KNOWLEDGE SHARING

4.1 | Co-creation

Co-creation is broadly defined as any collective creativity action shared by more than one person with physical, metaphysical, material, and spiritual applications (Sander & Stappers, 2008). Multiple interdependent stakeholders within ROFIP were involved in the project co-creation, innovation and interaction processes. The different stakeholders brought their (1) knowledge (what they know), (2) networks (who they know) and (3) identity (who they are) to the project (Keeys & Huemann, 2017; Wiltbank et al., 2006).

As a result, four model 'nature labs' for native grass reseeding were co-designed and established to benefit different end users (e.g. researchers, students, local authorities and practitioners). More than 200 farmers participated in farmer field days (FFDs) and farmer exchange visits hosted in the 'nature labs' (Figure 3). In addition, 1500 practitioners visited the 'nature laboratories' and demonstration plots during open field days organized by the consortium and the local government. Subsequently, the initial four 'nature labs' led to the establishment of 10 additional community-led 'nature labs'. Inclusiveness and diffusion of power among multiple interested actors and consortium with diverse viewpoints in ROFIP resulted in more engaged and satisfied stakeholders. This process also provided

TABLE 2 The Roads For Indigenous Pasture production and improved rural livelihoods in semi-arid Kitui, Kenya (ROFIP) project impact pathway.

Research outputs	Indicators	Progress achieved	Research outcomes	Indicators	Progress achieved	Impact
New knowledge and insights gained, applied and shared on indigenous pasture production in dryland environment	• Scientific journal articles • Individual farmers, women and youth groups trainings • Grass traits data • Indigenous pasture production farmers' practical manual	• Peer reviewed publications • Trainings provided new insights to local farmers and groups • Ecological data sets statistically analysed, species/treatments compared • ROFIP F&B Knowledge Platform • Practitioners manual • Multiple use of established grasses—hay, seed, rehabilitation of degraded land, soil conservation	• Uptake of the grass reseeding technology by individual farmers • Also incorporated as an enterprise in youth and women groups • Increased farm level pasture production and utilization by local farmers • Livelihood and sources of income diversification by farmers • Change in mindset—significance and potential of indigenous pasture farming • Skills and knowledge transferred (multidirectional between stakeholders)	• Marketing and sale of indigenous grass hay and seeds by local farmers • Increased forage yields and cover at farm level among farmers and groups • Increase in farm acreage under pasture farming among local farmers and groups • Increased levels of income, milk and meat production among adopters of pasture farming • Good condition scores for livestock	• Use of different methods of harvesting and conserving hay and grass seeds • In-situ morphoecological monitoring of established pastures across seasons • Incorporation of pastures in croplands as mixtures and/or pure stands • Livestock fertility—reproduction of healthy lambs from Dorper sheep • Livestock feed trials	• Sustainable native pasture production at farm level • Increased vegetation cover in reseeded pastures areas using selected perennial indigenous grasses—thus combating land degradation and improving soil health and protection against soil erosion • Healthy livestock, especially during periods of pasture scarcity in grazing land. Harvested hay cushions the practitioners • Indigenous pasture farming has diversified sources of rural livelihood and increased household sources of income (indigenous pasture farming as business). Specific women groups have been addressed in this regard
Enhanced insights gained, applied and shared for harvesting rainwater from roads for pasture farming	• Conference presentation • Soil moisture-rainwater harvesting structures data set • Indigenous pasture production farmers practical manual • Documentary on dryland pasture production	• Journal articles • ROFIP F&B Knowledge Platform page • Project report • Farmers practical manual	• Uptake of the different rainwater harvesting technologies by farmers, youth and women groups that is diverting runoff from roads and in-situ catchments • Change in mindset—significance and potential of runoff harvesting for enhanced pasture farming. Fallacy challenged • Practical skills and knowledge transferred (multidirectional between stakeholders)	• Increase in forage and vegetation cover at farm level • Construction of runoff and rainwater harvesting structures at farm level • Increase in volume of rainwater harvested and prolonged soil moisture availability in reseeded pastures • No damage to farmland	• Monitoring of soil moisture as influenced by established rainwater harvesting structures • Simultaneous use of multiple rainwater structures • Establishment of indigenous grasses on soil harvesting structures bands for soil stabilization • Maintenance of RWH structures by farmers	• Improved human nutrition—milk and purchase of other food products in local markets for example cereals and pulses, from income generated through sale of grass hay, seeds and healthier animals • Improved integration between local farmers/farmer groups, local and international NGO's, entrepreneurs, media, private companies, local government and research institutions (research centers, universities)
Knowledge gained and shared on forage quality of selected indigenous grasses for livestock production	• Scientific journal article • Forage quality of selected indigenous grasses analysed • Grasses forage value data set • Webinar	• Article submitted and under peer review in Animal Production Science Journal (CSIRO) • PhD student data analysis and manuscript writing.	• Increased level of knowledge and insights on pasture conservation for example baling hay • Ranking of selected indigenous grasses in terms of nutritive/forage value	• Increased animal weight gains and body condition scores of Dorper sheep • Voluntary feed intake of the selected indigenous grasses.	• Livestock fertility—reproduction of healthy 2 lambs from Dorper sheep • Livestock feed trials • Sheep weight gains	• Increased interest from (international) organizations to include and promote pasture management in different areas in Kenya's drylands and beyond. Pasture management in drylands adopted in the new policy of the Embassy of the Netherlands in Kenya
Insights gained and shared on the Value chain of pasture production	• Analysis of value chain of pasture production	• Report developed and being finalized • Mapping of livestock markets, dominant livestock sold in markets • Linkages made to private sector in livestock production value chain	• Increase in the number of farmers, women and youth groups in the value chain of pasture production • Training of women/youth on seed/hay banks and value addition	• Purchase and sale of livestock at local markets • Purchase and sale of hay and grass seeds at farm gate between farmers	• Healthier animals available for sale • Seed and hay banks (conservation for sale) • Value addition—baling of grass hay	• Contribution to the value chain of indigenous pasture production

FIGURE 1 Trench for rainwater harvesting to enhance native pasture production and revegetation (Photo credit: Kevin Z. Mganga).

FIGURE 2 Practitioners knowledge exchange session on pasture harvesting and conservation (Photo credit: Nancy Kadenyi).

valuable information for identifying, considering and further upscaling beneficial co-creation options.

Traditional knowledge (TK) is unique to a particular culture and society and is critical for local decision making in agriculture and natural resource management (Sen, 2005). Unfortunately, the knowledge, experiences and values of indigenous people are often not incorporated into applied research projects for development. This often results in a partial understanding of the core issues and limits the potential for locally and culturally appropriate solutions to environmental and ecological challenges, especially in Africa (Nsikani et al., 2022). To address this within the knowledge co-creation project activities, the consortium and stakeholders shared and learned from each other's expertise and knowledge about the establishment of native pastures, for example, ecology (scientific and traditional ecological knowledge), agronomy, multiple uses, characteristics, contribution to livestock production, rainwater harvesting techniques and socioecological significance of established pastures. Specifically, individual practitioners and CIGs shared their knowledge of traditional methods of seedbed preparation, for example use of ox-plough for in situ rainwater harvesting and preference of different native grass species by grazing livestock (Table 1).

This broad spectrum of knowledge was integrated in the implementation of the project. Consequently, the applied research project culminated in a practical set of innovative tools and knowledge

TABLE 3 Number of practitioners and land area covered by the selected grasses established during the project period.

Category	Number of practitioners	Land area (acres)
Year (2019)		
Individual farmers (practitioners)	5	7.0
Common interest groups (CIGs)		
Mwiwe Dairy Cooperative group	20	1.0
Mutui Museo farmer group	8	0.5
Total	33 (out of 63 practitioners)	8.5
Year (2020)		
CIGs		
Kanyekine	12	10.2
Wikivuvwa	10	6.5
Kwa Syonzola	11	10.7
Kavaini	8	6.5
Kithambangii	11	7.4
EMBEKI Self Help Group	10	7.0
Bondoni Farmers and Dairy Self Help Group	8	6.5
Kavuvwani	8	5.4
Yenzuva	8	9.0
Walalawa	11	11.0
Kikungu	11	12.0
Ndaluni	9	8.7
Thokoa	10	10.6
Thitani	12	16
Kasanga	13	15
Kiusyani	10	10
Total	162 (out of 169 practitioners) Women—56%, Men—44%	152.5
Year (2021)		
Selected model practitioners (Training of trainers, ToT model)	80	40
Practitioners adopting practice	2000	1000
Total	2080	1040

of combining in situ water harvesting and retention with grass reseeding. Furthermore, a comprehensive approach was proposed to produce and conserve quality grass seed for subsequent reseeding and hay as livestock feed. Stakeholder engagement at the initiation phase of the co-creation process is an integral part of identifying benefits of applied research projects. This is because it augments the probability that benefits will (1) reflect and incorporate the needs of

FIGURE 3 Practitioners visiting a field site that serves as nature lab and knowledge hub for knowledge exchange (Photo credit: Nancy Kadenyi).

diverse and multiple stakeholders, (2) be realizable and (3) facilitate up-take and up-scaling of the initiatives (Keeys & Huemann, 2017). The quality of stakeholder engagement therefore fostered understanding of value perceptions and benefits determination and ultimately strengthened the extent and nature of co-creation.

4.2 | Research uptake and knowledge sharing

Knowledge and information are key components to enable practitioners to deal with climatic and environmental challenges (e.g. drought, environmental degradation, biodiversity loss) and emerging opportunities (e.g. new agricultural technologies). Furthermore, rural communities need more knowledge about farm-to-farm strategies to improve their livelihoods. Thus, on-site field demonstrations, farmer visit exchanges, local dialect FM radio stations airing educational programs, farmer field trainings, and online based webinars were used to generate and share new knowledge in soil and water conservation and native perennial grass reseeding in dryland environments. These different knowledge co-production approaches were aimed at building the capacity of practitioners to identify and evaluate their knowledge gaps and transform them into action plans to access services and acquire additional skills (Abdon & Raab, 2005). Knowledge coproduction generated desirable skills to address diverse challenges facing practitioners with different needs and interests (Malmborg et al., 2022).

Practitioners were sensitized and exposed to innovative land management practices. Additionally, peer-to-peer knowledge sharing among practitioners facilitated faster spread and adoption of the shared knowledge, technologies and approaches. This led to a significant shift in mind set. The peer-to-peer learning phenomenon greatly affects the adoption decisions of new technologies (Conley & Udry, 2010). Specifically, the project practitioners took up the shared technologies and now view native pasture establishment as a getaway to healthier livestock, mitigation against environmental degradation and a viable source of income (agribusiness) through the sale of grass seeds and hay (Figure 3).

Furthermore, due to the foreseeable benefits of native pasture farming and growing interest within the farming community, demand for native perennial grass seeds adapted to dryland climate has also increased. Unfortunately, the scarcity of these native grass seeds in formal markets remains a major challenge for adoption and up-scaling. Thus, community-based forage seed system approaches remain the main source of native grass seeds in the arid and semi-arid drylands of Kenya (Mganga et al., 2015). Subsequently, during the project implementation, we also supplied seeds of two native grass species, that is, *C. ciliaris* and *E. superba*, to several farmer groups. This was to support farmers with initial stock for subsequent seed production. To achieve this end result, we trained the groups on seed propagation, harvesting and storage for planting in subsequent growing seasons.

5 | STORIES OF MOST SIGNIFICANT CHANGE

In the past, the farming community in the project area largely viewed runoff, for example, from roads, generated during rainfall episodes as a threat to their croplands. Similar views are commonplace in other dryland environments characterized by patchy vegetation cover and bare soils, especially during fallow dry seasons. This point of view has been mainly attributed to the perceived 'potential destructive' nature of the generated runoff. To challenge this fallacy and myth, we reached out and engaged the farming community in the project area in a discussion on how runoff water can be better harnessed and harvested to improve agricultural production.

Together with the community, we demonstrate how runoff from 'green roads' can be directed into rainwater harvesting structures, for example trenches and furrows in farmlands, to prolong soil moisture availability and support native pasture production (Mganga et al., 2022). Ultimately, on-farm demonstrations and campaigns (radio programs, farmer exchanges and visits) have led to a paradigm shift. Practitioners now view the harvesting of runoff water from roads and directing it into trenches as a viable and climate-smart option for prolonging the availability of soil moisture for crop and pasture production. Subsequently, through numerous trainings and field demonstrations, more farmers are now 'putting knowledge into practice' by constructing their own customized rainwater harvesting structures, especially to take advantage of the runoff from the roads for the establishment of pastures.

Additionally, as a result of this project, the local county government started an initiative to select and train two model farmers (Training of Trainers [ToT] model) per administrative ward (i.e. total of 80 model practitioners in 40 administrative wards) to spur the adoption of the new approaches and technologies. This cohort of model farmers was able to reach approximately 2000 additional practitioners (Table 3). The farmer-to-farmer extension model is a low-cost approach for promoting climate-smart agricultural practices (van de Fliert & Braun, 2002). In addition, the local government has incorporated a new approach and dimension in agricultural extension by focusing more on native pasture production in line with its flagship livestock breeding program. These priority areas were developed by the consortium and other stakeholders during the implementation of the project. This has been seen as a major game changer in the county's agricultural policy and strategy that will spur other initiatives in the food and water security nexus. This scoping project demonstrated that combining pasture management, improved agricultural practices, and rainwater harvesting and retention has great potential to support sustainable livestock production in the arid and semi-arid drylands. Eventually, this will contribute to secure livelihoods that can withstand climate vagaries and land degradation.

6 | REFLECTIONS AND LESSONS LEARNED

Land degradation characterized by depletion of vegetation cover and decline in soil health is a major environmental challenge in African drylands. Combining SLM practices such as rainwater harvesting and reseeding using native perennial grasses can contribute significantly to enhancing vegetation cover, rehabilitate, and restore degraded landscapes to support pastoral livelihoods. However, in order to achieve a broad spectrum of goals that complement each other, there is need to consolidate effort, knowledge, expertise and skills of different stakeholders. Highlighted below are key lessons and practical experiences learned during the implementation of the ROFIP project. These can be considered when executing similar applied research projects in Africa:

- The peer-to-peer process and the use of trainer-of-trainers (ToT) methods to share and exchange knowledge and experiences contributed significantly to the upscaling and adoption of new approaches and technologies.
- Integrating Indigenous knowledge and expertise, for example preference of grasses for ecosystem restoration and livestock production, when co-designing applied research projects provided valuable information to align priorities of the project to the practitioners interests.
- Common interest groups (CIGs) play a crucial role in influencing other practitioners, especially through horizontal learning, adoption, and upscaling.
- Active involvement of local authorities and different stakeholders at the inception and implementation phases of applied research projects facilitates the incorporation of the project outputs in informing policy formulation and supporting synergies with other similar ongoing programs and projects.
- Co-designing and establishing 'natural laboratories' and 'knowledge hubs' is an excellent approach to introduce new technologies and innovations among practitioners. This strategy facilitates adoption and customization of the new technologies to suit their specific interests, thus enhancing their capacity to be more innovative.

AUTHOR CONTRIBUTIONS

Kevin Z. Mganga, Frank van Steenbergen and Nashon K. R. Musimba conceived the ideas and designed the methodology; Eric Kaindi, Nancy Kadenyi, Bobsammy Munyoki, Kevin O. Amollo, Theophilus Kioko, Aphaxard J. N. Ndathi, Gilbert K. Musyoki and Stephen M. Wambua practitioners and coordinated data collection activities and co-designing nature labs and knowledge hubs; Kevin Z. Mganga, Kevin O. Amollo, Luwieke Bosma and Nancy Kadenyi led the analysis and writing of the manuscript. All authors critically contributed to the drafts and gave their final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest. Kevin Z. Mganga is an Associate Editor of Ecological Solutions and Evidence but took no part in the peer review and decision-making processes for this paper.

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