Physiognomies of the Temporal Patterns of Small-Scale Farmer-Managed Soil Moisture Conservation Interventions in the Semi-Arid Lands of Kenya

Kasuki M. M.*, Dr. Mwangi M., Dr. Mutia G.****

Margaret Mbinya Kasuki
Department of Water and Wastewater, Kenya Water Institute
Dr. Moses Mwangi
Department of Hydrology and Aquatic Sciences, South Eastern Kenya University
Dr. Grace Mutia
Department of Hydrology and Aquatic Sciences, South Eastern Kenya University

DOI: 10.29322/IJSRP.16.06.2026.p17422
https://dx.doi.org/10.29322/IJSRP.16.06.2026.p17422

Paper Received Date: 10th May 2026
Paper Acceptance Date: 24th June 2026
Paper Publication Date: 28th June 2026

Abstract
The smallholder farmers indigenous soil moisture conservation practices in the semi-arid lands of Kenya go through different experiences in dry and wet seasons. Temporal weather variations that characterize in the name of erratic rainfall, prolonged dry spells, and fluctuating temperatures dictate the effectiveness of the soil moisture conservation practices. Researches on farmer-managed systems have not established clear time-based patterns that show when farmers build their soil moisture conservation systems and use and repair them and make changes to their systems. Therefore, this paper shares findings from a study on the seasonal practices and challenges in establishing, using and managing soil moisture conservation methods in semi-arid regions. A total of 60 small scale agropastoralist farmers in the Ikanga-Kyatune Ward in Kitui County, Kenya were involved in the research. The study used structured questionnaires in data collection and descriptive statistics in analysis. The study results show that the majority (80%) of the farmers create soil conservation structures during the dry seasons as the most convenient period in readiness to collect and store moisture during the wet seasons. 76% of the farmers of the use the local agricultural calendar for the structures maintenance activities to pave way for crops planting. The main challenge resulting from the seasonal weather variations emanates from moisture evaporation losses as experienced by 78 percent of farmers. Damages by pests is associated by 45% of the farmers to weather changes with moisture presence attracting the problem. Farmers show adaptive abilities with 28 percent of them embracing new techniques, characterized by system redesign that appropriately retains moisture retention in the soil. 72% of the study participants were found not to make any changes in the designs despite the challenges faced which are associated to low knowledge skills and economic positions. The study concludes that temporal shifts require adaptive, localized management practices to maximize water storage in the soil in the vulnerable zones. Consequently, the study proposes a time-sensitive framework while supporting farmer-managed soil moisture conservations in the semi-arid areas.

Index Terms: effectiveness, farmer-managed, maintenance, rainfed, vulnerable.

I. Introduction

he challenges of conserving soil moisture in the semi-arid areas Trepresent temporal problems because of the region's scarcity of rainfall and variability with respect to when it occurs, how long it lasts, and how much falls (Seneviratne, *et al.,* 2010; Vereecken, *et al.,* 2014). Farmers are called to capture and store adequate water when it becomes available to base their crops' production for the duration of the dry period. The mismatch between when water is available and when crops need water is the most defining characteristic of rain-fed agriculture in the dry lands (Rockström, *et al.,* 2010). However, the available literature related to water-soil conservation has generally lacked temporal consideration. Most research documents are concerned with how farmer grow crops but not the timing or significance of the timing (Mwangi, *et al.,* 2020; Mutiso, *et al.,* 2020). Cognizance is the success of soil moisture conservation practice depends primarily upon the timing of the practice compared to average rainfall and crop development and seasonal rhythms of the farmer (Kader, *et al.,* 2017). The judgement of for example when farmers create bunds and/or terraces, clear channels, apply mulch/manure and repair damage from excessive rainfall are just as important as the design of the practice (Zhang, *et al.,* 2015). Bunds that are constructed after the beginning of the rainy season will not collect much water, and/leaving the clearing of channels until too late do not help alleviate water logging issues, and delays the repair of damage until the damage is done may likely lead to complete loss of a cropland in that growing season (Zhang, *et al.,* 2015).

The second inadequacy in the existing literature is that it is largely limited to studying researcher-managed interventions in isolation from studying how farmers are managing soil moisture conservation. Researchers have made numerous attempts to evaluate the biophysical performance of different techniques under controlled experimental circumstances and have produced many examples of studies which document the biophysical effectiveness of a wide variety of different types of conservation technologies (Lehmann, *et al.,* 2021; Bai, *et al.,* 2022). However, studies do not provide much information on how farmers manage soil moisture conservation on their own in seasons if they do not have access to the same type of technical assistance provided to them through researcher-managed systems, the type of temporal rhythms of farmer-managed systems, and what types of obstacles farmers face when managing soil moisture on their own. This knowledge gap is important because the majority of smallholder farmers in semi-arid zones are managing soil moisture solely on their own (Mwangi, *et al.,* 2020; Mutiso, *et al.,* 2018). Very few farmers have access to agricultural extension services, the vast majority of external interventions involving conservation techniques are temporary, and most farmers are planning, implementing and maintaining their own conservation efforts independently using only their own local knowledge, labour and materials (Van Beek, *et al*., 2020; Jellason, Conway, & Baines, 2021). Consequently, understanding the realities of autonomous systems can help researchers in designing interventions that support and compliment farmer innovation. Many authors who refer to indigenous soil and water conservation have taken a static view of such practices. This study has however aimed to illustrate that they operate within dynamic, time-structured systems that have various challenges, among them being climatic.

A. Statement of the Problem

The main obstacle to seasonal soil moisture conservation efforts in the semi-arid lands exists because of their need to address challenges over extended time periods. Rainfall occurs infrequently while its patterns of occurrence and intensity show extreme variability according to Seneviratne, *et al.* (2010) and Vereecken, *et al.* (2014). Farmers consequently need to collect and keep water during their unpredictable short rainfall periods so they can protect their crops throughout the entire duration of dry weathers. Rainfed agriculture in the regions experience its most critical aspect when there is a time gap between the water supply which exists for farming and the water requirements which crops need to grow (Rockström, *et al.,* 2010). Researches from multiple decades have shown farmers to practice building bunds and terraces and channels together with selection of materials which includes soil and stones and crop residues such as maize, millet and beans. The research studies however lack sufficient information about the times when farmers build their structures, when they do maintenance, or the challenges and timing of events affect farmers' work process. On the whole, the effectiveness of conservation practices depend on timing needs to match both rainfall patterns and crop growth stages and the seasonal patterns that govern farming activities in household settings (Kader, *et al.,* 2017 and Zhang, *et al.,* 2015). A bund constructed after the rains capture little water, channels cleared too late cannot prevent waterlogging, and repairs delayed until after damage occurs may come too late to save a season's crops. The outcomes of the process depend on both the time-based choices which people make and the actual design work which the engineers conduct to establish the system's structure (Rockström, *et al*., 2010; Vereecken, *et al*., 2014). The majority of smallholders in the semi-arid ecological zones practice farmer-managed systems because they face a major gap between their current understanding of time and their actual farming operations. As such, soil moisture conservation activities depend on farmers who execute own plans with own resources while extension services provide only temporary support (Mwangi, *et al.,* 2020; Mutiso, *et al.,* 2018).

Researches have not yet established the temporal decision-making patterns which govern farmer choices in the semi-arid land areas where majority of farmers rely on rainfed agriculture. Study findings reveal that soil conservation practices face various obstacles that mitigate appropriate adoption (Mburu, *et al.,* 2018; Mutua, *et al.,* 2021) and discovered (Mwangi, *et al.,* 2020; Waswa, *et al.,* 2021). They however do not explore the critical timing questions. Agricultural practices in the semi-arid areas require different approaches at various times which include construction, operation and maintenance of structures, and operational loss assessment through evaporation versus runoff damage. The gap has significant importance because it requires temporal pattern comprehension to determine conservation success or failure because structural failures occur from incorrect construction, maintenance schedules, and design flaws. Subsequabtly, there is need for temporal data about different agricultural activities to provide timely assistance to farmers to overcome experience such as evaporation, pest, runoff and waterlogging issues. There is need for creation of interventions that match farmers' natural work patterns which will lead to effective implementation. The gap between different factors results in two main challenges for farmers. Farmers demonstrate resistance to change because they operate in time-constrained environments. The lack of knowledge about the specific moments which farmers face and their impact on decision-making result in missing intended goals. The present study addresses this gap by providing a systematic empirical documentation of temporal patterns in farmer-managed soil moisture conservation in the Ikanga-Kyatune Ward. The research examines three main aspects which include determining when conservation structures are constructed, how they are used and the benefits accrued, and how maintenance activities are planned in relation to specific timing, frequency patterns, seasonal challenges and corresponding solutions, specific moments when conservation activities break down and when conservation activities stop working. The study investigates when farmers carry out their activities and the reasons behind this behavior to create a time-based framework which help design farming activities that match the natural working cycles of smallholder farming operations in the semi-arid regions of Kenya.

III. Study Methodology

A. Description of the Study Area

The study was carried out in the Ikanga-Kyatune Ward of Kitui County, Kenya. The area is between latitudes 1°30' S to 2°30'S and the longitude range is between 37°30'E to 38°30'E. The climatic conditions are of Agro-Ecological Zones V & VI (Semi-Humid to Semi-Arid and Arid) where annual rainfall averages between 400mm and 700mm over a given area and seasonally (Jaetzold, 2012; Wambua, 2019). It has temperatures ranging from 20 °C to 32 °C. However, due to occurrence of high levels of evaporation and transpiration, soil moisture quickly evaporates in the period immediately following rainfall (Seneviratne, *et al*., 2010; Vereecken, *et al*., 2014). Soils and landforms in the area have a basement complex rock formation which cause the texture to consist primarily of sandy loam, having poor soil structure, organic matter content and ability to hold water (Kihiu & Mberu, 2021; Okeyo, *et al.,* 2018).

The Ikanga-Kyatune region exhibits rugged and undulating terrain which gives way to steep slope causing increasing runoff and risk for erosion. The smallholder farmers in the region use rainfall as their main means of water for sustaining crop production, and primarily grow short-cycle crops like maize, millet, sorghum, green grams, cowpeas, and pigeon pea (Mutua, *et al.,* 2021). Raising livestock supports the production of crops that heavily rely on family labour. Water availability is limited, with the area being dominated by seasonal rivers. Groundwater exists at significant depths due to the nature of the basement complex geology that make up the area, hence proving difficult to access (WRMA, 2020). Most farmers in the area largely rely on rainfed agriculture for production, therefore, making it paramount for farmers to conserve moisture content of soils to ensure production is achieved.

B. Data Collection and Analysis

Data collection was effected in February 2026 by a team of research assistants that applied structured questionnaires on 60 smallholder farmers. The research team used snowballing effect sampling to contact farmers because there were no complete farmer records available in the study area. The study sought information on biophysical factors which affect soil moisture conservation by choosing villages that represented three different topographic areas namely, flat, gentle slope and, steep slopes. Three distinct soil types (loamy, clayey and sandy) and two different drainage systems (well-drained, poorly drained) were considered. The research questions were translated from English to Kikamba language before conducting administering them on interviewees.

The study purposed to document the timing of construction, use, maintenance and benefits derived from soil moisture conservation structures on a seasonal basis. The approach allowed establishment of the frequency and timing of interventions, as well as the activities performed, identification of the temporal patterns of challenges faced by farmers and the adaptive responses, distinguishing the temporal disjunctions that diminish the effectiveness of conservation efforts and, providing an explanation of the temporal patterns identified through an examination of farmers' decisions, resource constraints, and environmental conditions. Descriptive statistics were employed to build an understanding how the farmers' temporal farm work patterns.

IV. Results and Discussions

A. Types of Soil Moisture Conservation Structures

Table 1 shows that the Kianga-Kyatune Ward farmers have various methods to conserve moisture in the soil. Bunds are used by 58% of farmers, terraces by 18%, and channels/ditches by 12%. Other methods include cover crops (7%), manure application (2%) and tree planting (2%). Analysis show that soil comprising of sandy loam and shallow soils derived from basement complex rock formation was the main material used by 85% of farmers with soil moisture conservation structures, followed by stones (8%) harvested from the local landscape (fields and riverbeds) crop residues (5%), and manure (2%). The soil moisture conservation practices reveal that farmers only make use of materials known and available to them. The measures preference is a reflection of what is observed in most of sub-Saharan Africa, where farmers have historically used materials and labor that are available to them (Reij, *et al.,* 1996). No farmer was found to use biochar and only one farmer was found to use mulch as cover crops on fruit trees, consequently livestock feed and fuel. However, people acknowledge that a crop grown in former charcoal kilns *(ndumbia)* spots does better compared to others in the vicinity.

Table 1. Soil Moisture Conservation Methods

Method	[N=60]
Bunds	35
Terraces	11
Channels/ditches	7
Cover crops	4
Manure application	2
Planting trees	1

B. Temporal Patterns of Use and Benefit

Farmers reported using their soil moisture conservation structures across multiple seasons (Table 2).

The majority (58%) of farmers were found to use the structures during the wet season because they capture the heavy rainfall, retain water, and increase crop moisture levels. 12 farmers (20%) use captured rainwater during the dry periods from earlier rains to maintain moisture levels, which supports dry-season cropping and provides moisture for perennial crops**.** 5 farmers (8%) were found to use the structures throughout both seasons because their conservation structures serve multiple functions across the agricultural calendar, providing benefits during the wet season, dry season, and short rains depending on water availability and crop needs**.** About 14% of the farmers did not say what season they preferred, mostly due to issues tied to remembering things, plus the fact that their farming habits don’t follow a steady

Table 2. Seasonal Use of Structures

Season	Structure Use [N=60]	Most Beneficial [N=60]
Wet season	35	20
Dry season	12	18
Short rains	0	15
Both seasons	5	0
Not specified	8	7

seasonal rhythm. In a few cases, it was also that they simply could not tell which season was giving the most benefit.

20 farmers (33%) indicated to reap the highest benefits in the wet season, 18 farmers (30%) realizing their greatest benefit during the dry season while 15 farmers (25%) in the short rains. The distribution of benefits across different seasons reflects the multiple functions that soil moisture conservation structures serve throughout the year. The short rains offer a third dimension of benefits because they provide more dependable rainfall than long rains which occur in the semi-arid region. The system which collects and holds rainwater from the storm events enable farmers to grow crops during the critical time when proper planting determines their entire farming season success. The soil moisture conservation structures function as multiple agricultural calendar benefits because they operate through different agricultural seasons. The first temporal disjuncture emerges because most (80%) of the structure's construction happens during the dry seasons while farmers benefit during wet seasons and short rains. This separation affects how people feel about their work and how they choose to invest their resources. The pattern of building during dry seasons to gain benefits during wet seasons shows the fundamental hydrological logic of dryland farming which Rockström, *et al.* (2010) describe.

Farmers build their water-harvesting systems to handle the unpredictable and intense rainfall which occurs during specific times while their crops require water throughout the entire growth period. Kader, *et al.* (2017) show that effective in-situ water conservation requires structures to exist before rain occurs because they enable moisture collection and storage. The farmers' preference for dry season construction thus reflects sound hydrological reasoning embedded in local practice. Similar findings have been noted in other areas such as the Sahel region where farmers create zai pits during the dry season to collect moisture and nutrients in order to grow crops once the rain begins (Reij, *et al.,* 1996). Likewise, U.S. farmers who plant cover crops encounter this same processing; with their benefits coming later in the subsequent crop cycle, many farmers will not continue with such practices, thus demonstrating that the time lag between the investment in conservation and the return will be a major aspect of all dryland farming systems globally.

The dry season serves as the time when farmers construct soil moisture conservation structures because labour availability is possible. On one hand, agricultural tasks of planting and weeding and harvesting are limited during dry periods while dry soils offer superior workability, are easier to dig, shape, and manipulate compared to waterlogged or saturated soils, resulting in better-formed and more durable structures. The construction work that takes place during the dry season establishes complete operational structures which function properly before the arrival of rain. The peak period for material availability occurs after harvest because there are abundant and accessible crop residues and other organic materials which farmers use for conservation structure building. The combination of these factors establishes a specific time sequence which shows that conservation construction work can be accomplished during the dry season because it provides all the necessary elements for successful execution.

The use of the dry period is due to the fact that the agricultural calendar creates identifiable peaks and valleys in labour demand. Therefore, farmers do not have the flexibility to change the timing of the structure construction because of the agricultural calendar an aspect also reported in Van Beek, *et al.,* (2020). Farmers face competing demands on their time and resources during peak seasons. Therefore, in allocating labor, they give preference to those activities that provide immediate benefits, such as planting crops that determine whether a crop can be harvested, rather than maintaining their land or equipment that may impact future production outcomes (Rosário, *et al.,* 2022).

Farmers who work on slopes with 13% steepness report that they do dry season construction work because terracing work needs more workers and longer time periods which dry seasons offer. All construction operations need to occur during dry conditions in order to reach operational status before the first rains arrive which brings the strongest and most important rainfall. Cognizance is there is much more material available immediately after harvest, as there is much more organic material available, which can be used in construction activities. In Nepal, farmers have traditionally built and maintained gully control structures during the dry season in preparation for the monsoon rains (Atreya, *et al.,* 2008). The objective is of managing channeled water during the rainy season and conserving it for the dry season. The farmers use locally sourced materials and traditional knowledge (Atreya, *et al.,* 2008). A similar phenomenon is noted in the Ethiopian highlands, where farmers build soil and water conservation structures during the dry season with the objective of having them ready for the start of the main rainy season (Adimassu, *et al.,* 2017). The fact that this phenomenon is noted in different geographical settings can be taken to imply that the temporal logic of constructing moisture conservation structures in the dry season for the benefit of the wet season as a principle of indigenous soil moisture conservation in bimodal rainfall environments.

C. Maintenance Activities and Timing

The process of maintaining moisture conservation structures serves as an essential component of plants water conservation management. More than three-quarters (76%) of farmers have a proactive maintenance schedule for structures before they plant (Table 3). 27% of farmers do not however maintain their structures until after the rainy season. 15% of farmers only repair their structures after damage is evident. A major concern is that in 53% of all reported damages occur as a result of rains. This presents a time delay between when structures fail and when they are fixed. There are therefore times when a farmer has to wait for repair on the structures until a later point in time, because some of the damages cannot be anticipated, similar to the findings reported in Mupangwa, *et al.,* (2020).

Table 3. Timing of Maintenance Activities

Activity	**[N=60**
Before planting	42
After rains	15
When damaged	8

Heavy rain can happen during a rainstorm that can exceed the design capacity of a structure used for soil moisture conservation, and/or the amount of water concentrated from unusual rainfall patterns can flow through a place that was not anticipated that the farmers will have an issue when that happens (Van Beek, *et al.,* 2020). The timing of the maintenance work matches farming schedules because it happens during the time when farmers prepare their fields and assign workers to their cropping tasks, which enables them to perform maintenance activities without interrupting their regular duties.

The combination of maintenance strategies reflect the complex situation farmers face, balancing ideal management practices with the unpredictable nature of the weather and the practical limits of available labor and resources. While some farmers report engaging in maintenance tasks at different times throughout the year, 15 reported conducting maintenance after rains. The method handles repair work from the previous rainy season which requires fixing during the favorable weather conditions. Farmers who use this method opine that delays in fixing the damaged soil moisture conservation practice create worse problems during consequent seasons, which requires them to fix before the start of the next rainfall season. Eight farmers reported maintaining their structures only after breakage. The farmers react at this particular time because of resources availability issues and the source and extent of damage. Some types of damage emanate from strong storms that can neither be predicted.

The presence of reactive maintenance which occur immediately after damaging events establishes the second temporal disjuncture because it creates a time delay between damage occurrence and repair. Farmers who delay their response until they find damage experience crop losses, water losses and soil losses. The challenge of maintenance timing is a recurring theme in the literature on indigenous soil and water management. In the Indian highlands of Himachal Pradesh, farmers have developed their own seasonal farming practices which include ploughing at dawn to maintain soil moisture until its evaporation (Sharma, *et al.,* 2020). The researchers documented more than 30 native technological methods which indigenous peoples used to manage soil and water resources, and these methods operated at specific times according to climatic patterns (Sharma, *et al.,* 2020). Research about conservation agriculture practices in Tanzania and South Africa shows that farmers do not maintain their fields when they have limited workers because they prefer to focus on planting and harvesting activities (Kahimba, *et al.,* 2014; Mkonda & He, 2018). The current study found that farmers in semi-arid areas rely on the availability of workers to determine when to complete maintenance work. Indigenous gully control technology in Nepal show that the construction and maintenance of gullies demands attention during the busy agricultural calendar, significantly adding to the labour costs (Atreya, *et al.,* 2008). The different context shows that labour scheduling problems exist because smallholder farmers use farming systems with structural problems.

D. Seasonal Patterns and Soil Moisture Conservation Adversities

Farmers in the Ikanga-Kyatune Ward have an indigenous seasonal soil moisture conservation calendar that guides on when to build, when to maintain, and how to prepare for subsequent activities. The seasonal patterns face various challenges which determine successes and failures. Table 4 shows the various soil moisture conservation challenges in the study area, based on the dry and wet seasonal patterns.

78% of the farmers repute the dry season to present them with the main problem of high soil moisture losses due to evaporation that result from prevailing high temperatures, low humidity and absence of rainfall. The condition allows mulch to decompose or be removed, consequently exposing soils to moisture losses. Pests and termites menace are experienced by 45 percent of farmers, causing damage to crops. While pests target the last remaining plants and crop waste and stored items, termites attack buildings and live plants. 42% of the farmers experience agricultural losses because plants fail to survive. Drought-tolerant crops like millet, sorghum and cowpeas show better survival because dry periods continue until all soil moisture is used before their harvesting stage. According to 13% of the farmers, soil compaction through repeated wet-dry cycles cause surface crusting which hinder water infiltration and seedling emergence. The arrival of rains brings a complete shift in challenges. Intense rainfall on dry crusted soils creates surface runoff which removes topsoil and nutrients and organic matter while stopping water from entering the ground and recharging groundwater, a finding also recorded in Mupangwa and Ngwira, (2020).

Farmers face damage to soil moisture conservation structures through heavy rains. 53% of the farmers indicate experiencing destruction of their systems by rains which wash the structures away, breach channels and collapse terraces. Waterlogging affects 28% of farmers because flat lands with clay soils and poor drainage create conditions that generate saturated root zones which exclude oxygen and drown crops during germination and later growth stages. The 23% of farmers who experience sediment accumulation in channels and behind structures face the additional maintenance needs because soil particles from upslope areas settle where flow velocity decreases during peak wet season activities. The seasonal differentiation shows consistency with research findings from other dryland regions. Bogie *et al*. (2018) shares on the Sahel experiences where dry season rock-hard soils that produce high runoff and erosion rates during first rain events. Heavy rains create structural damage in the

Table 4. Seasonal Challenges Faced by Farmers

Dry Season Challenges	[N=60]	Wet Season Challenges	[N=60]
High evaporation losses	47	Runoff/erosion	37
Termite/pest damage	27	Damage from heavy rain	32
Poor plant survival	25	Waterlogging	17
Hard/compacted soil	8	Sediment build-up	14
Clogging	1	None reported	2

Ethiopian highlands which leads to conservation maintenance needs (Adimassu, *et al.* 2017). The southern African farmers report a unified pattern because they experience dry season problems which include evaporation and pest control and they face wet season issues which include runoff and erosion and water-logging (Mupangwa, *et al.,* 2020). The findings show that dryland farming systems across the world experience seasonal challenges because these systems depend on their basic seasonal patterns. The finding shows that dry season solutions need to solve evaporation problems while controlling pests. The solution requires wet season solutions which need to manage runoff and strengthen structural elements which CIAT (2025) also vouches for.

E. Adaptive Responses to Challenges

Table 5 show the various soil moisture adaptive practices in the study area aimed to overcome challenges. 60% of farmers never modified their soil moisture conservation structures. Improved drainage systems were adopted by 19% of farmers while 10% reshaped their structures by using bund and terrace systems to control water flow and water runoff. 6% of farmers adapted their structures by modifying their size and spacing. The farmers who changed their materials were 3% of the farmer population who used soil bunds with added stones. Most farmers failed to adapt because of multiple and interlinked factors. A farmer added reinforcement while another carried out reconstruction works of the moisture conservation structures. 95% of the farmers cited knowledge constraints to be a primary challenge in embracing different practices. By and large, farmers depend on their self-knowledge without physical access to different techniques or successful moisture conservation alternatives. Resource limitations prevent adaptation because modifications require additional materials and labour, yet subsistence farmers who operate with minimal buffers cannot afford experimentation. Farmers who depend on their annual success for survival choose known suboptimal outcomes instead of taking unpredictable risks to protect their livelihoods.

Table 5. Adaptive Responses to Challenges

Adaptation Measure	[N=60]
No modification made	36
Improved drainage	11
Reshaped structures	6
Adjusted size/spacing	4
Changed materials used	2
Added reinforcement	1

Farmers who cannot access essential resources because institutional isolation prevents them from joining farmer groups and receiving extension services and knowledge-sharing platforms that would help them learn from nearby successful growers. Farmers who adapted demonstrate improved drainage and reshaping, spacing adjustments that benefit from the local knowledge systems. The challenge involves establishing institutional systems which enable knowledge dissemination between various parties. In Tanzania, only 17.4% of farmers practiced recommended conservation techniques despite awareness of benefits, with pests, erratic rainfall, and lack of information and resources identified as major barriers (Mkonda & He, 2018). The three main barriers that farmers face in South Africa include limited input availability and restricted information access and insufficient financial resources according to research by Mkenda, *et al.* in (2023). In the study area, information access emerged as the most (80%) important factor in driving adoption and adaptation practices among farmers. Jellason *et al*. (2021) established that farmers who join groups and receive extension services and learned from fellow farmers increased their practice adaptation to local conditions. This demonstrates that institutional mechanisms serve as essential elements for effective learning and knowledge sharing processes.

F. Crop Choices and Temporal Strategies

Farmers cultivate a variety of crops during the wet season which included maize and beans and green grams and cowpeas and pigeon peas and millet and sorghum and vegetables, revealing crop choices temporal strategies (Table 6). The dry season experiences limited crop production with maize being the main crop. Smaller sections of land are used to grow vegetables which include tomatoes, green grams and kales, made possible by residual moisture and small-scale irrigation. 28% of the farmers cite the ability of farmers to engage in dry season cropping being dependent on adequacy of residual moisture from previous growing seasons that was cited by. The second aspect is whether the farmers can supplement the residual moisture using irrigation methods such as shallow wells or channels to get additional water (Shah, *et al.,* 2012). The farmers who reported engaging in dry season cropping had access to this moisture due to good landscape position, functional conservation structures, or irrigation infrastructure.

Table 6. Crops Grown by Season

Dry Season Crops	[N=60]	Wet Season Crops	[N=60]
Maize	12	Maize	58
Tomatoes	2	Beans	28
Kales	2	Green grams	40
Beans	1	Cowpeas	30
None	43	Pigeon peas	8
		Millet	3
		Sorghum	3
		Vegetables	3

Another factor contributing to the temporal disconnection is the difference between the farmers that invest in structures for the purpose of having a crop during the dry season versus the farmers that have a crop during the dry season and are motivated to continue maintaining the same structures that allow for crop production. Even though maize is a much less drought resistant crop compared to traditional grains such as millet and sorghum, the consistency in growing maize indicates a general trend of growing crops based on the average dietary preferences and market reliance patterns across the eastern region of Africa (Smale, *et al.,* 2013). The average farmer is therefore systematically growing maize during the wet season and then is unable to continue growing crops during the dry season. Throughout the Sahel, researchers have identified numerous examples of farmers demonstrating how they can use alternate land management systems such as agroforestry to enhance agricultural production during dry periods (Bogie, *et al*., 2018). While the benefits of the temporal and spatial separation of water use research conducted on two native shrubs, *Piliostigmareticulatum* and *Guierasenegalensis* are realized predominantly during periods of water availability/farmer demand misalignment. Consequently, farmers can make a significant investment by integrating the native shrub systems into their crops. By enabling temporal complementarity through experience, not managed in its own right, these four disjunctions can also be seen as a way to harness opportunities where they exist rather than manage the challenges created by the disjunctions.

V. Conclusion and Recommendations

This study concludes that farmer-managed soil moisture conservation system in the semi-arid is structured around time frames that farmers have developed for constructing, maintaining, using and adapting to technology based on biophysical cycles, social structures, and accumulated experience. The temporal structure results in several temporal disjuncture that impede the capacity of farmers to effectively conserve moisture in the soil. Interventions that do not consider the temporal dynamics end up being ineffective in helping farmers. Successful interventions will therefore need to work with farmers' seasonal rhythms by assisting them with construction during the dry season, providing technical assistance for appropriate maintenance pre-planting, addressing seasonal challenges as they arise, and helping farmers to create conditions that foster collective adaptive capacity and knowledge sharing. The timing of extension and development agencies conservation support should therefore correspond with the schedule of farmers rather than with administrative calendars. Support staff services need training on how to make their interventions start with the peoples' knowledge, and use temporal analysis to provide seasonally appropriate information such as pest and evaporation control during dry seasons, and storm-water management during rainy seasons. Investment in farmer organizations is vouched for to provide opportunities for knowledge sharing and collective action through learning. On the whole, farmers' development support agencies are recommended to conduct temporal assessments before designing interventions in order to ensure that their interventions are structured in concert with farmers' rhythms while at the same time establishing learning opportunities through farmer exchange programs and demonstration events. Researchers in the semi-arid regions are called upon to include temporal variables in their soil moisture conservation studies by documenting the farmers' practices, recognizing prevailing seasonal variations.

References

[1] Alliance Biodiversity International - CIAT (2025) Cropping calendar and agro-advisory system: Delivering timely guidance to Ghanaian farmers. Alliance Biodiversity International.

[2] B. M. Wambua, F. Mutua, & F. Nzioka (2019) Rainfall variability and trends over Kitui County, Kenya. Journal of Meteorology and Related Sciences, 12(1), 45–58.

[3] C. L. Van Beek, M. Ong'ayo, & K. E. Giller (2020) Farmer perceptions of biochar and mulch technologies in sub-Saharan Africa: A review, Agronomy for Sustainable Development, 40, 15.

[4] C. Reij, I. Scoones, & C. Toulmin (1996). Sustaining the soil: Indigenous soil and water conservation in Africa. Earthscan Publications.

[5] E. Mutua, R. Kimani, & R. Njeru (2021) Field evaluation of biochar and mulch for soil moisture retention and crop growth in Kitui and Makueni counties, Kenya. Journal of Soil Science and Environmental Management, 12(4), 56–67.

[6] F. C. Kahimba, K. D. Mutabazi, S. D. Tumbo, K. F. Masuki, & W. B. Mbungu (2014) Adoption and scaling-up of conservation agriculture in Tanzania: A case of Arumeru and Karatu districts. Livestock Research for Rural Development, 26(4), 1–12.

[7] F. Mutiso, S. Wambua, & J. Mutua (2018) Farmer innovation in dryland water management: Lessons from Makueni, Kenya. African Journal of Agricultural Research, 13(23), 1181–1192.

[8] F. Mutiso, S. Wambua, & J. Mutua (2020) Participatory approaches to conservation technology adoption in Makueni and Machakos counties. Journal of Environmental Management, 266, 110626.

[9] Government of Kenya (2021) Kenya National Adaptation Plan 2021-2025, Ministry of Environment and Forestry.

[10] H. M. Mwangi, C. K. K. Gachene, & J. K. Mburu (2020) Socio-economic constraints to adoption of soil moisture conservation practices in eastern Kenya. Land Use Policy, 95, 104654.

[11] H. Vereecken, J. A. Huisman, Y. Pachepsky, C. Montzka, J. van der Kruk, H. Bogena, L. Weihermüller, M. Herbst, & J. A. Vrugt (2014) Spatio-temporal dynamics of soil moisture at field scale. Journal of Hydrology, 516, 76–96.

[12] J. Lehmann, A. Cowie, C. A. Masiello, C. Kammann, D. Woolf, J. E. Amonette, M. L. Cayuela, M. Camps-Arbestain, & T. Whitman (2021). Biochar in climate change mitigation. Nature Geoscience, 14, 883–892.

[13] J. M. Okeyo, M. Mucheru-Muna, & J. Mugwe (2018) Selected soil physico-chemical properties in smallholder farms in Kitui County, Kenya. Journal of Soil Science and Environmental Management, 9(5), 63–73.

[14] J. N. Pretty, I. Guijt, J. Thompson, & I. Scoones (1995) Participatory learning and action: A trainer's guide. International Institute for Environment and Development.

[15] J. Rockström, L. Karlberg, S. P. Wani, J. Barron, N. Hatibu, T. Oweis, A. Bruggeman, J. Farahani, & Z. Qiang (2010) Managing water in rainfed agriculture - The need for a paradigm shift. Agricultural Water Management, 97(4), 543–550.

[16] J. Rosário, L. Madureira, C. Marques, & R. Silva (2022) Understanding farmers' adoption of sustainable agriculture innovations: A systematic literature review. Agronomy, 12(11), 2879.

[17] K. Atreya, S. Sharma, R. M. Bajracharya, & N. P. Rajbhandari (2008) Developing a sustainable agro-system for central Nepal using reduced tillage and straw mulching. Journal of Environmental Management, 88(3), 547–555.

[18] M. Smale, D. Byerlee, & T. Jayne (2013) Maize revolutions in sub-Saharan Africa. World Bank Policy Research Working Paper, No. 6687.

[19] M. W. Mburu, C. K. K. Gachene, & B. M. Mwangi (2018) Effect of biochar and mulch combinations on soil moisture retention in semi-arid Kenya. Journal of Soil Science and Environmental Management, 9(3), 25–33.

[20] M. Y. Mkonda & X. He (2018). Adoption of Conservation Agriculture in Bahi District, Tanzania: Farmers' attitudes and constraints. Journal of Agricultural Extension and Rural Development, 10(1), 1–10.

[21] N. A. Bogie, R. Bayala, I. Diedhiou, M. H. Conklin, M. L. Fogel, R. P. Dick, & T. A. Ghezzehei (2018) Hydraulic redistribution by native Sahelian shrubs: Bioirrigation to resist in-season drought. Frontiers in Environmental Science, 6, 98.

[22] N. P. Jellason, J. S. Conway, & R. N. Baines (2021) A systematic review of barriers and drivers to climate change adaptation in smallholder farming systems in sub-Saharan Africa. Climate and Development, 13(8), 714–728.

[23] P. A. Mkenda, K. D. Mutabazi, & J. R. Makindara (2023) Barriers to Conservation Agriculture adoption in South Africa: A smallholder perspective. Land Use Policy, 126, 106542.

[24] R. Chambers (1994). The origins and practice of participatory rural appraisal. World Development, 22(7), 953–969.

[25] R. Jaetzold, H. Schmidt, B. Hornetz, & C. Shisanya (2012) Farm management handbook of Kenya: Natural conditions and farm management information (2nd ed.). Ministry of Agriculture, Kenya.

[26] S. I. Seneviratne, T. Corti, E. L. Davin, M. Hirschi, E. B. Jaeger, I. Lehner, B. Orlowsky, & A. J. Teuling (2010) Investigating soil moisture–climate interactions in a changing climate: A review. Earth-Science Reviews, 99(3-4), 125–161.

[27] S. N. Kihiu & J. N. Mberu (2021) Soil fertility status and management practices in Kitui County, Kenya. East African Agricultural and Forestry Journal, 85(1-2), 45–58.

[28] S. Sharma, S. K. Sharma, & S. Sharma (2020) Indigenous technological knowledge in soil and water management: A case study of Himachal Pradesh. Indian Journal of Traditional Knowledge, 19(1), 1-10.

[29] S. Zhang, L. Lövdahl, H. Grip, Y. Tong, X. Yang, & Q. Wang (2015) Effects of mulching and catch cropping on soil temperature, moisture and wheat yield. Soil & Tillage Research, 153, 1-10.

[30] W. F. Waswa, F. S. Mairura, & A. N. Gitau (2021) What influences farmers' adoption lag for soil and water conservation practices? Evidence from Sio-Malaba-Malakisi River Basin of Kenya and Uganda Borders. Agronomy, 11(10), 1985.

[31] W. Mupangwa, C. Thierfelder, & A. Ngwira (2020) Seasonal rainfall variability and the performance of conservation agriculture in southern Africa: A review. Agricultural Systems, 184, 102894.

[32] Water Resources Management Authority (WRMA). (2020) Groundwater Resources Assessment for Kitui County.

[33] Z. Adimassu, S. Langan, R. Johnston, W. Mekuria, & T. Amede (2017). Impacts of soil and water conservation practices on crop yield, run-off, soil loss and nutrient loss in Ethiopia: Review and synthesis. Environmental Management, 59(1), 87–101.

[34] Z. Bai, J. Wang, E. Blagodatskaya, & Y. Kuzyakov (2022) Global adoption patterns of biochar for soil moisture retention: A meta-analysis. Agricultural Water Management, 257, 107187.

AUTHORS

First Author – Margaret Mbinya Kasuki, BSc. MBA, MSc, Kenya Water Institute, margaretmbinyakasuki@gmail.com

Second Author – Dr. Moses Mwangi, PhD, South Eastern Kenya University, mmwangi@seku.ac.ke

Third Author Dr. Grace Mutia BSc, MSc, PhD, South Eastern Kenya University, gmutia@seku.ac.ke

Correspondence Author – Margaret Mbinya Kasuki, margaretmbinyakasuki@gmail.com
+254725 805 459