



Agropastoralist Community-led Restoration of Degraded Drylands: Factors Influencing Adoption of Soil Conservation Practices in Semi-arid Regions of Kenya

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ABSTRACT

Background: The conventional approach of soil conservation practices in degraded drylands has shown little success. Lack of knowledge on factors influencing inhabitants of such regions to adopt appropriate conservation practices is the primary cause of low adoption. This is because the disseminators of conservation practices assume a one-fit-all design, resulting in a disconnect between them and farmers. Thus, this study aimed to understand factors influencing soil conservation practices in agropastoral dryland communities of semi-arid lowland West Pokot, with a particular interest in terraces.

Methods: A concurrent mixed-method approach embedded in a cross-sectional survey was used and data were collected through semi-structured questionnaires, focus group discussions and field measurements of existing terrace attributes. Data were subjected to descriptive analysis, Spearman's rho correlation, Kruskal Wallis and Chi-Square test of Independence.

Result: The community-driven approaches, gender, size of land and topography are key factors contributing to terrace adoption. Sixty percent of farmers living in degraded high-sloped lands have portions of their farms terraced with average terrace dyke volumes of $103.8 \pm 21.45 \text{ m}^3$, $105.89 \pm 33.13 \text{ m}^3$ and $129.6 \pm 15.97 \text{ m}^3$ for highly sloped, relatively flat and moderately sloppy areas respectively. The study further established terrace dyke sedimentation and limited terrace embankment reinforcement options as the major challenges facing terracing adoption in the region.

Key words: Agro-pastoral communities, Degraded drylands, Fanya juu, Fanya chini, Soil, Water conservation.

INTRODUCTION

Soil degradation is one of the major challenges affecting agroecosystems worldwide (Scherr, 2019; Zhu, 2020). The process deprives more than 35% of the arable landmass of its ecological functions (Pennock *et al.*, 2015). In Sub-Saharan Africa, soil degradation is aggravated mainly by improper agricultural practices (Tindwa *et al.*, 2019). This is spurred by extensive farming, which makes land size the main factor determining crop yield. Thus, clearing natural vegetation for crops is rampant, contributing to soil erosion (Adonia and Kakurungu, 2014). This practice accounts for more than 70 billion tons of agricultural soil loss annually, with the statistics projected to exponentially increase with increasing population pressure (FAO, 2017).

In Kenya, land degradation is highly intensified in arid and semi-arid regions where soils are inherently weak with crop-growing inhibitors (Sidle *et al.*, 2019). The regions tend to be home to the most impoverished communities, who depend on natural resources for livelihood (Gaur and Squires, 2018). Their low resource status further contributes to low adoption of conservation management strategies (Shiferaw, 2002). As the rate of degradation continues rising, many counties in Kenya are on the verge of losing their productive farmland (Nguru and Rono, 2013). West Pokot County, is an example of a severely degraded arid and semi-arid (ASAL) region, transformed to its current status through anthropogenic activities (LADA, 2016).

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In response to the soil loss problem farmers in the these drylands of Kenya adopt easy-to-apply, biological measures but recently have started venturing into mechanical soil conservation strategies, with terrace, emerging as one of the most important practices (Mudalagiriappa *et al.*, 2019; Oteng'i *et al.*, 2000; Zougmore *et al.*, 2014). The structures' prominence and effectiveness are underscored by their ability to split the land's slope into small hydrographic units, hence controlling surface runoff (Tenge *et al.*, 2011), particularly on high sloped lands. Further studies

(Gachene *et al.*, 2019) indicate that terraces could reduce surface runoff by more than 90% and curb soil loss by more than 85% on different slope levels, these findings corroborate with findings conducted in other parts of the world including Cyprus (Camera *et al.*, 2018).

Although communities in drylands show efforts to combat soil erosion, the level of adopting soil conservation practices in agro-pastoralist communities of Kenya and across Africa has been low. Such a trend has not only resulted in continued soil erosion and increasing land degradation but also hindered the propagation of effective conservation practices. Therefore, this study aimed to evaluate factors determining the adoption of indigenous soil and water conservation practices in drylands and challenges associated with terracing as a soil and water conservation practice.

MATERIALS AND METHODS

The study was conducted in three villages (Parak, Kaporowo, Kapkitony) of Korellach Sub-location, Chepareria ward in West Pokot County from the year 2019 to 2021. The villages are positioned between 35°7' and 35°27' East and 01°15' and 01°55' North as shown in Fig 1. Parak village lies on altitudes ranging between 1906 to 1954 meters above sea level (asl) and with an average slope of >20%. Kaporowo is on the middle slopes (10-20% slope) and at an altitude ranging between 1776 and 1905m asl. The slightly gentle slopes of <10% are found in Kapkitony with an elevation of 1683-1755m above sea level (Maphill, 2011).

The residents of the ward are mainly agro-pastoralists, cultivating their land during the long rainy season running from April to August, thereafter, opening up lands for animal grazing. This unregulated practice has severe erosion implications particularly on the poorly developed and young soils (Touber, 1991).

Study design

The study adopted a concurrent mixed-method approach embedded in a cross-sectional survey design. A three-tier methodology approach was used in data collection; (i) one-on-one interviews (ii) focus group discussion (FGD) and (iii) field measurement of terrace attributes.

One-on-one interviews

A sample size of sixty two households out of 120 households was cluster-sampled across three villages (Etikan *et al.*, 2016). The interview provided primary qualitative and quantitative data that were complemented by FGDs. The questionnaire used for interviews comprised of a mixture of open and closed-ended questions for data collection. The survey was centred on farm-level soil conservation measures, their benefits and general perception towards soil degradation and contributing factors to terracing and household members involved in soil conservation.

Focus group discussion (FGD)

The discussions (1-2 focus group) were conducted in each village. According to the sparsely populated nature of the landscape number of the FGDs was estimated as adequate to achieve theme saturation for the content required to support the one-on-one interviews. Participants of each FGD comprised 10 farmers, with a follow-up discussion with 5 key informants to validate the information. For each FGD, at least 40% of the participants were women as per the two-third gender rule requirement (Kaimenyi *et al.*, 2013; Opoku *et al.*, 2018). The FGDs focused on the following thematic areas; community perception of soil conservation, drivers and barriers to adopting soil conservation practices in their community, socio-economic dynamics intensifying or alleviating soil erosion and potential solutions.

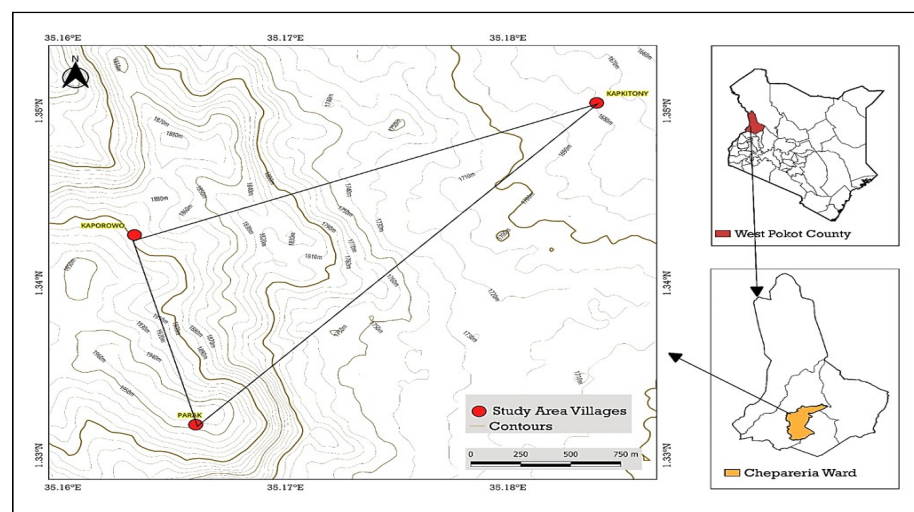


Fig 1: A map of the study location layered on elevation contours: Chepareria ward, West Pokot, Kenya.

Measurements of constructed terrace attributes

Terrace characteristics were measured on 44 farms belonging to farmers who had adopted the technology and participated in one-on-one interviews. The measurements included horizontal interval (m) (Sheng, 2002), dyke cross-sectional area (m²) (Saiz *et al.*, 2016), terrace length (m), terrace volume siltation level (m³) and farm slope (%). *Fanya Juu* and *Fanya Chini* terraces are shown in Fig 2. According to the designs used by farmers during construction, terrace volume was calculated as the product of cross-section, the width of cross-section and the length of the channel (width×breadth×height). The same method was used to calculate the amount of silt accumulation in the dyke.

RESULTS AND DISCUSSION

The Focus Group Discussions (FGDs) elucidated information that was common across the three areas on some themes, however, some of the themes received contradicting points during the discussions. All participants across the FGDs agreed on the occurrence of soil erosion both on-farm and on the landscape, however, the severity of erosion was highly acknowledged in Kaporowo and Kapkitony citing weak fragile soils and poor soil structure for soil erosion occurrences. The thematic discussions were synthesized into four points.

Soil erosion awareness

Community awareness of soil erosion is evident and residents recognize the impact of erosion on various socio-economic aspects. Participants highlighted several indicators, such as declining soil fertility, erosion rills and threatening gullies that pose risks to crops and fodder production and livestock survival. To address the issue, the community ingeniously adopted and adapted various measures from different sources. Common practices include live fences, stone bands, cover-cropping and terraces with the latter (*Fanya Juu* and *Fanya Chini*) being hailed as the most effective and well-suited for their region.

Implementing these terraces has visibly resulted in increased crop production and rapid vegetation recovery.

Drivers and barriers to adoption

Participants acknowledged that historically, the Pokot community solely depended on livestock for sustenance and income, with no tradition of crop cultivation. In the 1980s, the concept of soil erosion and its challenges dawned on them, posing a completely unfamiliar concept. This lack of awareness left the farmers oblivious to the dangers of soil erosion. The failure to adopt mitigation measures can also be attributed to low literacy levels and a rigid gender-based social structure. However, as literacy levels improved and with the intervention of extension services and non-governmental organizations, the community's understanding of soil conservation has transformed. They have been enlightened about soil conservation practices and the advocacy for gender inclusivity has further reduced the gender barriers.

Benefits and challenges of *Fanya Juu* and *Fanya Chini* terraces

The participants highlighted numerous benefits spanning from on-farm like improved soil quality supporting crop growth during dry periods of growing season to landscape benefits like reduced soil deposition into rivers. Challenges included sediment build-up in the dykes hence compromising terrace efficiency, high labour demand and lack of information on where and how to appropriately place the terraces for optimal benefits.

Strategies for solving terrace adoption challenges

The community faces challenges in soil conservation due to the absence of suitable embankment reinforcement plants that can endure the harsh local climate. As a result, alternative erosion control methods need exploration. Educating farmers on soil conservation is key to improving awareness of the problem.

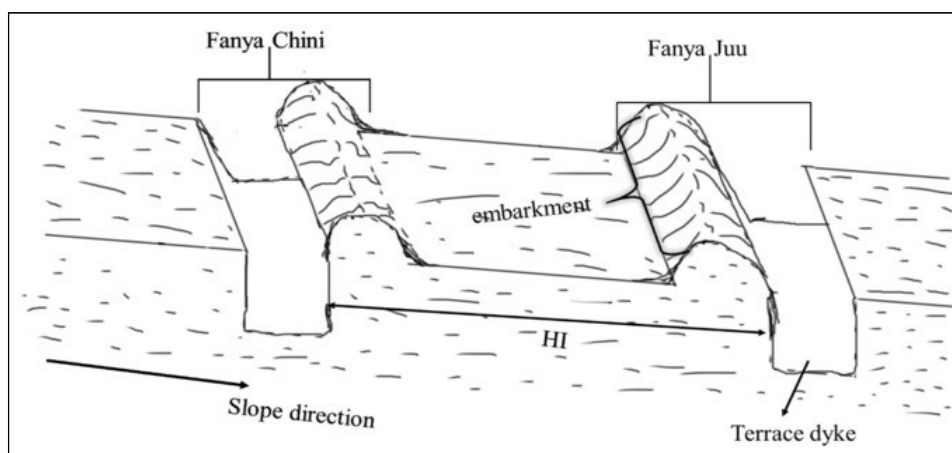


Fig 2: *Fanya Chini* and *Fanya Juu* terrace design field layout.

Indicators and impacts of soil degradations

Communities of drylands of Chepareria are aware of the soil degradations actively occurring at both landscape and farm levels. Loss of soil fertility, gully development, vegetation loss, silt build-up in water resources and on-farm soil loss are the most conspicuous indicators of soil degradation; with a significant rating of 61.0%, 78.0%, 67.8%, 33.9% and 64.4% respectively. Perceived impacts of degradation cut across the reduction of food production areas to the loss of animals, which accidentally fall into deep gullies. Fig 3, shows the impacts of degradation on the farmers.

Farm-level soil conservation practices adopted by farmers

The farmers use six main soil and water conservation practices at the farm level e.g. stone bands, enclosures, cover crops, terracing and ridges (Fig 4). The adoption of each technology varies with the villages and its suitability. Non-governmental soil conservation projects are the main

propagators of the technologies; however, practices such as stone banding have been indigenously developed and inherited.

Main factors influencing agro-pastoral community soil conservation

Among the factors evaluated; land size owned, household size, source of income, gender and agents of soil conservation were found to be ranked as the leading contributors. The latter two were found to significantly influence how the community perceived and reacted toward soil degradation across the villages. Gender is a critical factor in adopting and maintaining soil conservation measures at the farm level. The women initiated live fencing in 30% of the households in the three villages (Table 1). They are also credited for the majority of stone bands constructed in many farms across the topo-sequence. Men initiated live fencing in 25% of the households but participated more in constructing the terrace, either in groups or individually. The study also revealed that men were more engaged in terrace reinforcement than women,

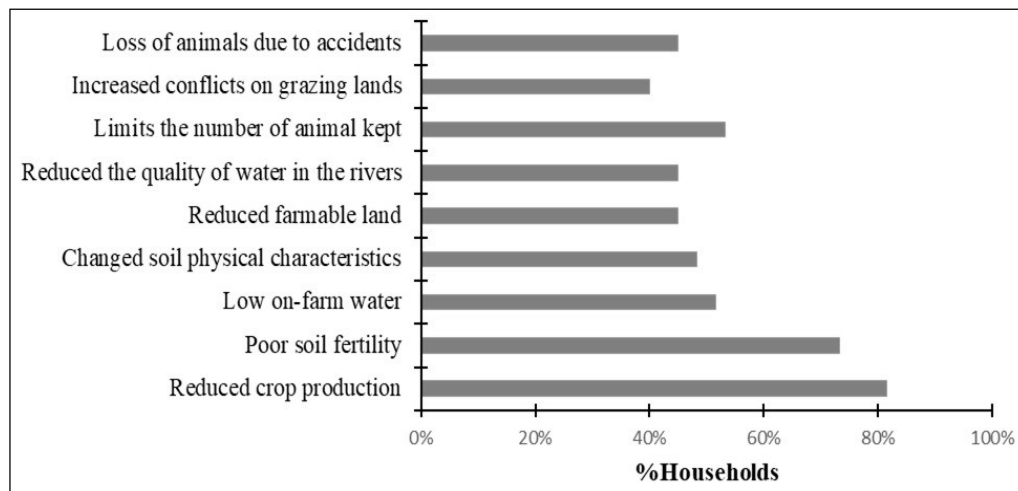


Fig 3: Soil degradation impacts experienced by farmers.

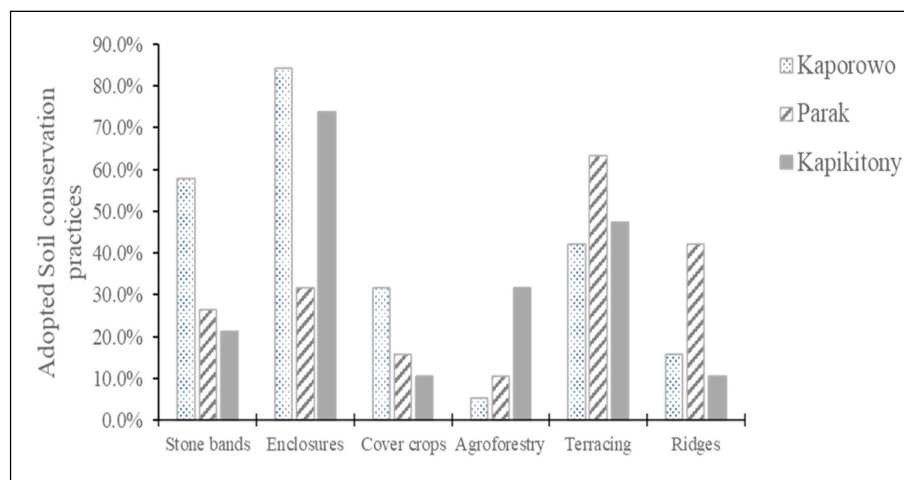


Fig 4: Farm-level soil conservation technologies adopted by farmers in Parak, Kapikitony and Kaporowo villages.

participating in the reinforcement of terraces in 22.7% of the farms where terracing is practised. In comparison, women had only contributed to 9.1% of the reinforced farms at the time of the study. Agents of soil conservation, including non-governmental organizations and research projects, are the main propagators of soil conservation knowledge accounting for 73.3% of SWC practices adopted by the community, especially the newly adopted practices such as agroforestry and terracing. Other agents include; indigenous knowledge inheritance (15.56%) and lead farmers (8.9%). Community participatory approaches such as merry-go-round dubbed “Kemorokorenyo” (meaning let us reclaim our land) are some of the mushrooming agents of SWC facilitating the sharing of soil conservation knowledge.

Terrace characteristics in chepareria ward

Fanya Juu and *Fanya Chini* are the only terrace designs practised in the area. The two designs are constructed in complementarity, with each playing a different role. Among the villages under study, Kaporowo village, located in the mid-slopes, was found to have the most substantial terrace volume per household with an average of $129.6 \pm 15.966 \text{ m}^3$.

Parak village recorded the second-largest volume of terraces per household and Kapikitony, with relatively flat land, had the least terrace volume; 105.89 m^3 (Table 2). Horizontal interval distances also varied as per the location; however, unexpectedly, terraces at high-sloped lands were constructed using long HI compared to other areas (Table 2).

Influence of slope on terrace siltation

Slope significantly contribute to terrace filling with farms that had a slope ranging between 15 and 30%, contributing most to the highest filling of 60 m^3 to 122.7 m^3 terrace volume in all the villages (Fig 5). Spearman's rank-order correlation further affirmed a linear positive correlation between slope and terrace sediment filling [$r_s(37) = 0.628$, $p = 0.001$].

Terrace sediment build-up

Terrace dyke sediment volume differs significantly per village (Fig 6) as shown by Kruskal Wallis (KW) test conducted on sediment volume per village; $H(2) = 6.699$, $p = 0.035$. Parak, which sits on high sloped land experiences on average $79.69 \pm 32.04 \text{ m}^3$ of sediment filling of their dykes during the long rainy season which is the highest among the three villages. Kaporowo and Kapikitony recorded

Table 1: Gender influence on the installation of soil conservation strategies.

	Terraces	Stone bands	Enclosures	Agroforestry	Cover cropping
Male	20%	10%	25%	37%	4%
Female	15%	20%	30%	15%	47%

Table 2: Average length, slope and horizontal interval for terraces constructed at the farm level in the three Chepareria villages.

	Average terrace volume (m^3)	Average horizontal interval (m)	Average slope (%)
Kaporowo	129.6 ± 15.966	22.18 ± 4.15	$15.83\% \pm 5.85$
Parak	103.8 ± 21.45	23.26 ± 10.14	$20.50\% \pm 12.57$
Kapikitony	105.89 ± 33.126	20.24 ± 7.21	$10.0\% \pm 4.47$

*Values in the table are presented as mean $\pm$ standard deviation (SD).

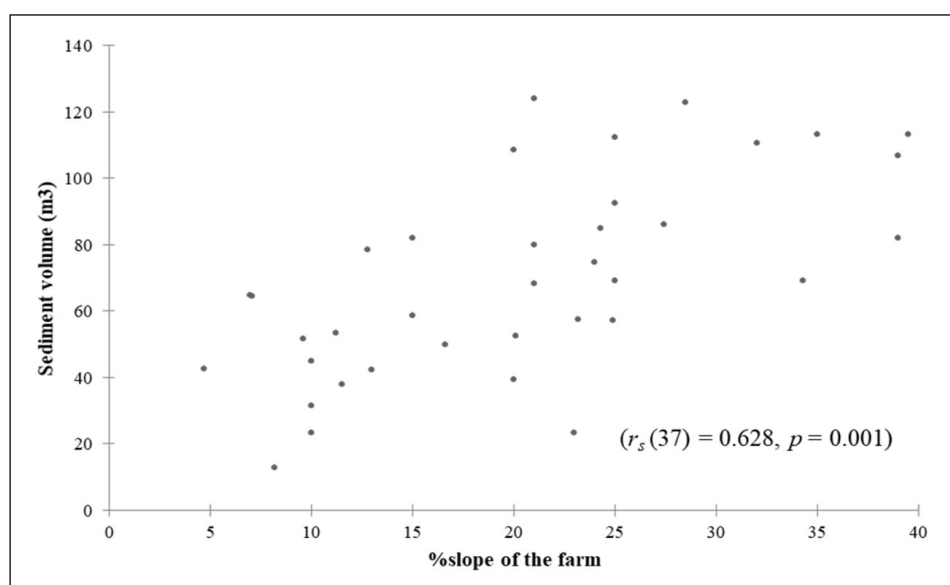


Fig 5: Influence of slope on terrace sedimentation volume.

69.26±27.47 m³ and 47.26±13.72 m³ of dyke filling volume. Farmers who experience the complete filling of their terrace dykes, estimated filling time to range between 12 and 24 months, depending on the terrace's spatial position relative to other terraces and slopes.

Terrace stabilization efforts

Reinforcement of terraces across the three villages is low. Only 31.8% of farmers with terraces had them reinforced. Terrace reinforcement does not significantly differ along with the topo-sequence, as indicated by the Chi-square Test of Independence, $\chi^2(2) = 1.564$, $p = 0.457$. Parak and Kapkitony, had 13.6% reinforced terraces while Kaporowo recorded 4.6%. Locally available herbaceous plants, including; *Aloe vera* (*Aloe spp*) and *Euphorbia spp* were identified as the common terrace reinforcement materials used by farmers. Despite the low number of farmers who practised terrace reinforcement at the time of this study, they all identified it as an important terrace maintenance practice. However, farmers also suggested criteria on which reinforcement materials were to be underscored. They desired multiple benefits grass, trees, or crops that could withstand the local agroecological characteristics. The study found that farmers' preferences were subjective as informed by climate, soil understanding and the need to optimize space. For instance, it was found that more than 60% of farmers in all the villages prefer sweet potatoes, while more than 50% of farmers would use fodder grasses as reinforcement materials (Table 3).

Benefits of terraces as a soil conservation measure

Terrace adoption has a wide spectrum of benefits, ranging from soil conservation at the farm level to restoration of degraded lands on landscape levels. Improvement of food and fodder productivity is ranked by 63.6% of farmers, 5% realized reduced soil erosion across different land slopes, 22.7% indicated increased vegetation regeneration and 31% cited reduced farm surface runoff. Improved water conservation at the farm level was also highlighted as a result of terracing by 27% of farmers. However, the realization of such benefits is subjective to individual farmers and past soil degradation challenges.

Community soil degradation awareness and conservation measures

For a community that is on a transition from pastoralism to crops-animal co-culture, it's expected that their awareness of matters related to soil is shallow. However, in extreme scenarios, the awareness is intrinsically raised by the impacts such as poor crops and fodder production, formation and development of gullies and losses of animals attributed to a reduction in grazing area. The latter directly wrecks the basis of their livelihood and sources of income which elicit the crafting of indigenous solutions. For instance, stone banding and enclosures are indigenously developed practices for soil conservation. However, the nature of these solutions is appropriated by the community social-economic framework, accessibility and availability of the materials within the local context.

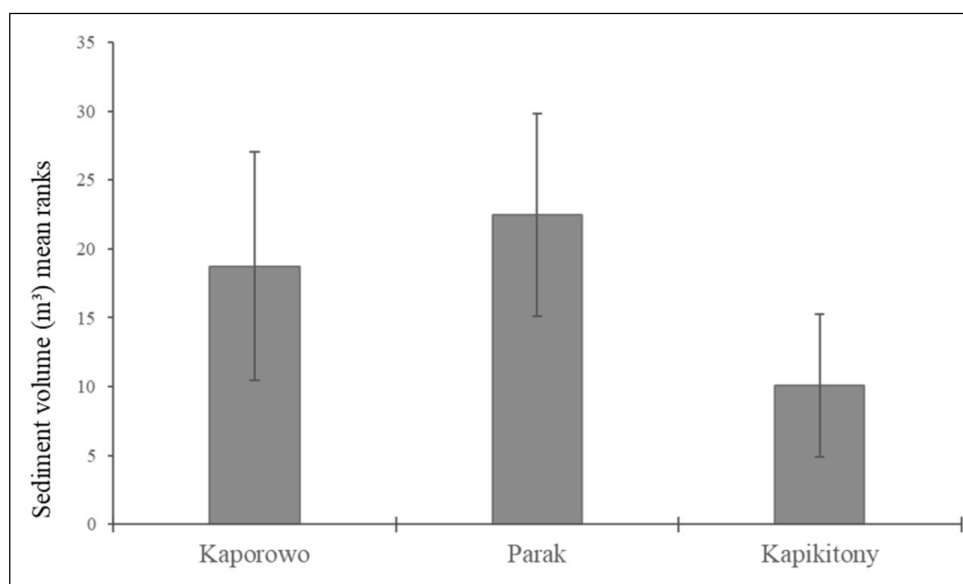


Fig 6: Terrace-dyke sediment volume in the three villages of Chepareria, West Pokot.

Table 3: Some of the terrace reinforcement materials suggested by farmers.

	Fodder grass	Fruit trees	Sweet potatoes	Vegetables	Shrubs	Legumes
Kaporowo	50.0%	50.0%	66.7%	0%	0%	0%
Parak	70%	20%	80%	10%	10%	10%
Kapkitony	80%	60%	60%	0%	20%	0%

In addition, soil conservation agents, particularly research institutions and non-governmental organizations' activities, have been at the forefront of creating awareness among dryland communities. Models like Farmer Research Networks (FRN) (Richardson *et al.*, 2022) and merry-go-rounds are emerging as platforms for participatory community knowledge sharing. Direct participation of the community in co-creating soil conservation solutions has also been found critical in concerting efforts for conservation, as observed by Nigussie *et al.* (2018), they reported the beneficial impacts of centralizing conservation measures around the local communities making them the drivers of the process. Results of the participation approach have been reflected in the increasing numbers of farmers in Parak, Kapkitony and Kaporowo villages who have their farms terraced alongside other soil conservation practices.

The introduction of terraces has set forth numerous benefits in the landscape, translating to improved food and fodder production which are at the heart of agropastoralist livelihood. These benefits support vegetative regrowth in the region, providing farmers with an opportunity to diversify their livestock. Such observations have been recorded worldwide, including Arnáez *et al.* (2015). The two indigenous terraces; (*Fanya Juu* and *Fanya Chini*) are therefore ideal for communities inhabiting drylands with landscape characteristics of West Pokot.

Gender influence on the community soil conservation

Gender disparity is a significant challenge in pastoral communities and significantly affects farm-level soil conservation, as shown by gender contributions toward the adoption of different conservation measures. Women tend to participate more in installing stone bands and live fences than men. The two are perceived as low labour intensive by men, although they require more time to construct indicating that women in the community spent more time on farm activities. Men on the other hand are involved in highly labor-intensive practices like terrace construction. These alone manifests disproportionality of gender participation towards conservation and might be the key reason for the low adoption of some practices. However, with increased awareness of soil degradation and efforts by conservation stakeholders, the gap is rapidly narrowing (Willy and Holm-Müller, 2013).

Influence of slope on terrace sediment Build-up

Terrace filling is severe and happens within 12-24 months after the construction of the terrace, particularly on high-sloped lands compared to moderately and relatively flat-lands. There are several explanatory aspects as the terrace design might not be suitable for the slopes of more than 20%, as suggested by (Masereka, 1983; Mati, 2010). At the high hilly slopes, soils are shallow and fragile with high sand contents and this makes them easy to erode and the embankment formed is very weak to withstand the high amounts of erosive surface run-off experienced at such slopes.

Reinforcement of terrace embankments

Farmers practicing *Fanya Juu* terraces were found to have adopted locally available herbaceous plants such as *Aloe spp* species for terrace reinforcement. Terrace embankment reinforcement is key in reducing sedimentation of the dykes and contributes to the terrace's general efficiency (Gebreyess and Amare, 2019). However, the material used for reinforcement depends on their availability and users' agro-ecological zone e.g. drought-resistant grass has been recommended for upper Tana, Kenya (Muriuki and Macharia, 2011), while vetiver grass (*Vertiveriazizanooides*) has been recommended for the upper Blue Nile, Ethiopia (Sultan *et al.*, 2018). Contrary to findings made in this study, reinforcement materials should possess other benefits besides stabilizing terrace embankments (Ahmed, 2018), such as fodder or crops. Adopting locally available herbaceous plants like *Aloe spp* for reinforcement reflects farmers' desperation to access information and lack of appropriate materials for that purpose.

CONCLUSION

Soil erosion is the main land degradation process experienced in agro-pastoral drylands aggravated by land characteristics (high slope), soil characteristics (young and fragile) and anthropogenic activities. The advent of participatory community farm-level soil management practices raises awareness of land degradation and improves how conservation practices are adopted. More effective conservation practices, like terraces, have been adopted through the approach. Despite terraces proving a potential solution to farm-level soil degradation, sediment build-up in the dykes has compromised their efficiency and increased maintenance costs. The two factors introduce trade-offs that might hinder the adoption of the structures by income-constrained agro-pastoral communities. Furthermore, inadequate information on the effectiveness of cover crops as reinforcement materials for terraces is a challenge that has extensively hindered their use and thus a study on it is warranted.

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Conflict of interest

All authors declare that they have no conflict of interest.

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