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Effectiveness of soil conservation practices in semi-arid rangelands of Northern Kenya

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Abstract

Climate change and population growth have profound impacts on arid and semi-arid regions, particularly those hosting agro-pastoral communities dependent on natural resources. Consequently, these communities encounter significant challenges in establishing grazing land and cultivating agricultural products. Water harvesting emerges as a sustainable and effective method to address their needs, aiming to reduce migration and enhance production in rain-fed agriculture.

An example of intervention is the one of the Drylands Transform Research Project (DTR). DTR has chosen four areas in East Africa's drylands, one of which is in the remote and isolated region of North Kenya: West Pokot, specifically in Chepukat village in Chepareria ward. Here, a Livestock Cafè (LC) and a Livestock Cafe annex (LCa) serve as centres for , practical demonstrations of various restoration technologies and information dissemination. LCa features contour bunds, half-moons, manure application, and the cultivation of grasses with stable root systems and nutritious components including forage legumes ideal for livestock.

The primary aim of this thesis research is to find solutions that enhance productivity for the Pokot community, addressing challenges related to water scarcity and land degradation. The specific objectives involve analysing the efficiency of these practices in terms of soil and water retention and gauging the local community's interest in soil and water conservation.

To facilitate comparison, four different land management types are selected: pure grazing regime, cultivated alternated with grazing regime, degraded regime, and experimental regime. To facilitate a comprehensive comparison, three distinct fields are identified for each land management regime. Field activities are divided in two sections: soil physical analysis and socio-economic analysis, spanning from May 17 to July 30, 2023. The soil physical analysis covers soil texture, soil porosity, soil moisture, saturated hydraulic conductivity (Ksat), and infiltration velocity. Simultaneously, socio-economic analysis involves individual interviews and focus group discussions (FGD).

The study identifies three main soil textures: sandy clay loam, sandy loam, and loamy sand. Over three soil samplings at three-month intervals, it is observed that porosity decreases significantly with higher sand content and varies based on land management practices. Specifically, porosity mean values are lowest (42.4%) for degraded land, and highest for the for the cultivated and grazed regime (47.1%) and experimental regime (45.7%). Soil moisture varies, being lowest in grazing land (8.5%) and highest in cultivated-grazed land (13.7%) and experimental plots (13.5%). Ksat results show consistent moderate conductivity in experimental plots in May, becoming moderately rapid in July. The infiltration velocity, measured once per field, indicates a notably high rate in one experimental plot (0.93 cm/h) compared to land with higher sand content, except for grazing land, where the rate is 0.94 cm/h. Individual interviews and focus group discussions shed light on the presence of traditional soil and water conservation techniques, which are deemed efficient but not entirely sufficient. The Pokot community is aware of severe degradation issues and the need for improvement. Indeed, they express a keen interest in acquiring further knowledge about soil and water conservation practices, citing lack of information as a significant barrier.

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List of Acronyms

ASALs	Arid and semi-arid regions of Kenya
UoN	University of Nairobi
ICRAF	World Agroforestry
LC	Livestock cafè
LCa	Livestock cafè annex
NDMA	National Drought Management Authority
LDSF	Land Degradation Surveillance Framework
KNBS	Kenya National Bureau of Statistics
R+L	Reseeding+ planting legumes
R+M	Reseeding+ adding manure
R+L+M	Reseeding+ planting legumes+ adding manure
R	Reseeding
C	Control
DTR	Drylands Transform Research Project
CL	Cluster
G	pure grazing
C+G	Cropping alternated with grazing
D	Degraded
P	Project plots with reseeding plus manure
Ksat	Saturated Hydraulic Conductivity
FGD	Focus Group Discussion
SWH	Soil Water Harvesting
YI	Yield Increase
PD	Production Diversification
SP	Soil Preservation
OF	Organic Farming
IES	Increase Economic Stability
PT	Planting Trees
DT	Ditches and Terraces
S	Sisal
St	Stone
TB	Tree Branches
F	Fences
BbtC	Break between the Cultivation
AV	Planting *Aloe Vera*
IB	Increase Biodiversity

SC	Soil Conservation
CH	Cattle Health
EC	Economic Stability
WH	Water Harvesting
HWH	Household Water Harvesting
SWH	Soil Water Harvesting
GC	Governmental Construction

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Introduction

In today's world, water and soil are increasingly becoming scarce due to the growing gap between demand and supply (Morante-Carballo *et Al.* 2022) . This challenge is further compounded by the current unpredictability of precipitation, which poses significant threats to water availability and land degradation (UN, 2023). Those who depend primarily on natural resources for their livelihoods, are particularly vulnerable to these changes. Many vulnerable communities are situated in the global South, most of which are in sub-Saharan Africa where poverty is widespread and population growth is high (UN, 2023).

Arid and semi-arid regions are at the forefront of these challenges, with water scarcity emerging as the primary limiting factor (Saleh H. *et Al.*, 2009). This introduction lays the foundation for research aimed at addressing the challenge of water scarcity exacerbated by climate change and population growth, significantly impacting semi-arid regions. These regions can benefit immensely from the implementation of water harvesting techniques, which not only mitigate soil erosion but also enhance water storage capacity (Xiao-yan *et Al.*, 2004).

1.1 Water harvesting and ancient techniques

Water harvesting aims at retaining rainwater typically lost due to runoff in regions where the water collected in watersheds is in short supply. This encompasses a range of techniques defined as "*The collection and management of floodwater or rainwater runoff to enhance water availability for domestic and agricultural use, as well as to sustain ecosystems*" (Rima Mekdaschi Studer *et Al*., 2013). Water harvesting offers a simple and effective way to reduce soil erosion, maintain soil fertility, and retain moisture within the terrain. Many communities have developed their own traditional water harvesting methods. For instance, in the Middle East, wadi diversion has been employed for generations (Camacho, 1987). It involves diverting floodwater into a lateral channel directed toward the cultivated field. Similarly, the Pokot community in Kenya utilizes various traditional water harvesting systems, such as terraces called *törömö* and breaks called *pörech* designed to increase pastureland and as fences with tree logs called *kara* to mitigate soil erosion (Fig. 1). These techniques remain highly relevant today, especially in regions with unreliable rainfall, such as arid and semi-arid areas.

Fig. 1: Example of terraces, *törömo*, in Mtelo (M. Virginia Bile, August 2023).

1.2 Arid and semi-arid regions

Arid and semi-arid regions encompass approximately 30% of the world's land surface (Williams, W. D. *et Al*, 1999) (Fig. 2). These areas are characterized by frequent droughts and unpredictable precipitation patterns.

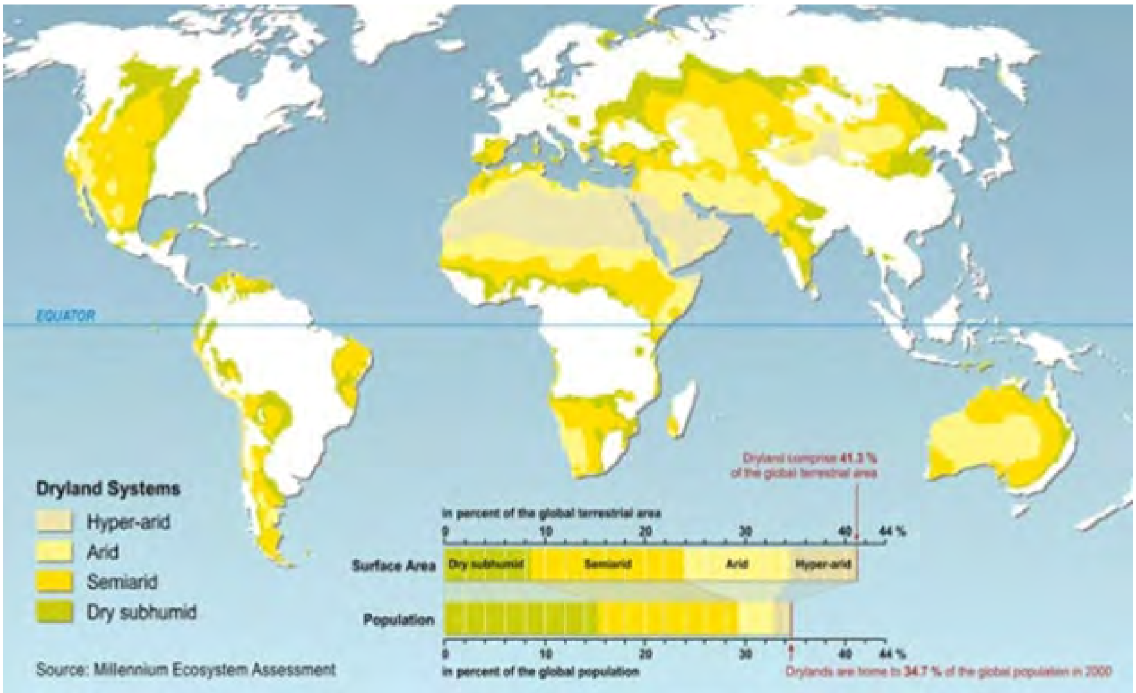

Fig. 2: Hyper arid, arid, semi-arid and dry sub-humid regions map (M. Abdelhak, 2022).

They are predominantly located in Africa, Asia, South America, and North America and are inhabited by approximately 20% of the global population. Africa alone accounts for 43% of the continent's land area and supports 325 million people who rely heavily on its natural resources (Wei, 2021) (Fig. 3).

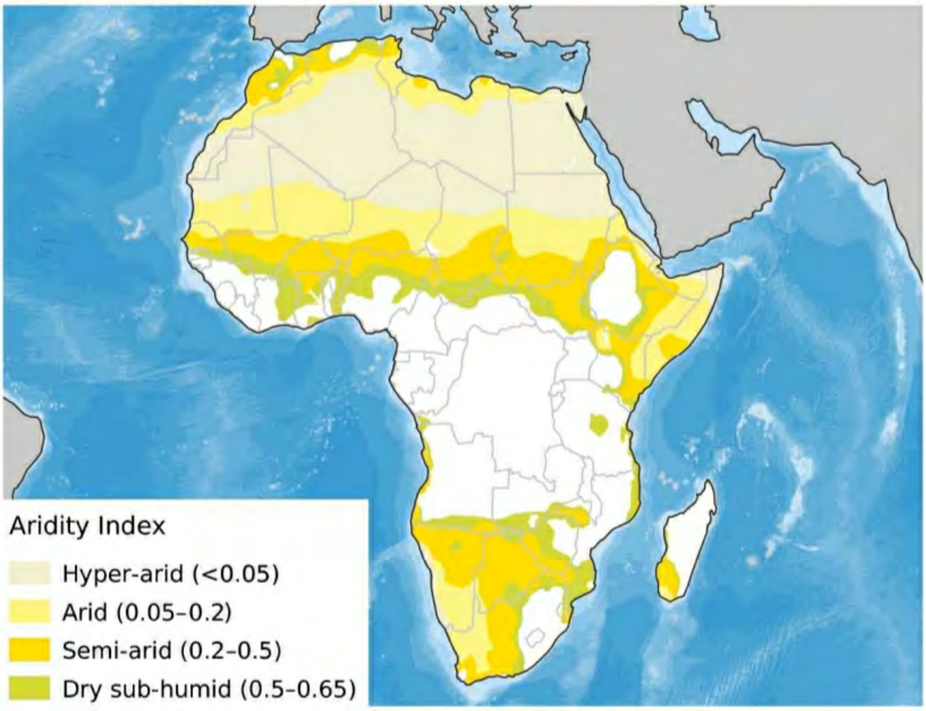

Fig. 3: Hyper-arid, arid, semi-arid and dry sub-humid regions in Africa (F. Wei *et Al.*, 2021).

1.3 Arid and semi-arid regions of Kenya

In 2022, the global population reached 8 billion, with sub-Saharan Africa experiencing a 57% growth rate (Repubblica, 2022). Kenya, in particular, stands out as one of the countries with the highest concentration of drylands, as it comprises 67% of the nation's landmass. In Kenya, arid and semi-arid regions (ASALs) cover roughly 80% of the total land surface and are home to 70% of the country's livestock population and around 38% of its human population (Ministry of East African Community, 2009) (Fig. 4).

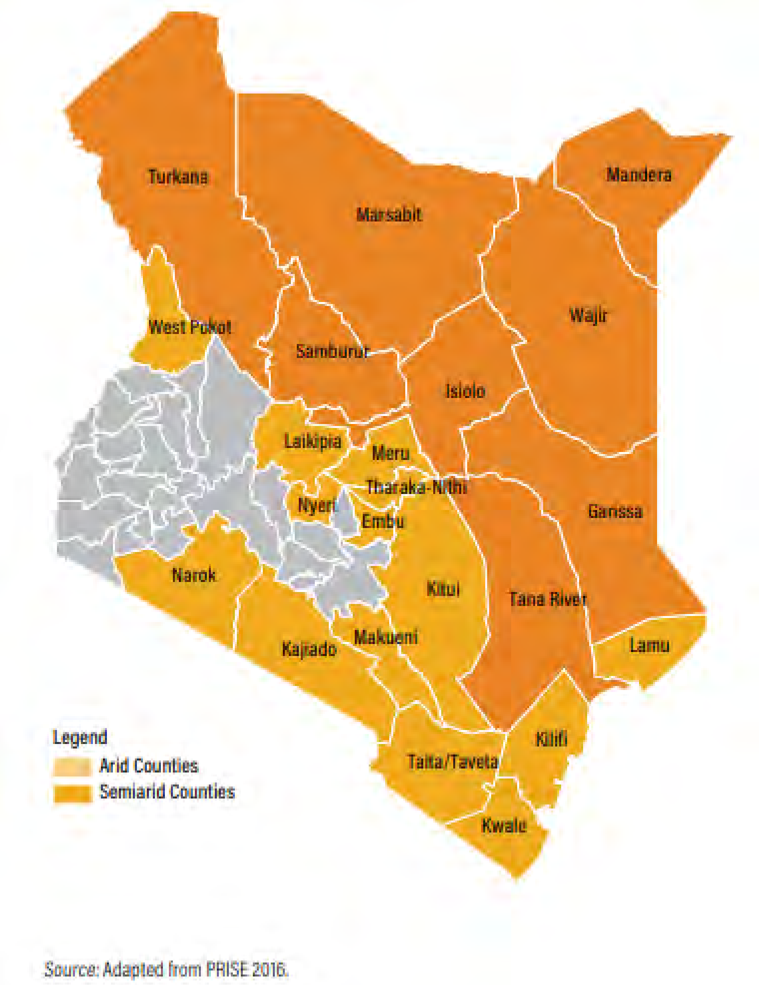

Fig. 4: ASALs regions of Kenya (Chaudhury *et Al.*, 2020).

According to the recent "Executive Order No. 1 of 2022" report issued by the State Department for ASALS and Regional Development , these ASALs exhibit the lowest indicators of development in the country. Notably, half of the 25 billion people living in global drylands fall below the United Nations poverty line (Lian *et Al.*, 2021). The economy of arid districts primarily revolves around mobile pastoralism, while semi-arid regions support a more diversified economy, including rain-fed and irrigated agriculture, agro-pastoralism, bio -enterprises, and conservation or tourism-related activities (Fitzgibbon C., June 2012). Kenya experiences an average mean precipitation of 680mm annually, ranging from less than 250 mm in northern ASAL areas to approximately 2,000 mm in the western region (World Bank Group, 2021). West Pokot County is one such ASAL region.

1.4 West Pokot County

West Pokot County is situated in north-western Kenya and is known for its remoteness, lacking essential infrastructure and government support (M. Cirani 2020). Geographically, West Pokot County lies between latitudes 10° 10'N and 30° 40'N and longitudes 34° 50'E and 35° 50'E (Fig. 5).

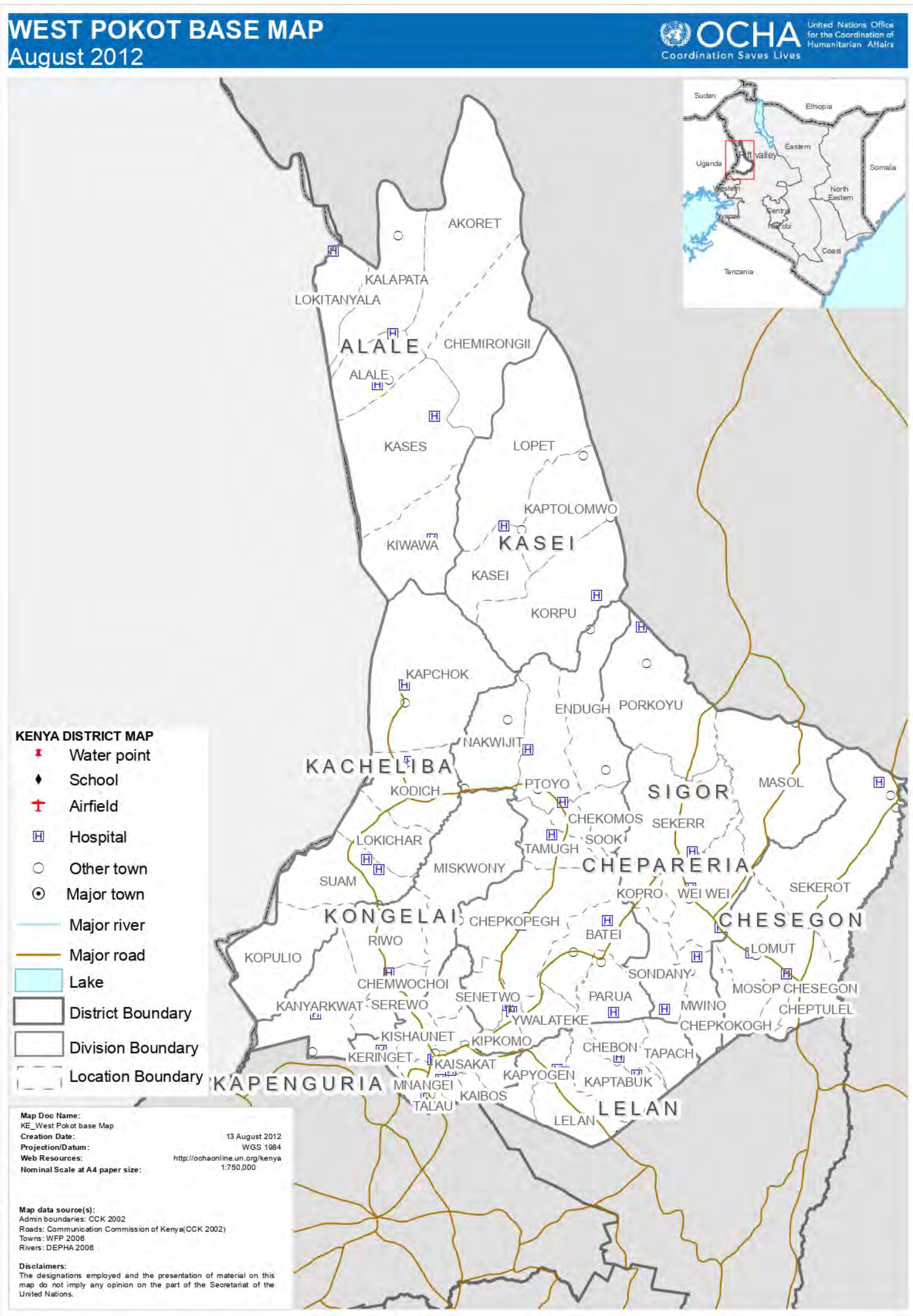

Fig. 5: Location of West Pokot County and map of the county from UN, 2012.

The County covers an area of approximately 9,100 square kilometres and experiences two distinct rainy seasons: the "long rains" from March to June and the "short rains" from September to November. The climate in this region varies from semi-arid to arid, with annual rainfall ranging from 700 mm in the lowlands to 1600 mm in the highlands. Temperature ranges from 15°C to 30°C in the lowlands and can drop as low as 9°C in the highlands. About 80% of the county's land falls under arid or semi-arid classification (Huho J., 2012). Kapenguria town serves as the largest urban centre and administrative hub in the county. West Pokot County is primarily a rangeland and is traversed by Rivers Turkwel, Kerio, and Nzoia, with Turkwel and Kerio flowing northward into Lake Turkana and River Nzoia draining into Lake Victoria to the south. The county is inhabited by the Pokot ethnic group, with a population of 512,690 people and a population density of 56 persons per square kilometer (Government of Kenya, 2009). The Pokot community has had historical conflicts with neighboring tribes, exacerbated by arbitrary British boundaries drawn in the 20th century without considering ethnic groups' affiliations. For instance, Pokot and Karamojong are divided by two rivers, Turkwell and Kanyangareng, which were taken as mark points to define Kenya-Uganda border but those two rivers were bringing them into closer contact. The British, however, blocked access to these rivers, further fueling tensions between the two tribes (International Journal of Social Science and Technology, 2016). While historical rivalries among the Pokot and neighboring pastoral communities such as Turkana, Sabaot, Samburu, Marakwet (in Kenya), Sabiny, and Karamajong (in Uganda) have diminished, conflicts over water and pasture access in the county and neighboring regions persist, often linked to extreme climatic events (Huho J., 2012).

1.5 The agro-pastoralist Pokot community

Kenya is home to 43 distinct tribes, broadly categorized into three main groups: Bantu, Nilotes, and Cushites. The Nilotic group, originating from the Nile River region, comprises various subgroups with diverse livelihoods, depending on their proximity to water basins, valleys, or drylands. The Pokot tribe, residing in the Rift Valley's drylands, has a rich pastoral tradition. Historically, the Pokot have practiced seasonal migration between lowlands and highlands (E.G.C. Barrow, 1986). This migratory lifestyle often led to conflicts with neighboring communities. However, in the 2000s, the Pokot began to assert land ownership rights, reducing conflicts and cattle rustling incidents. Enclosure initiatives, supported by the Vi Agroforestry rehabilitation program (Wairore *et Al.*, 2016), played a pivotal role in stabilizing the Pokot community and promoting diversified agriculture (Wairore J.N. *et Al.*, 2015b). Today, the Pokot can be characterized as an agro-pastoralist community. Their farming activities are for subsistence, focusing on crops like maize, beans, sorghum, and millet, along with occasional kitchen gardens. Livestock remains integral, serving as a source of both food and economic stability. It is, in essence, their "bank." Each village holds a weekly market day where families engage in various transactions, such as selling surplus livestock, buying cows for marriage, or selling vegetables to cover school fees. Animals hold such cultural and economic significance that marriages are contingent upon the prospective husband providing the agreed number of cows to the bride's father (M. Cirani 2020).

1.6 Drylands Transform Research Project

Given the increasing unpredictability of climate patterns and the inherent challenges of drylands, combined with the presence of indigenous communities heavily reliant on these limited resources, the Drylands Transform Research Project aims to explore innovative techniques for enhancing forage productivity, sustaining kitchen gardens, and mitigating erosion. This research initiative, led by the Swedish University of Agricultural Sciences, operates in collaboration with a multidisciplinary team from the Intergovernmental Authority on Development, Linnaeus University, Makerere University, Umeå University, University of Gothenburg, University of Nairobi (UoN), and World Agroforestry (ICRAF). The project has established four experimental sites known as "Livestock Cafés" in East Africa: two in Uganda (Napak and Moroto districts) and two in Kenya (Turkana County and West Pokot County).

The West Pokot site is in a semi-arid area, situated in Chepukat village within Chepareria ward. The Livestock Café (LC), comprises a fodder production area, a communal kitchen garden open to the entire community, and an experimentation area located 3km away known as Livestock Café annex (LCa). This later site is being used by a PhD student for her experimentation work, as well as show-casing to the community on improved fodder production and hay baling.

Geographically, Chepareria ward is positioned between latitudes 1°15′ and 1°55′ N and longitudes 35°7′ and 35°27′ E, 18km from Kapenguria town. The region features gently undulating plains encircled by mountain ranges, some of which reach heights of up to 3,000 meters. Chepareria experiences an average annual rainfall of approximately 600 mm. The National Drought Management Authority (NDMA) notes a bimodal rainfall pattern in Chepareria, with an extended rainy season from March to May and a shorter one occurring between August and November (NDMA 2014). The soil composition in Chepareria varies, ranging from shallow and friable in the lowlands to deep, well-drained, reddish brown sandy loams in the higher elevations of Chepareria. As per the Land Degradation Surveillance Framework (LDSF) analysis of land cover, a significant portion of the area has been utilized for animal grazing, predominantly characterized as wooded grassland, with some areas categorized as bushland. According to data from the Kenya National Bureau of Statistics (KNBS), the population of Chepareria ward stands at approximately 41,563 individuals (KNBS 2009) (Wairore J.N. *et Al.*, 2015a).

1.7 Livestock Cafè and Livestock Cafè annex

LC is a communal space at Chepukat village. It serves as a knowledge-sharing hub where innovative degraded land restoration technologies and management options are demonstrated. Particularly, the technologies demonstrated in LC included: gully control, tree planting, half-moons, banana circle, contour gardens, sack gardens, mulching, planting methods, seed-bed preparation and organic amendments (Nyaga M.N., 2022c). Three km away from this area is a 0.8ha enclosed land known as LCa. LCa is divided into four blocks separated by 5 metres, and each block consists of 20x20m plots of randomly distributed treatment type: the first treatment consists of reseeding and planting legumes (R+L); the second treatment consists of reseeding, planting legumes and adding manure (R+L+M), the third treatment consists of reseeding and adding manure (R+M), the fourth consists in only reseeding (R); and the fifth is the reference(C) (Fig 6).

Fig. 6 : Treatment types in LCa. R+L corresponds to the treatment reseeding and planting legumes; R+L+M corresponds to the treatment reseeding, planting legumes and adding manure; R+M corresponds to the treatment reseeding and adding manure; the R corresponds to the treatment reseeding; C corresponds to the no-treatment or the reference area (Nyaga M.N., 2022a).

The grasses used together with the rangeland species for the reseeding treatment are: *Cenchrus ciliaris*, *Eragrostis superba, Chloris roxburghiana;* while the legumes used are: *Crotalaria juncea*, *Clitoria ternatea*, *Macroptilium atropurpureum* (Siratro) and *Neonotonia wighti* (Nyaga M.N., 2022a) Additionally, half-moons and three contour lines are installed to reduce the pressure of surface runoff. The contour lines are designed through sacks filled with river sand, manure and mixture of soil in a ratio of 1:1:1 and with Vetiver grass (*Chrysopogon zizanioides*) (Nyaga M.N., 2022b) (Fig. 7). In this regard, LCa serves as an example of the application of water harvesting techniques aimed at reducing erosion and increasing soil moisture.

Fig. 7: Women planting vetiver grass on the sacks laid along a contour line in June 2022 at the LC (Nyaga M.N., 2022b).

Objectives

2.1 Broad Objective

In response to the challenge of water scarcity and land degradation exacerbated by climate change and population growth that is affecting West Pokot County, this study aims to enhance productivity while acknowledging the existence of local soil conservation techniques like enclosure, terraces named *törömo*, breaks named *pörech*, and tree logs named *kara*. The central question this research seeks to answer is: *Can solutions be found to help the Pokot community increase their productivity while addressing the challenge of water scarcity and land degradation?*

2.2 Specific Objective

Specifically, the study evaluates the techniques employed by the Drylands Transform Research Project (DTR) in terms of soil and water conservation. This involves soil sampling to measure moisture content, porosity, and hydraulic conductivity, as well as field tests for infiltration velocity. Simultaneously, the research seeks to understand the community's views on erosion, water scarcity, and their openness to new knowledge. This is achieved through individual interviews and focus group discussions.

The research addresses two key questions:

1) *How efficient are the the soil and waterconservation techniques in Cheipareria?*

2) *To what extent are local farmers informed and willing to adopt new soil and water conservation techniques?*

3. Methodology

3.1 Field activity

In this study, three different enclosure management regimes are analysed: a) pure grazing; b) cropping alternated with grazing; c) degradation sites due to overgrazing, poor management, and erosion. These three land use types are compared with the land use experimented by the Drylands Transform Research Project in Chepukat. The experimental land use consists of four blocks, each containing five plots (each plot measuring 20m×20m). For the purpose of this research, the focus is solely on the plots with reseeding plus manure treatment, as they are easily replicable by local farmers.

The enclosures management regimes are located within the clusters of the LDSF, proposed by ICRAF to assess land degradation worldwide. This framework involves various measurements, including current and historical land uses, land cover, topography, habitat impact, soil health, and land degradation. Each LDSF site covers an area of $100km^2$, with 16 clusters (CL) of $1km^2$ defined within it. Within each cluster, 15 plots of $1000m^2$ are assessed. The enclosures management regimes are strategically placed within the LDSF clusters to facilitate data comparison. The specific clusters chosen for this study are CL10, CL16, and CL7 (Table 1) (Fig. 8). These clusters are selected based on the presence of the experimental land use in CL7, forming a triangular configuration. Some clusters were excluded due to accessibility challenges, such as ephemeral rivers, extensive gullies, or the absence of roads.

Table 1: List of the 16 CLs associated with the coordinates of a random representative point (point 5). The CLs selected as the study area are highlighted in blue.

CLUSTER (CL)	Coordinates Point 5
CL1	N 01°21.843’, E 035°08.901’
CL2	N 01°23.447’, E 035°09.127’
CL3	N 01°24.223’, E 035°08.773’
CL4	N 01°25.279’, E 035°08.740’
CL5	N 01°21.838’, E 035°09.935’
CL6	N 01°23.073’, E 035°10.441’
CL7	N 01°24.979’, E 035°10.370’
CL8	N 01°25.704’, E 035°10.349’
CL9	N 01°22.163’, E 035°11.659’
CL10	N 01°23.125’, E 035°11.269’
CL11	N 01°24.327’, E 035°11.815’
CL12	N 01°25.754’, E 035°11.800’
CL13	N 01°21.801’, E 035°13.422’
CL14	N 01°23.132’, E 035°12.651’
CL15	N 01°24.296’, E 035°12.865’
CL16	N 01°25.616’, E 035°12.701’

Fig. 8: Map with the red LDSF points and the clusters selected as study area in yellow.

In each selected cluster, all three enclosure management regimes are well-represented. In Cluster 7, three out of the four experimental plots from the Drylands Transform Project with the "Reseeding plus Manure" management system were randomly selected. Additionally, three standard enclosure management regimes are selected in Cluster 7. In total, there are 12 plots under investigation: three for pure grazing (G), one each in CL10 (CL10G), CL16 (CL16G), and CL7 (CL7G); three for cropping alternated with grazing (CG), one each in CL10 (CL10CG), CL16 (CL16CG), and CL7 (CL7CG); three for degraded soil (D), one each in CL10 (CL10D), CL16 (CL16D), and CL7 (CL7D); and finally, three plots with reseeding and the application of manure in CL7 (CL7P2, CL7P3, CL7P4).

3.2 Sample Collection

For each plot, the perimeter is measured using a GPS tool to calculate the distance between each edge. All plots have a rectangular shape. Additionally, the diagonal of each rectangle is measured and divided into three equidistant points (Figg. 9-10).

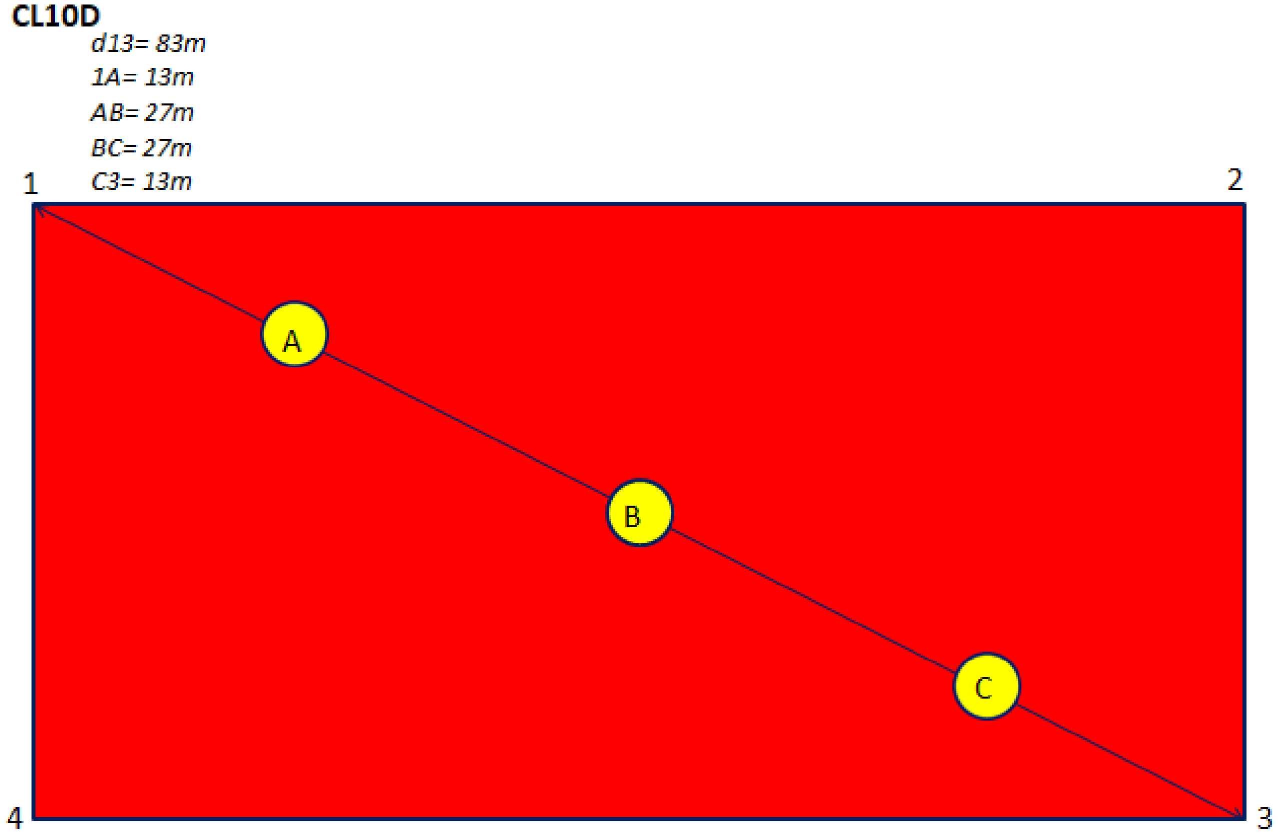

Fig. 9: Shape of CL10D, with the diagonal in evidence (d) and the three equidistant point (A,B,C) of the sample collection.

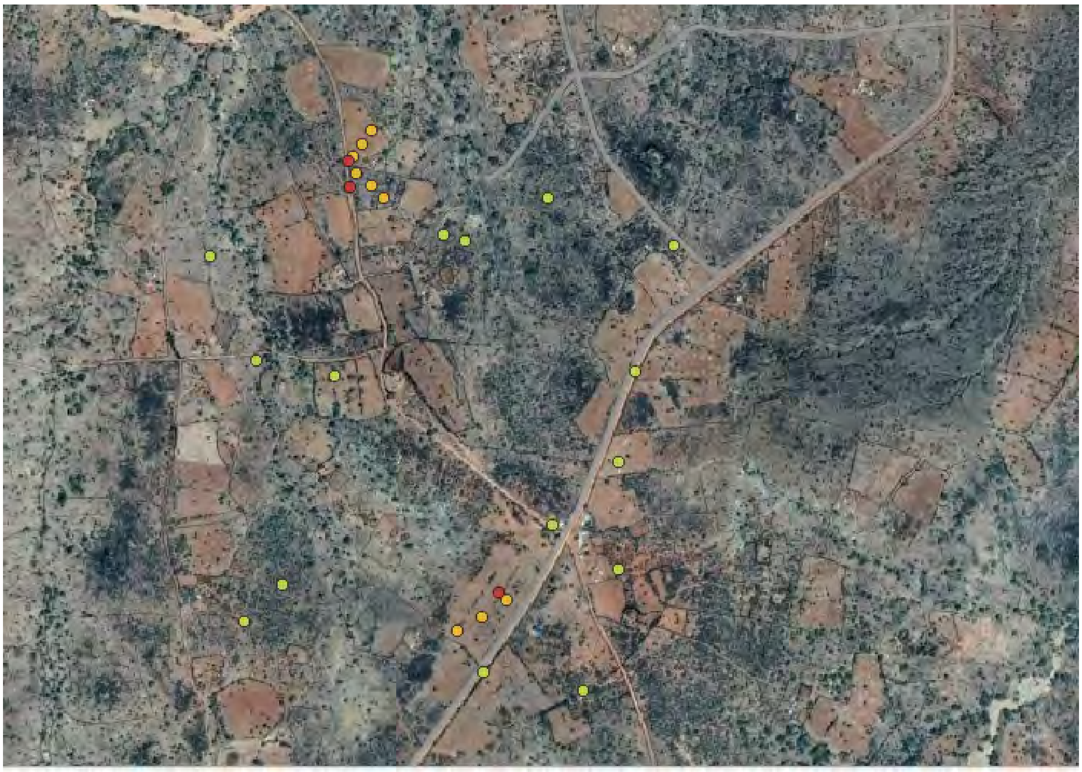

Fig. 10: Overview map of CL16, in orange the soil sampling points, in red the study area and in green the LDSF points. In background Google Hybrid.

These three points serves as sampling points for gravimetric analysis. Infiltration tests are conducted at the centre of the diagonal (Fig. 11).

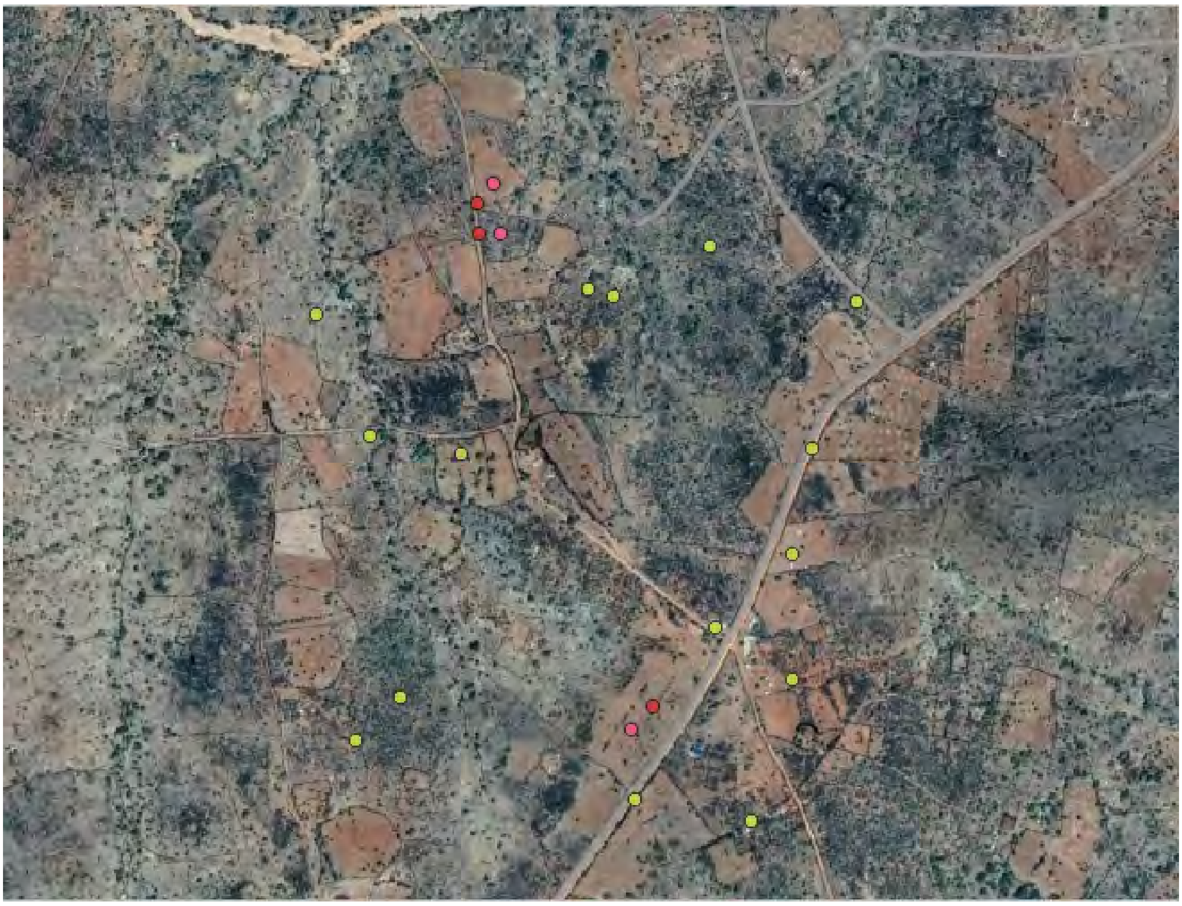

Fig. 11: Overview map of CL16, within in pink the infiltration test point, in red the study area, in green the LDSF points. In background Google Hybrid.

3.3 <u>Soil Physical Analysis</u>

The soil physical analyses are conducted in accordance with the procedures outlined in the ICARDA's 2013 manual, “Methods of Soil, Plant, and Water Analysis”. These analyses encompass key parameters such as the coefficient of saturation, conductivity class, moisture percentage, bulk density, and porosity. The sampling dates are set for May 25-26, 2023, June 28-29, 2023, and July 28-29, 2023.

For each plot, a total of three soil samples are collected from the topsoil to a depth of approximately 20cm (G. Estefan *et Al.* in 2013). This procedure results in the collection of a total of 36 samples. The University of Nairobi's Laboratory supplies hermetic rings with a height of 4cm and a diameter of 5.5cm. These hermetic rings are specifically designed to retain soil moisture over extended periods, making them ideal for addressing any travel time requirements.

Hence, once the exact point is identified through GPS, the upper part of the soil is removed due to the presence of grasses, stones, or eroded soil. The ring is then hammered into the top centimetre of the terrain. To remove it, a knife is used to loosen the soil around the ring, avoiding soil losses during removal. Once removed, the ring is closed with two plastic caps, labelled, and covered with an aluminium foil (Fig. 12).

Fig. 12: Procedures soil sampling: a) removing the upper part of the soil b) hammering the ring c) loosening soil around the ring d) extracting the ring with e) closing and labelling the ring f) covered ring with aluminium foil (M. Virginia Bile, May 2023).

When all 36 samples are collected, they are sent to the University of Nairobi's lab. In the lab, the aluminium foil is removed, the two caps are taken off, and the underside of the ring is covered with a thick layer of lint secured with an elastic band. The exact weight of the fresh soils is then recorded (Fig. 13).

Fig. 13: Measuring the fresh weight of soil samples (M.Virginia Bile, August 2023).

Afterwards, the rings are submerged in water for 24 hours to reach the soil's saturation level. This is made possible because the lint allows the passage of water but not soil (Fig. 14).

Fig. 14: Saturating the soil sample for 24h (M. Virginia Bile, August 2023).

After 24 hours, the saturated hydraulic conductivity (Ksat) is measured using a constant head machine, which distributes the same amount of water at the same time to nine rings (Fig. 15).

Fig. 15: Ferdinand Anyika-soil physics technician at UoN starting to measure the saturated hydraulic conductivity through a constant head machine (M. Virginia Bile, August 2023).

The water percolated after one hour is measured, allowing the calculation of Ksat using a specific formula $Ksat = \frac{Q \cdot L}{A \cdot T \cdot \Delta H}$ (Table 2) (Reynolds *et Al.* 2002).

Table 2: List of acronyms used for the formula associated with their numeric value.

Ksat	Saturated hydraulic conductivity	
Q	Percolate through the soil sample (ml)	
L	Length of the sample (cm)	4 cm
A	Cross sectional area of the sample (cm^2)	23.67 cm^2
T	Time taken (hr)	1hr
ΔH	h+L (cm)	5.8-6 cm
H	Effective water height (cm)	1.8-2 cm

The Ksat values are then used to determine the conductivity class based on a provided table 3.

Table 3: Classification of hydraulic conductivity of soils (Landon, 1991).

m/day	**Cm/hr**	**Conductivity class**
0.2	<0.8	Very slow
0.2-0.5	0.8-2.0	Slow
0.5-1.4	2.0-6.0	Moderate
1.4-1.9	6.0-8.0	Moderately rapid
1.9-3.0	8.0-12.5	Rapid
>3.0	>12.5	Very rapid

Once Ksat is measured for all 36 samples, they are placed in an oven at 100°C for 24 hours. Afterward, all the rings are weighed again, but this time when they are dry. Soil particles are then removed to weigh only the ring, lint, and elastic band. Now, the moisture content can be measured by subtracting the fresh soil weight from the dry soil weight and dividing by the dry soil weight minus the ring, lint, and elastic band weight (Fig. 16).

Fig. 16: Weighting the samples after dried and weighting the rings once removed the soil (M. Virginia Bile, August 2023).

Bulk density and porosity are also measured following a specific formula:

$$Bulk\ density = \frac{Dry\ weight - ring\ weight}{Volume\ of\ the\ ring}$$

$$Porosity = \left(1 - \left(\frac{Bulk\ density}{2.6}\right)\right) \cdot 100$$ (G. Estefan *et Al.*, 2013)

2.6 represents the average bulk density of soils

3.4 Soil Texture Analysis

On June 28th and 29th, soil texture analysis is performed on samples collected from the three equidistant points where soil moisture samples are taken. Approximately three handfuls are collected at each point and mixed together for analysis (Fig. 17).

Fig. 17: Collecting soil sample for soil texture analysis (M. Virginia Bile, June 2023).

These samples are transported to Nairobi in a paper bag well labelled and closed with a masking tape, and the University of Nairobi uses the hydrometer method (Bouyoucos) to measure sand, clay, and silt content in all 12 samples.

3.5 Infiltration velocity test

For each land use type in the three clusters, one infiltration test is conducted on May 29th, 30th, 31st, and June 1st, 2nd, totalling 12 tests. These infiltration velocity tests adhere to the guidelines outlined in the LDSF Field Guide (2023). The tools required for this test include a GPS device, an infiltration ring (provided by the University of Nairobi) with a diameter of 28cm and a height of 25cm, a sledgehammer, a ruler, a knife, approximately 25l of water, and a chronometer.

The infiltration ring is placed precisely at the centre of the field's diagonal, determined using GPS coordinates. Before inserting the ring with the hammer, the soil at the location is carefully cleaned with a knife to remove any stones or vegetation. Once in place, the ring's stability is checked, and a ruler is inserted and secured with adhesive tape. The soil is saturated with 20cm of water for 15-20 minutes, with adjustments for recent rainfall events. Following the initial saturation period, a two-hour test commences by adding 20cm of water. During the first 30 minutes, height measurements are taken every 2 minutes, and after these initial measurements, the water level is returned to its starting height of 20cm. After the first 30 minutes, measurements are taken at 10-minute intervals. If the infiltration rate stabilizes, readings are taken every 20 minutes after the first hour (Fig. 18).

Fig. 18: Procedure infiltration test: a) cleaning the upper part of the soil b) hammering the ring c) saturating the soil d) recording the height according to my chronometer e) refilling with water to reach the initial height (M.Virginia Bile, May 2023).

3.6 Individual Interviews

The final objective of this research is to interview the local community to understand their soil and water prevention measures in the field. This information is highly relevant because it allows one to grasp the effectiveness of these practices, find more suitable solutions for local problems, and gain insights into how to inform local farmers about water and soil management practices. The chosen interview design is the fixed questionnaire. Questionnaires are ideal for gathering opinion research data due to their proven cost-effectiveness and efficiency in handling large volumes of information (Metzner *et Al.*, 1952).

The interviews section starts the 12th of June 2023 and it ends the 4th of July 2023. The interviews are conducted by the masters student ,Maria Virginia Bile under the guidance of Josphat Mn'angat Rotoko as local language interpreter. This allows the participants to express themselves more effectively. The local guide has a list of questions in English, which he presents in Pokot. After receiving the responses in Pokot, he translates them into English for the purpose of taking notes and to determine if any further questions need to be asked (Fig. 19). The interviews are recorded with verbal consent from the participants, so that later the guide can transcribe all details from Pokot to English in the laptop. The interviewees are purposively selected from the three clusters. In each cluster (CL7, CL10, CL16), five individuals from each target group (5 women above 30, 5 women under 30, 5 men above 30, 5 men under 30) are interviewed. The selection process depends on the daily availability of participants within the target group. The household inside the Clusters are visited individually, with inquiries made if anyone can allocate approximately one hour for the interviews. Community members typically demonstrate a high level of willingness and openness to engage with foreigners, particularly when approached in the local language. As a result, approximately five interviews are conducted daily. On average, each interview lasts approximately 30 minutes. As a token of appreciation for their time and contribution to the project, participants are given 100 Kenyan Shillings at the conclusion of the interview.

The questions are straightforward and categorized into 5 main sectors: livelihood, capacity building, field management, prevention of drought, water harvesting, and erosion. The questions are as follows:

Specifically regarding livelihood:

1. Name, age, and household size.
2. Land ownership and land size.
3. Main land-related activities: grazing, cultivation, or kitchen gardening?
4. Reasons for chosen activities.
5. Crops cultivated.
6. Number of cows, goats, and sheep owned.

For capacity building:

1. Education level.
2. Agricultural knowledge acquired in school, practical applications.
3. Previous training in farming.
4. Content of training.
5. Trainer identity.
6. Implementation of training lessons.
7. Reasons for not implementing training lessons.

For field management:

1. Existence of a planned field management approach.
2. Description of the approach.
3. Any suggested or observed field management techniques worth adopting.
4. Details of such techniques.
5. Implementation of these techniques.
6. Reasons for not implementing them, if applicable.

For drought prevention:

1. Recall of specific extreme drought years.
2. Year and any specific names associated.

3. Impact of drought on productivity and livestock.
4. Adoption of drought prevention measures.
5. Types of prevention measures.

Regarding knowledge of Water Harvesting:

1. Awareness of water harvesting.
2. Application of water harvesting techniques.

Concerning awareness of soil erosion:

1. Experience of land erosion.
2. Perceived causes of erosion.
3. Use of erosion prevention techniques.
4. Types of prevention techniques.
5. Reasons for not implementing prevention measures if applicable.

Additionally, if an expert were to introduce new techniques for increasing soil moisture, enhancing soil organic carbon, and preventing soil erosion, would they consider implementing these techniques in their fields? If not, what would be the reason?

Answers are subjected to both quantitative and qualitative analysis. IBM SPSS Statistic is used to analyse the data obtained, assigning a code to each answer. Qualitative questions are analysed using a representative set of definitions to compile the main responses from the farmers. This is done to assess the types of drought and erosion prevention measures, water harvesting practices, and suggestions. For quantitative answers, Excel is typically sufficient.

Fig. 19: Interviewing a Pokot farmer (M. Virginia Bile, June 2023).

3.7 Focus Group Discussions

Focused Group Discussions (FGDs) provide additional comparable results. In each cluster, 8 individuals are selected, comprising 2 women, 2 young ladies, 2 men, and 2 boys. This results in a total of three FGDs: : one in each cluster. These discussions are organized by community members who participated in the individual interviews and seem to have strong connections within the neighbourhood. They are tasked with inviting 8 individuals and checking their availability for a three-hour session on the days: 14th of July 2023 for CL7, 17th of July 2023 for CL16 and 20th of July 2023 for CL10. At the conclusion of each FGD, participants receive a token of appreciation, with 200 Kenyan Shillings, while the organizers receive 300 Kenyan Shillings. The discussion is managed by the master student Maria Virginia Bile and facilitated by the local guide Josphat Mn'angat Rotoko in Pokot, as it allows the participants to express themselves more effectively. Before starting it is asked the permission of recording the discussion to enable the writing of a detailed report on the laptop. To drive the discussion the local guide has a list of topics in the form of questions, and after every two or three answers, he translates into English allowing the note-taking and ensuring the direction of the discussion is on track (Fig. 20). The following questions are the one guiding the discussions:

Regarding livelihood:

1. Average land size owned by people in the area.
2. Primary agricultural activities in the area.
3. Prevalence of kitchen gardens among neighbours.
4. Main crops grown.
5. Average livestock ownership.

For capacity building:

1. Dominant school levels in the area.
2. Presence of individuals offering farmer training.
3. Effectiveness of farmer schools.
4. Existence of field management plans.

Concerning drought prevention:

1. Recollection of specific drought years.
2. Reasons for their impact.
3. Drought prevention measures.
4. Seasonal migration to Uganda or need-based migration due to drought, and changes over the years.

Awareness of soil erosion:

1. Percentage of land erosion in the area.
2. Primary causes of erosion.
3. Main erosion prevention methods.

For water harvesting:

1. Primary water harvesting techniques applied.

Willingness to learn new techniques for soil erosion prevention, increased soil moisture, and soil organic carbon enhancement.

Finally, these discussions are analysed using a descriptive method. This entails that qualitative questions and the reflections behind the quantitative questions are the outcomes of multiple opinions and empirical analyses that need to be faithfully transcribed, taking into account the various nuances. While for the questions with quantitative answers, such as the size of land per family, are integrated with the means obtained from the individual interviews.

Fig. 20: Focus Group Discussion in CL7 (M. Virginia Bile, July 2023).

4. **Results**

4.1 Soil Sampling Result

4.1.1 Soil Texture

Soil texture measurements assess the sandy, clay and silt component of the soil. Out of 12 tests, 5 result with a sandy clay loam texture, 3 with sandy loam and 4 with loamy sand. The results of the soil texture measurements are shown in table 4.

Table 4: Soil texture results. The project land management are highlighted in blue.

Field Ref	Sand %	Clay %	Silt %	Class
CL10 D	61	34	5	Sandy clay loam
CL7 P3	69	30	1	Sandy clay loam
CL16 GC	73	24	3	Sandy clay loam
CL7 G	73	24	3	Sandy clay loam
CL16 G	73	26	1	Sandy clay loam
CL7 P4	77	20	3	Sandy loam
CL7 GC	81	14	5	Sandy loam
CL7 P2	81	16	3	Sandy loam
CL7 D	87	10	3	Loamy sand
CL16 D	87	12	1	Loamy sand
CL10 GC	87	12	1	Loamy sand
CL10 G	89	10	1	Loamy sand

4.1.2 Porosity

The porosity values obtained in May, June, and July are summarized in the histograms and in the linear graphs below. The fields are divided into three main groups based on their texture: sandy clay loam, sandy loam, and loamy sand. The sandy clay loam group is the most representative, encompassing all types of land regimes: D, G+C, P, and G. Generally, for each field, three samples are utilized to calculate the mean and standard deviation.

As illustrated in Fig. 21 and 22, the sandy clay loam soils exhibit the lowest mean porosity for the degraded land regime across the three months. Conversely, the other three land management types show a uniform variation in porosity.

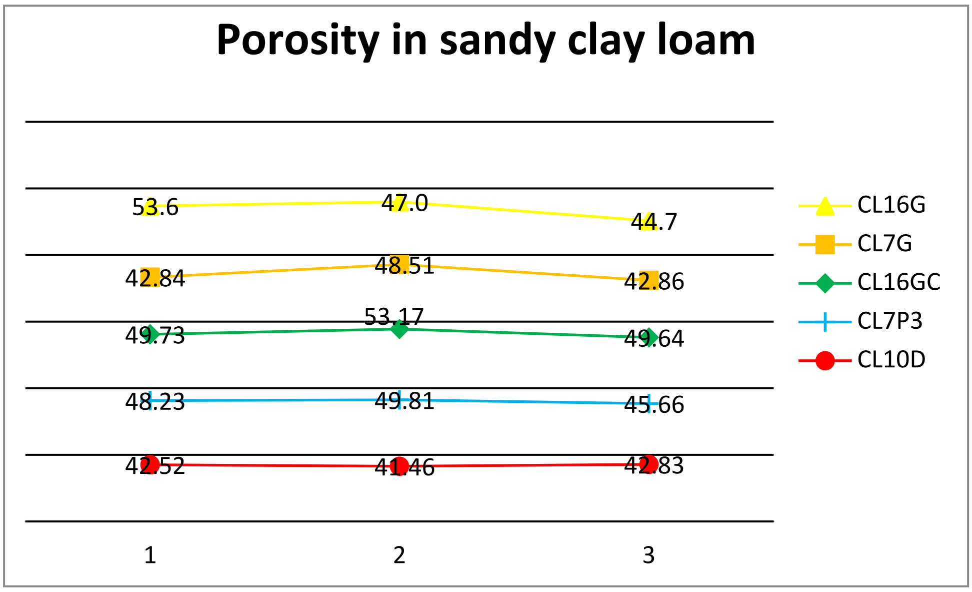

Fig. 21: Linear graph illustrating the mean percentage value of porosity in sandy clay loam soils for the months of May (1), June (2), and July (3). Each land management category is represented by a distinct colour: degraded in red, project in blue, cultivated alternated with grazing in green, and grazing in yellow.

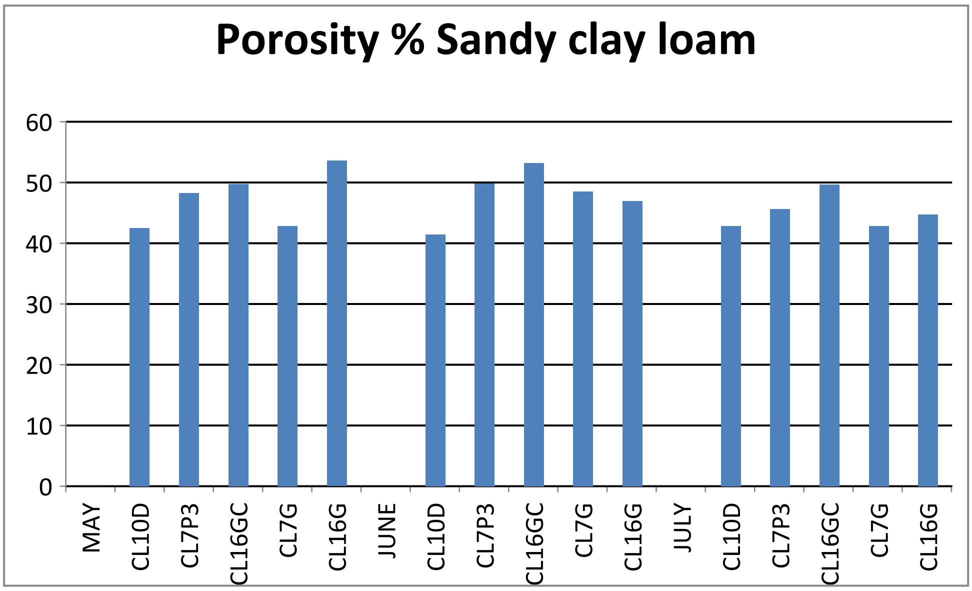

Fig. 22: Bar charts and error bars for the standard deviation representing mean porosity percentage of sandy clay loam soils for the month of May, June and July.

In sandy loam soils, only the two project plots and the G+C are considered. As both follow an enclosed regime, they exhibit a similar trend (Figs. 23-24), albeit with a higher standard deviation for G+C.

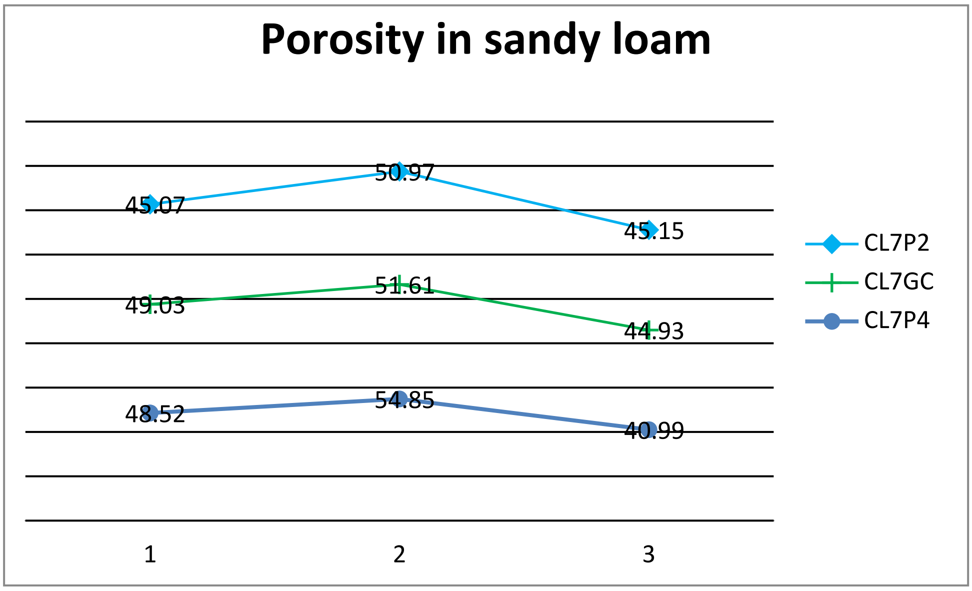

Fig. 23: Linear graph illustrating the mean percentage value of porosity in sandy loam soils for the months of May (1), June (2), and July (3). Each land management category is represented by a distinct colour: project in blue, and cultivated alternated with grazing in green.

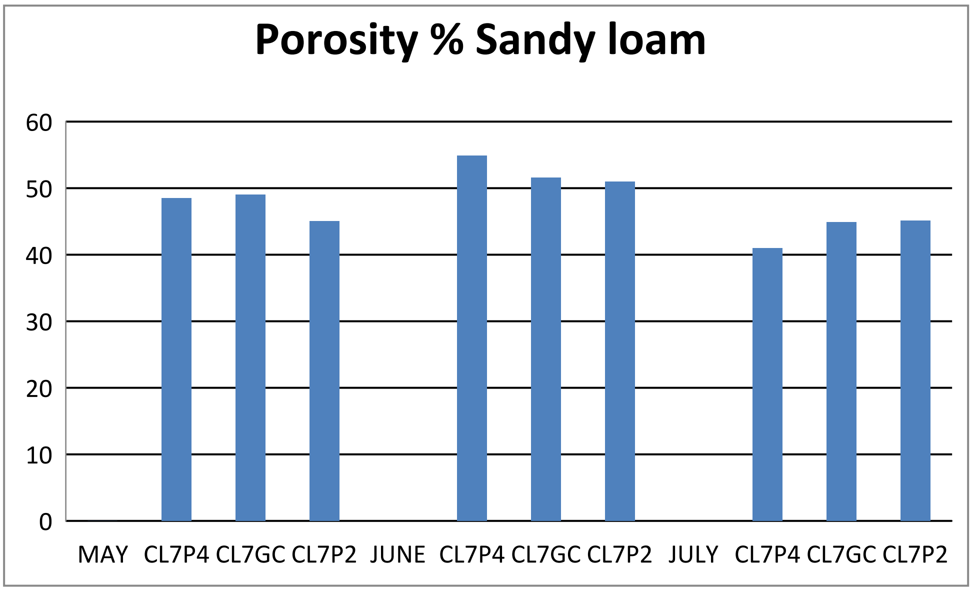

Fig. 24: Bar charts and error bars for the standard deviation representing mean porosity percentage of sandy loam soils for the month of May, June and July.

The last soil texture type is loamy sand, encompassing D, G, and G+C; the project plots are not included. Here a significant trend is not apparent (Figg. 25-26).

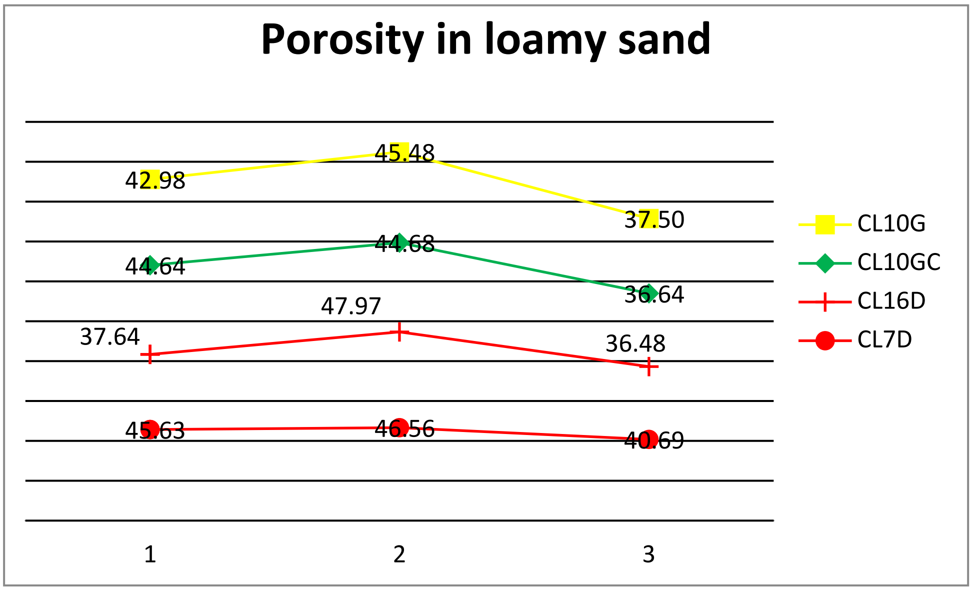

Fig. 25: Linear graph illustrating the mean percentage value of porosity in loamy sand soils for the months of May (1), June (2), and July (3). Each land management category is represented by a distinct colour: degraded in red, cultivated alternated with grazing in green, and grazing in yellow.

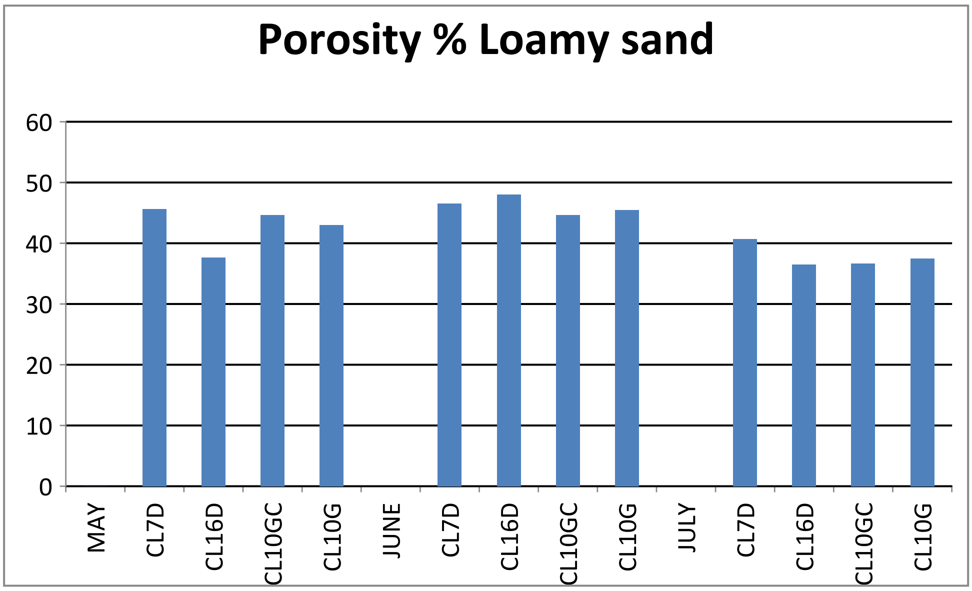

Fig. 26: Bar charts and error bars for the standard deviation representing mean porosity percentage of loamy sand soils for the month of May, June and July.

Overall, Figure 27 shows a comprehensive summary. While the project plots may not exhibit the highest porosity values, they consistently demonstrate more uniform values. Specifically, in sandy clay loam and sandy loam soils, G+C shows the highest porosity along with the highest standard deviation. While in loamy sand, the highest porosity value is found in D. Additionally, the figure 27 clearly illustrates how porosity decreases with an increase in sand content.

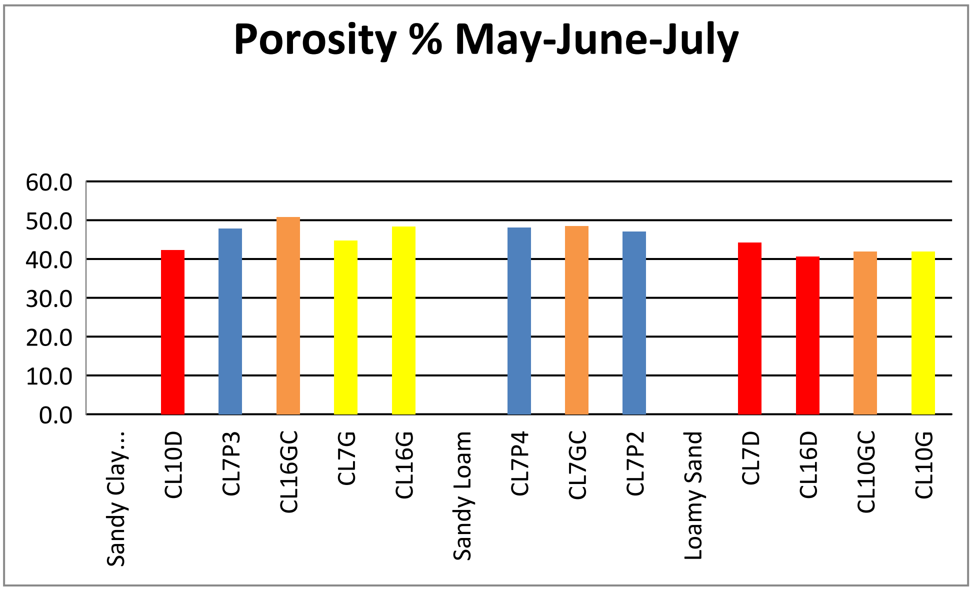

Fig. 27: Bar charts representing the mean porosity percentages for May, June, and July, along with error bars to show the standard deviation, are colour-coded as follows: red for the degraded land regime, green for the cropping and grazing regime, yellow for the grazing land regime, and blue for the experimental regime.

4.1.3 Soil Moisture

The soil moisture values obtained in May, June, and July are summarized in the table and histogram below. They reveal a soil moisture range from 2.8% to 29%. The fields are categorized into three primary groups based on their texture: sandy clay loam, sandy loam, and loamy sand soils. Sandy clay loam is the most representative, as it encompasses all four land regimes: D, G, G+C, P. For each field, three samples are taken, and both the mean and the standard deviation are calculated.

In sandy clay loam soils, the values of all land regimes vary significantly based on rainfall. The three regime that remain stable throughout all three months are the project plot, the G+C and the D (Fig. 28). While G+C and P present a similar trend with a central reduction and a lateral increase, D presents a constant decrease from May till July. In the figure 29 it is than possible to observe that G+C has a notably high standard deviation for the first two months, evidencing a lack of moisture uniformity across the entire field.

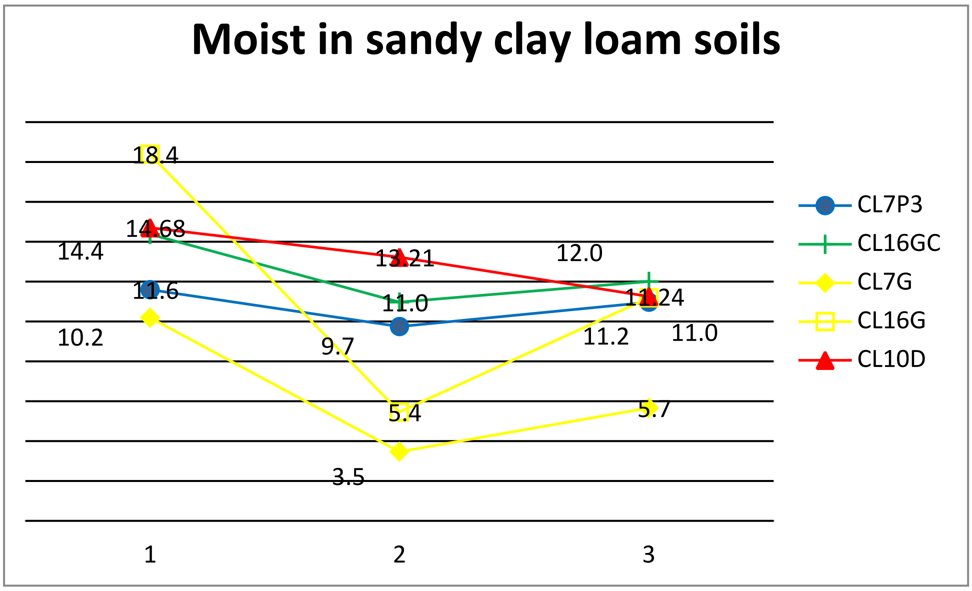

Fig. 28: Linear graph illustrating the mean percentage value of moisture in sandy clay loam soils for the months of May (1), June (2), and July (3). Each land management category is represented by a distinct colour: degraded in red, project in blue, cultivated alternated with grazing in green, and grazing in yellow.

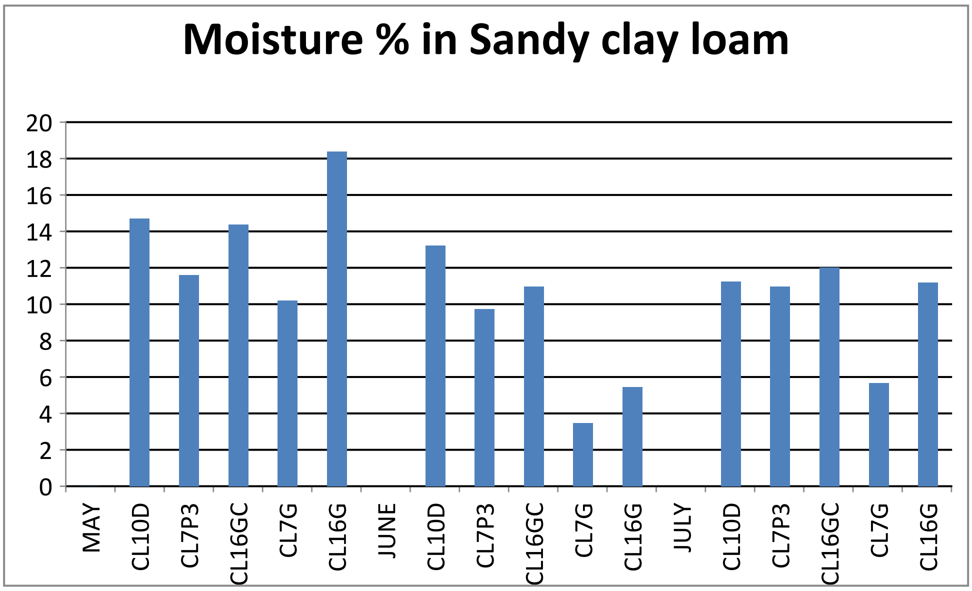

Fig. 29: Soil moisture mean percentage of May-June and July for the sandy clay loam soils represented with bar charts and error bars for the standard deviation.

In the sandy loam soils, the two land regimes found are P and G+C. Both exhibit relatively high values, but G+C has a high pick in June. The two project plots, instead, demonstrate a decreasing trend during the three months (Figg. 30-31).

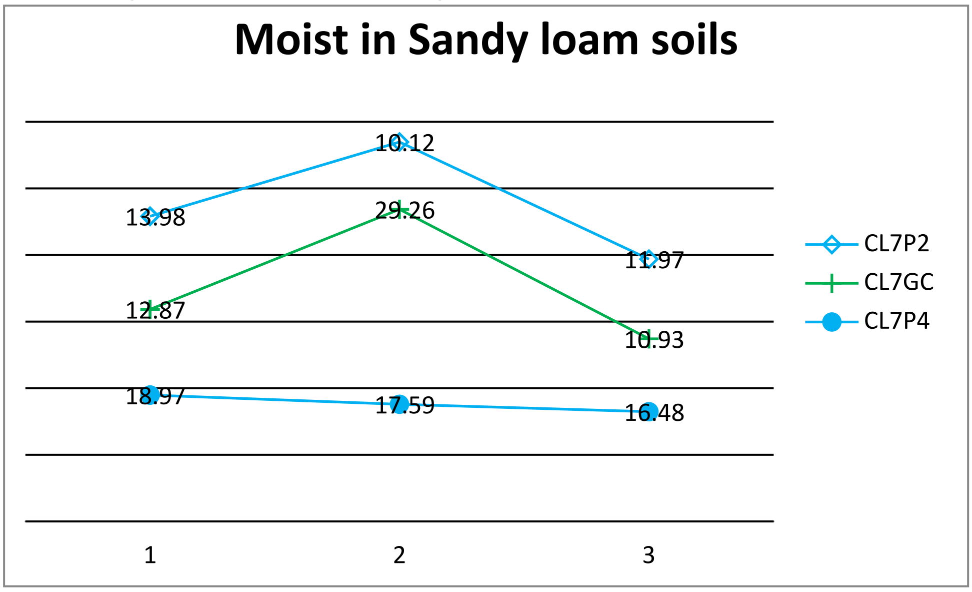

Fig. 30: Linear graph illustrating the mean percentage value of moisture in sandy loam soils for the months of May (1), June (2), and July (3). Each land management category is represented by a distinct colour: project in blue, and cultivated alternated with grazing in green.

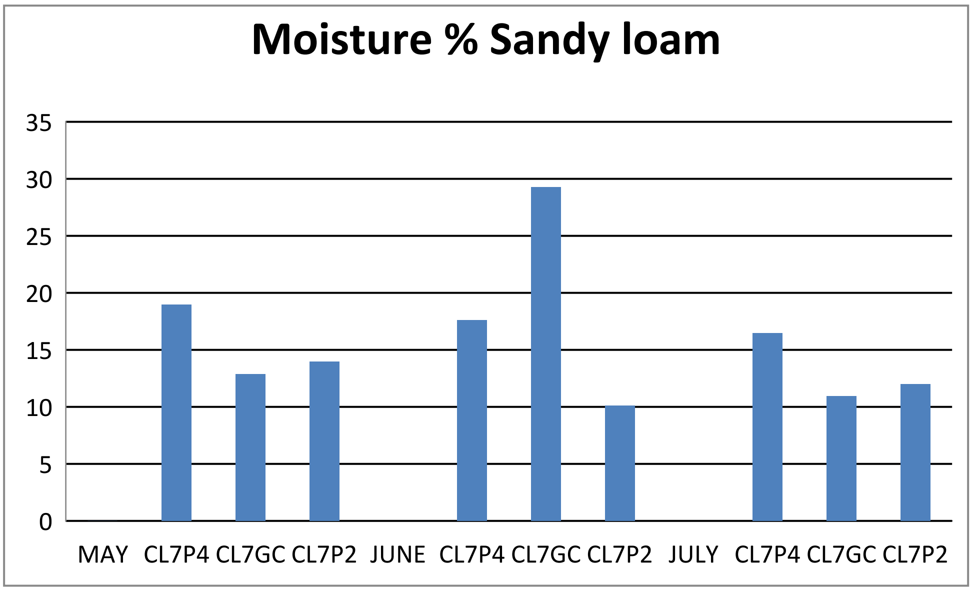

Fig. 31: Soil moisture mean percentage of May-June and July for the sandy loam soils represented with bar charts and error bars for the standard deviation.

Finally, the loamy sand soils present all land regimes except for the experimental one. What is evident from figures 32-33 is that G+C presents the highest values, except for the month of May, where D shows the highest values. Furthermore, in June, there is a noticeable decrease in moisture levels across all regimes in all clusters.

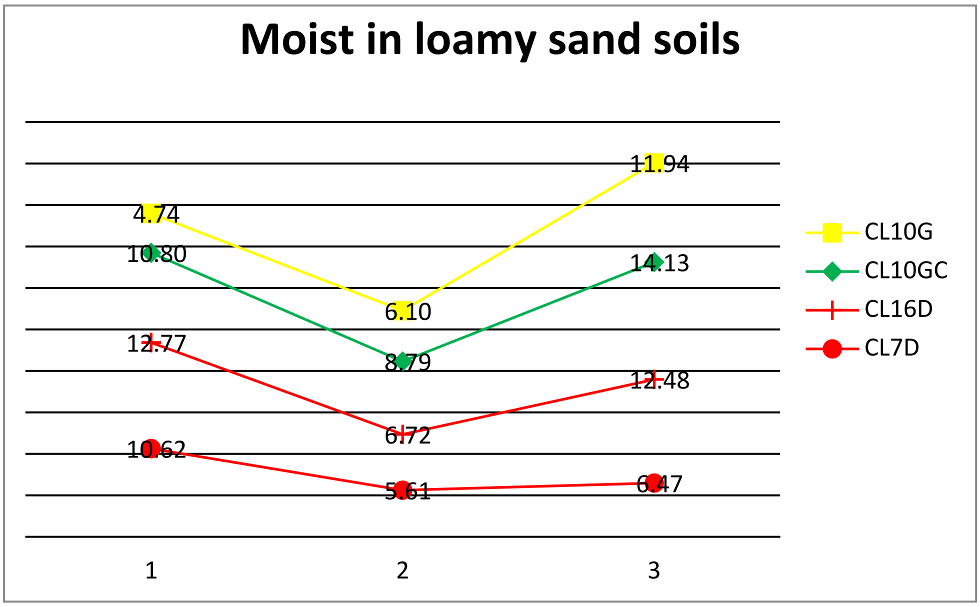

Fig. 32: Linear graph illustrating the mean percentage value of moisture in loamy sand soils for the months of May (1), June (2), and July (3). Each land management category is represented by a distinct colour: degraded in red, grazing in yellow, and cultivated alternated with grazing in green.

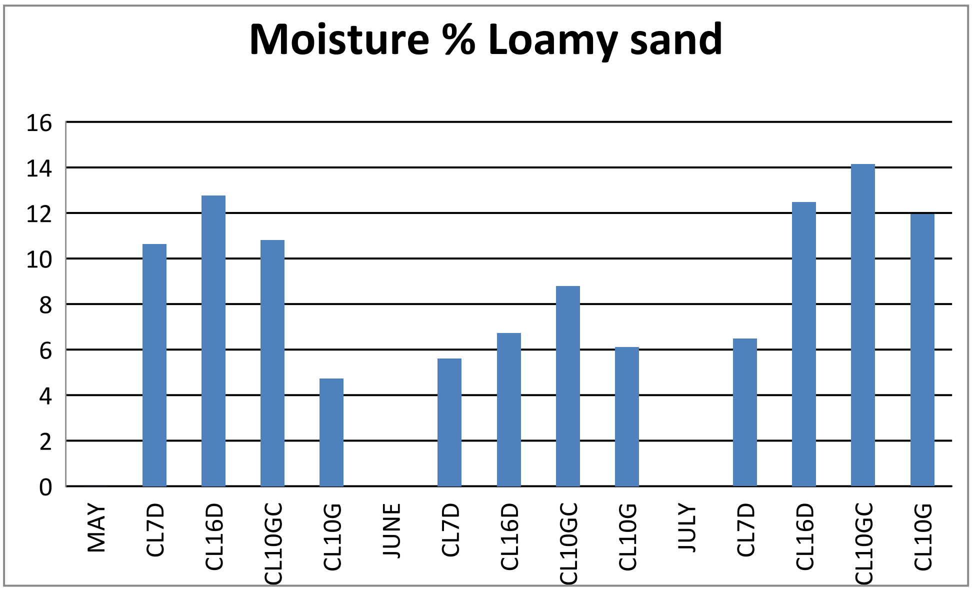

Fig. 33: Soil moisture mean percentage obtained in the month of May-June-July in loamy sand soils, represented with bar charts and error bars for the standard deviation.

Upon reviewing the latest graphs and calculating the mean for all three months, a clear understanding of the results emerges Firstly, there is a net decrease in all values in the month of June, except for CL7GC in the sandy loam soil. Secondly, as summarized in Figure 34, soil moisture decreases with higher sand content due to increased water percolation. In general, a direct connection between land regimes and soil moisture cannot be established, as these values are heavily dependent on no-uniform rainfall distribution (Table 9-10-11).

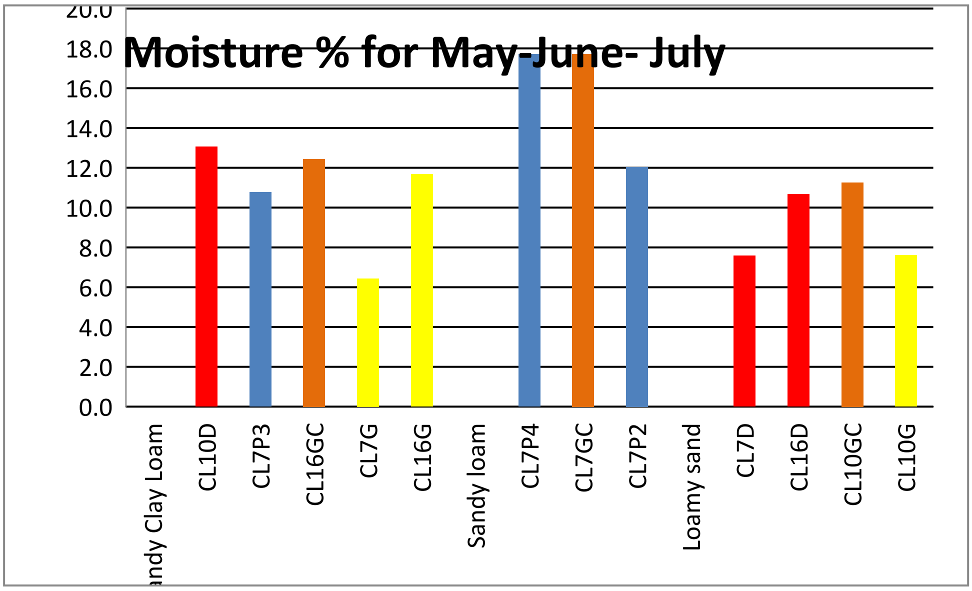

Fig. 34: Bar charts representing the mean soil moisture percentages for May, June, and July, along with error bars to show the standard deviation, are color-coded as follows: red for the degraded land regime, green for the cropping and grazing regime, yellow for the grazing land regime, and blue for the experimental regime.

4.1.4 Saturated Hydraulic Conductivity

The Saturated Hydraulic Conductivity (Ksat) is measured only in May and July, since in June the lab had some issues. The obtained values are summarized in the table and linear graphs below. The fields are categorized into three main groups based on their texture: sandy clay loam, sandy loam, and loamy sand soils. For each field three samples are taken and in the table below the following values are measured: the minimum, maximum, mean, standard deviation, and conductivity class.

The sandy clay loam soil is the most representative due to the presence of all land regimes: D, G, G+C, P. From Figure 35 and Table 5, it is evident that the Ksat of P is more consistent over the two months compared to the others. Specifically, for all land regimes, there is a significant increase in conductivity class between the two months, whereas for P, it consistently remains under the moderate class. An additional significant observation is that G demonstrates a higher value compared to G+C, but, at the very least, G+C still exceeds the degraded land.

Table 5: Minimum, Maximum, Mean, Standard Deviation and Conductivity class for the Ksat measured in the Sandy clay loam soil in May and July. The project Ksat values are highlighted in blue.

MAY	% Min	% Max	% Mean	Dev st	Conductivity class
CL10D	0.1	1.0	0.5	0.5	very slow
CL7P3	3.3	6.5	5.3	1.7	Moderate
CL16GC	1.0	2.4	1.7	0.7	Slow
CL7G	2.2	2.4	2.3	0.1	Moderate
CL16G	1.9	2.4	2.3	0.1	Moderate
JULY					
CL10D	0.6	8.7	5.8	4.4	Moderate
CL7P3	2.7	13.9	6.5	6.4	moderately rapid
CL16GC	2.3	13.9	6.5	6.4	moderately rapid
CL7G	3.5	19.4	10.0	8.3	Rapid
CL16G	13.5	15.1	14.3	0.8	very rapid

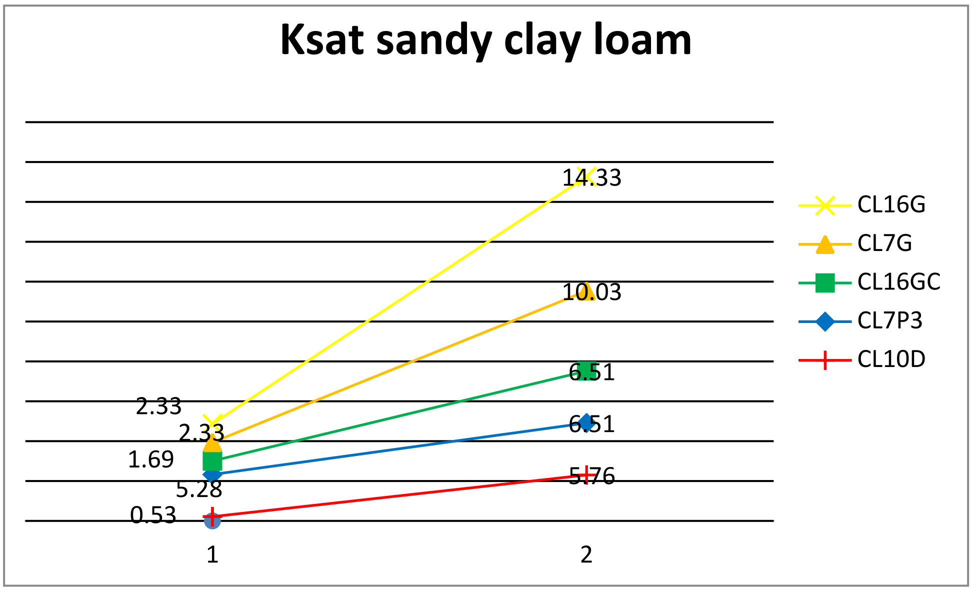

Fig. 35: Linear graph illustrating the mean percentage value of moisture in sandy clay loam soils for the months of May (1), and July (2). Each land management category is represented by a distinct colour: degraded in red, grazing in yellow, project in blue and cultivated alternated with grazing in green.

In sandy loam soils, only two categories of land regimes are present: P and G+C. The Ksat values show minimal differences, and both appear to be very uniform (Table 6, Fig. 36). Unlike the sandy clay loam soil, there is a reduction in Ksat from May to July, except for CL7P2.

Table 6: Minimum, Maximum, Mean, Standard Deviation and conductivity class of Ksat values in the sandy loam soils measured in May and July. The P values are highlighted in blue.

MAY	Min %	Max %	Mean %	Dev st	Conductivity class
CL7P4	0.4	3.5	2.3	1.6	Moderate
CL7GC	0.2	8.4	4.3	4.1	Moderate
CL7P2	1.6	2.1	1.8	0.3	Moderate
JULY					
CL7P4	0.4	3.1	2.1	1.5	Moderate
CL7GC	0.7	5.3	2.3	2.6	Moderate
CL7P2	2.8	9.6	6.9	3.6	moderately rapid

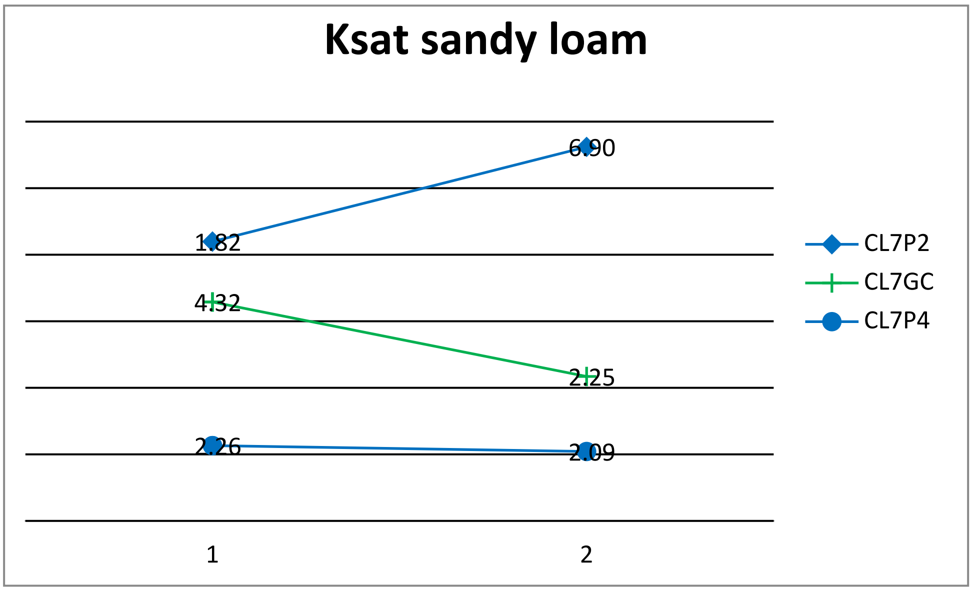

Fig. 36: Linear graph illustrating the mean percentage value of moisture in sandy loam soils for the months of May (1), and July (2). Each land management category is represented by a distinct colour: project in blue and cultivated alternated with grazing in green.

In the loamy sand soils, the present land regimes are D, G, and G+C. Their Ksat values are not particularly representative (Table 7, Fig.37), but they all present an increase in July.

Table 7: Minimum, Maximum, Mean, Standard Deviation and conductivity class of Ksat values in the loamy sand soils measured in May and July. The P values are highlighted in blue.

MAY	**Min %**	**Max %**	**Mean %**	**Dev st**	**Conductivity class**
CL7D	0.6	1.1	0.8	0.2	Slow
CL16D	0.7	0.9	0.8	0.1	Slow
CL10GC	0.3	2.5	1.4	1.1	Slow
CL10G	4.8	8.9	6.9	2.1	moderately rapid
JULY					
CL7D	2.2	5.6	4.5	2.0	Moderate
CL16D	1.0	2.5	1.8	0.8	Slow
CL10GC	1.9	2.4	2.1	0.3	Moderate
CL10G	0.3	10.2	4.0	5.4	Moderate

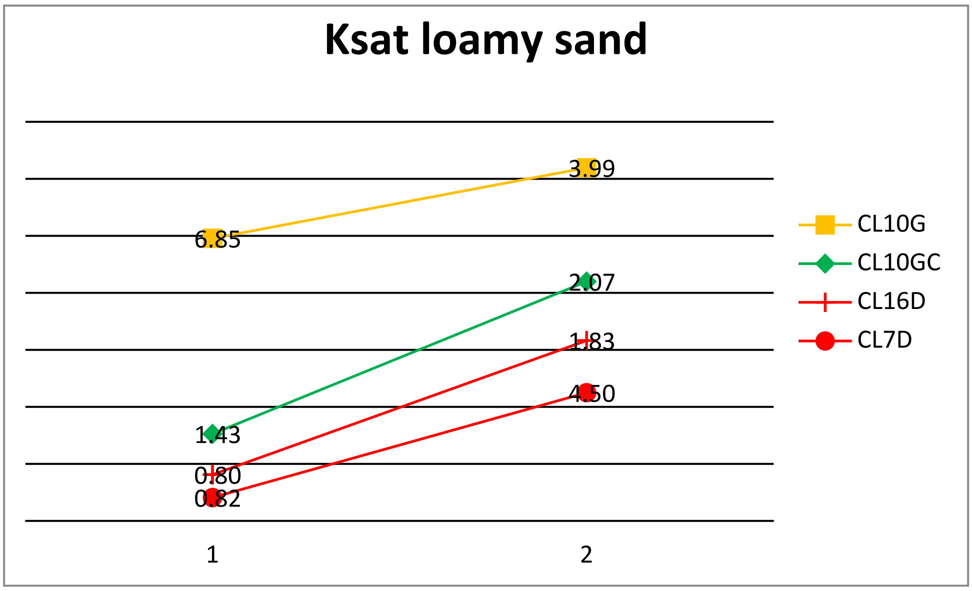

Fig. 37: Linear graph illustrating the mean percentage value of moisture in loamy sand soils for the months of May (1), and July (2). Each land management category is represented by a distinct colour: degraded in red, grazing in yellow, and cultivated alternated with grazing in green.

4.1.5 Infiltration velocity

Infiltration velocity is measured once for each field between May 29th and June 2nd. The values are presented in Table 8 and in the Figure 38, categorized by soil texture. Notably, the highest infiltration velocity, at 0.94 cm/min, is observed in the loamy sand soil of the grazing land CL10 due to the high sand content, with the second-highest in the highly vegetated field of the project, which has a sandy loam texture.

Table 8: This table reports the infiltration velocity (cm/min) for each land management system, with the CL7P project fields highlighted in blue.

Sandy clay loam	**Infiltration Velocity (cm/min)**
CL16 G	0.16
CL10 D	0.2
CL7 P3	0.27
CL16 GC	0.3
CL7 G	0.42
Sandy loam	
CL7 P4	0.09
CL7 GC	0.21
CL7 P2	0.93
Loamy sand	
CL16 D	0.14
CL7 D	0.17
CL10 GC	0.26
CL10 G	0.94

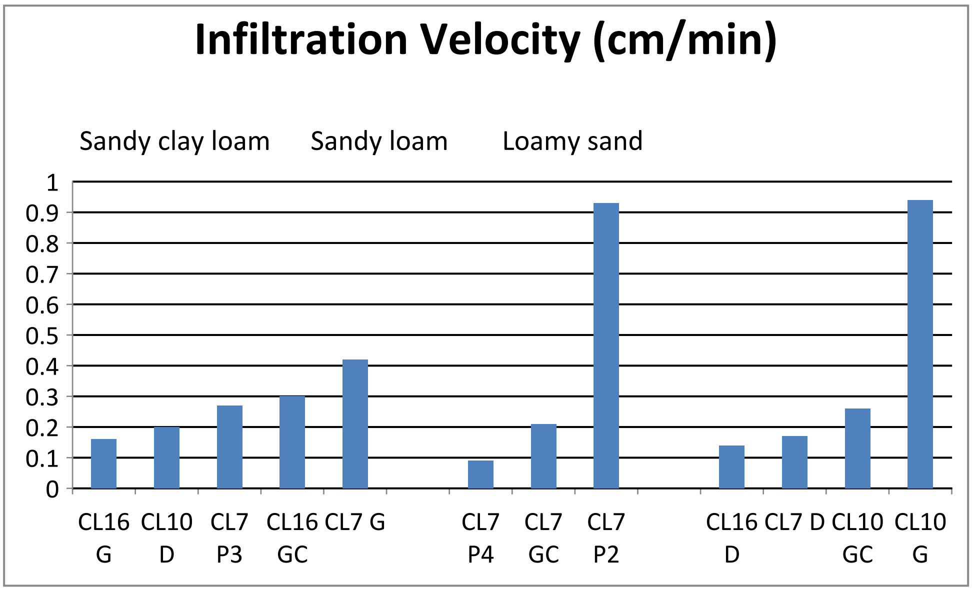

Fig. 38: This histogram shows the infiltration velocity values graphically in the form of a histogram.

4.1.6 Precipitation in Chepareria

It is possible to track the precipitation amounts throughout the months of the field test using the data provided in Table 9-10-11. Three rain gauges are strategically positioned: one at the Nasukuta Rainfall Station, the national meteorological station, one at the LCa and one at LC. Nasukuta Rainfall Station is close to CL10, LCa is inside CL7, and LC is between CL7 and CL16. Indeed, the distance from Nasukuta Rainfall Station and LCa is 5.6km; the distance from LCa and LC is 2.6km; the distance from Nasukuta Rainfall Station and LC is 8.2km.Moreover, the measurements at Nasukuta are automatically recorded and sent to the Nairobi Station, while those at LCa and LC are manually read, introducing a potential source of imprecision.

Table 9: Rain data collected in the month of May in the Nasukuta Rainfall Station, in the Livestock cafè annex and in the Livestock cafè.

Lat	1.3733		1.41023		1.4328
Long	35.18793		35.16542		35.16221
CL	CL10		CL7		CL7-CL16
Nasukuta	0	**LCa**	0	**LC**	1.3
	0		0		0.3
	4.1		0		0.6
	0		0		80.3
	0		0		2.1
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		1.7
	2.1		18		15.1
	0		25		20.1
	0		0		0
	0		0		0
	10.4		24		35
	0		0.5		15.1
	0		5		15
	0		5.5		0
	4.5		0		10.1
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		1
SUM	21.1		78		197.7

Table 10: Rain data collected in the month of June in the Nasukuta Rainfall Station, in the Livestock cafè annex and in the Livestock cafè.

Lat	1.3733		1.41023		1.4328
Long	35.18793		35.16542		35.16221
CL	CL10		CL7		CL7-CL16
Nasukuta	0	**LCa**	0	**LC**	0
	0		0		0
	5.1		0		0
	0		0		0
	0		0		0
	0		0		0
	10.1		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	11.4		55		5.5
	0		0		3
	2.1		0		0.09
	15.6		0		0
	0		0		0
	0		0		0
	14		0		5.5
	0		0		0
	0		0		0
	0		0		0
	0		0		1.7
	9		15		0
	0		3		5.5
	2.1		35		0
	0		0		10
	0		0		0
	0		0		0
	0		0		0
	0		0		0
SUM	69.4		108		31.29

Table 11: Rain data collected in the month of July in the Nasukuta Rainfall Station, in the Livestock cafè annex and in the Livestock cafè.

Lat	1.3733		1.41023		1.4328
Long	35.18793		35.16542		35.16221
CL	CL10		CL7		CL7-CL16
Nasukuta	15	**LCa**	25	**LC**	21.5
	29		50		24
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	5.1		0		0
	0		0		0
	5.4		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	0		0		0
	4		0		0
	3.1		0		0
	0		0		0
	0		0		0
	0		0		3.4
	15.7		15		0
	0		0		0
	0		0		0
SUM	77.3		90		48.9

4.2 Interview Result

4.2.1 Interview Result

Following the interviews, the mean number of family members is 6, with a maximum value of 18 and a minimum of 1. The average land size is 3.5 hectares, with 2 hectares being the most common value. The graph below illustrates the relationship between the number of family members and land size (Fig 39). It also shows the linear correlation between the data, which is

R^2=0.0039. This value indicates that there is no significant correlation between land size and family size.

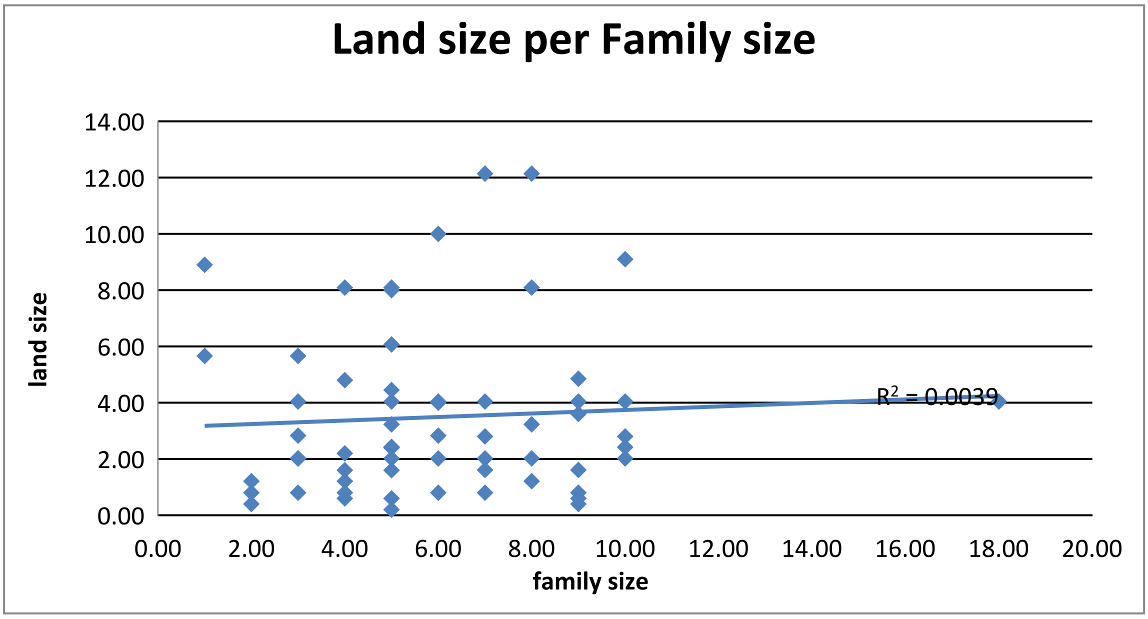

Fig. 39: Scatter plot representing the size of land per size of family within a regression line to measure the correlation between the data.

The primary activities conducted on the land include grazing, maize, and beans production, while 61.9% of households have a kitchen garden. On average, each family owns 5 cows, 10 goats, and 9 sheep. The graphs below (Fig 40-41-42) illustrates the number of cattle as a function of numbers of family components. It also shows the linear correlation between the data, which in this case indicate that there is no significant correlation between family size and cattle amount.

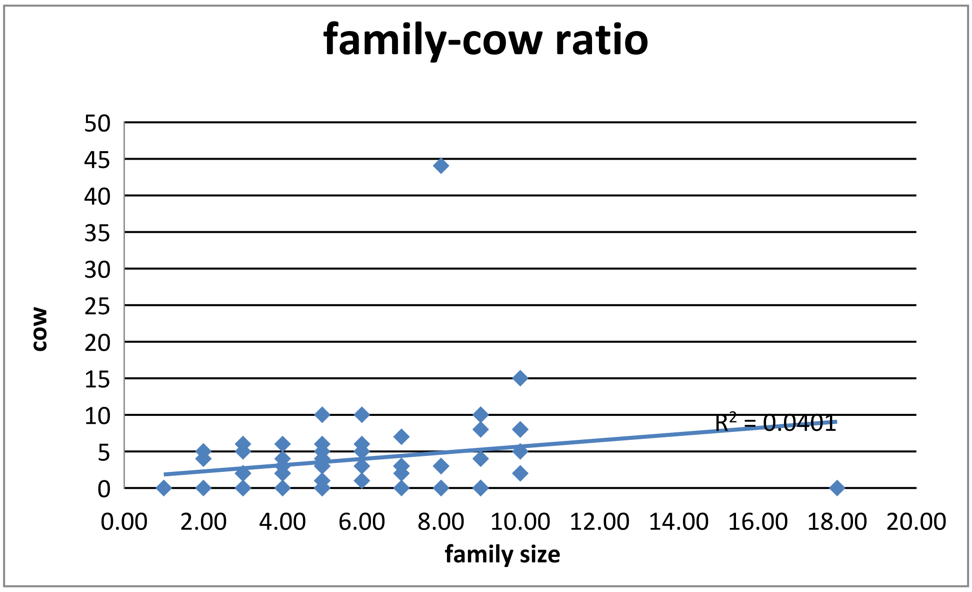

Fig. 40: Scatter plot representing the number of cows in each family within a regression line to measure the correlation between the data.

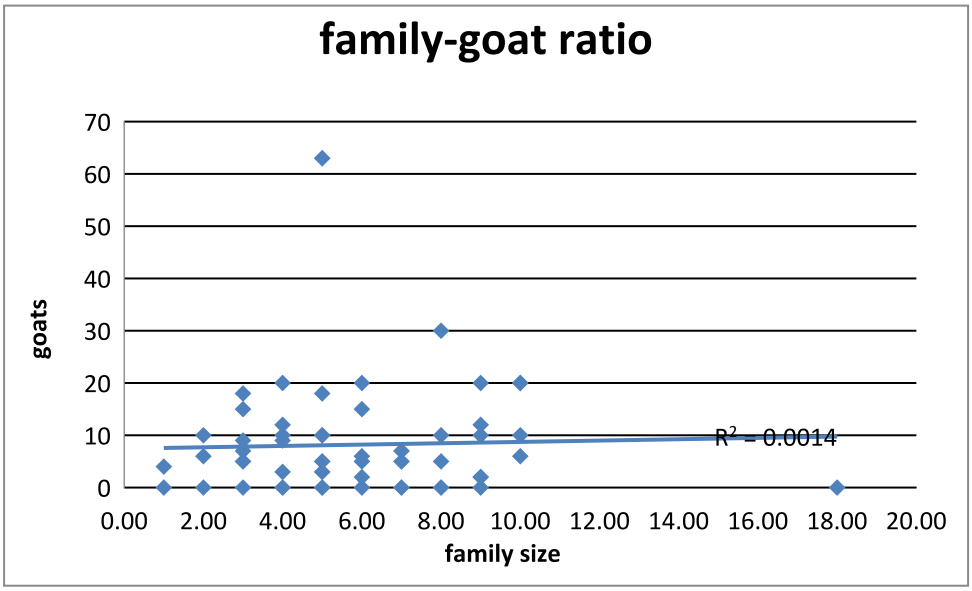

Fig. 41: Scatter plot representing the number of goats in each family within a regression line to measure the correlation between the data.

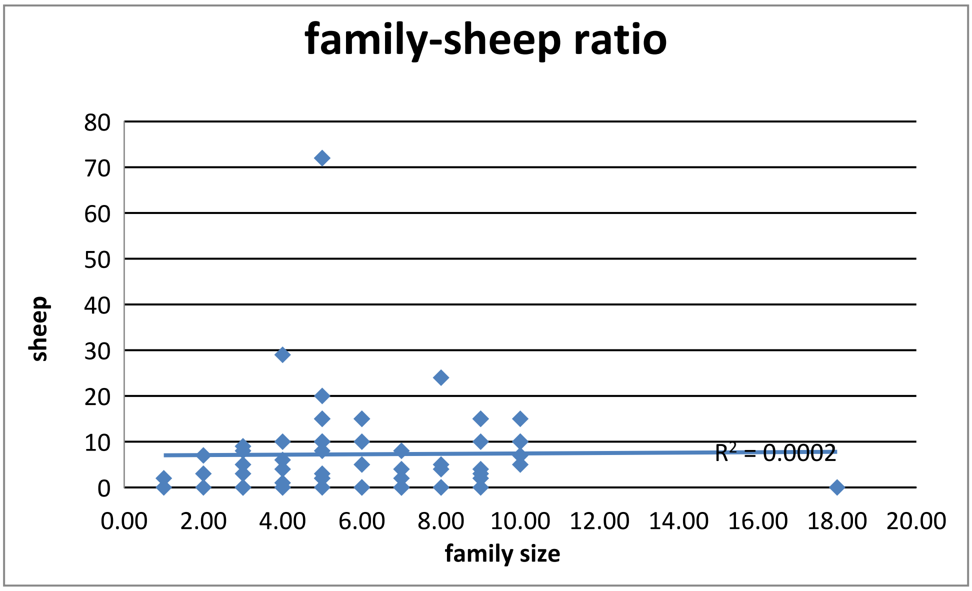

Fig. 42: Scatter plot representing the number of sheep in each family within a regression line to measure the correlation between the data.

4.2.2 Individual Interviews

Individual interviews provide valuable insights into individual behaviour concerning land erosion and water scarcity. It's worth noting that 61 interviews have been conducted instead of the initially planned 60. Approximately 51.9% of respondents mention suggestions and interesting observations shared by neighbours and friends pertaining to soil conservation and water harvesting (Figure 43). The answers are systematically categorized based on the nature of the suggestions or interesting observations provided by the respondents: responses emphasizing the use of ditches and terraces are classified under *Soil Water Harvesting*. Those suggesting the introduction of specific fertilizers or pesticides, along with recommendations for the type to be employed, are grouped within the *Yield Increase* category. Suggestions that involve the incorporation of various elements such as groundnut cultivation, specific cattle breeds, orchards, kitchen gardens, or the use of verified seeds are allocated to the *Production Diversification* category.

Observations related to practices like rotation grazing patterns (paddock), land enclosure, or the planting of grass and trees are placed under the *Soil Preservation* category. Ideas centred around the use of organic farming methods, particularly the use of manure, are designated as *Organic Farming*. Finally, responses that focus on expanding income sources, increasing goat herds, or enhancing maize cultivation are categorized as *Increase Economic Stability* (Table 12).

Table 12: List of suggestions type and the coding worlds used for the analysis in IBM SPSS.

Answer	**Code**
• Ditches, • Terraces	Soil Water Harvesting
• Introduction and type of Fertilizers and Pesticides	Yield Increase
• Cultivation of Groundnut, • Orchard, • Kitchen garden, • cattle breeding, • verified seed	Production Diversification
• Paddocking, • enclosing, • pasture establishment, • planting trees	Soil Preservation
• Manure	Organic Farming
• Income, • more goat, • more maize	Increase Economic Stability

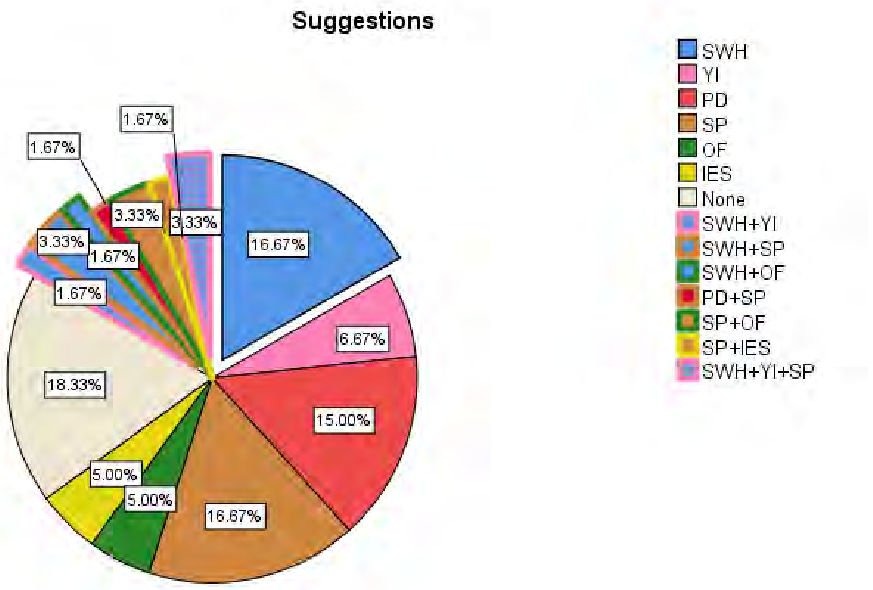

Fig. 43: Pie graph reporting the percentage of suggestions. The sections extracted in blue are related with water harvesting (SWH). The frame of the section containing two practices matches the colour of the slice of the second practice. The frame of the section containing three practises matches the colour of the slice of the second practice and the slice, instead, presents some line. The type of suggestions are divided into several groups: Soil water harvesting (SWH), Increase yield production (ITP), Increase diversified production (IDP), Soil Preservation (SP), Organic Farming (OF), Increase economic stability (IES), no suggestion (None), SWH+YI, SWH+SP, SWH+OF, PD+SP, SP+OF, SP+OF, SWH+YI+SP.

Considering that the approximated percentage of eroded land resulted by the individual interviews is 11%, various prevention measures need to be employed. The tables below highlight the types and frequencies of these prevention measures (Fig. 44). The most used prevention measurement results to plant sisal gaining 57.4%. Meanwhile, the type of answers are summarized in the table 13.

Table 13: List of prevention measures cited by the interviewers.

Answers:
Planting trees
Ditches and terraces
Planting sisal
Using stone
Tree branches
Fences
Planting *Aloe vera*
Break between the cultivation plots
Planting far from the river

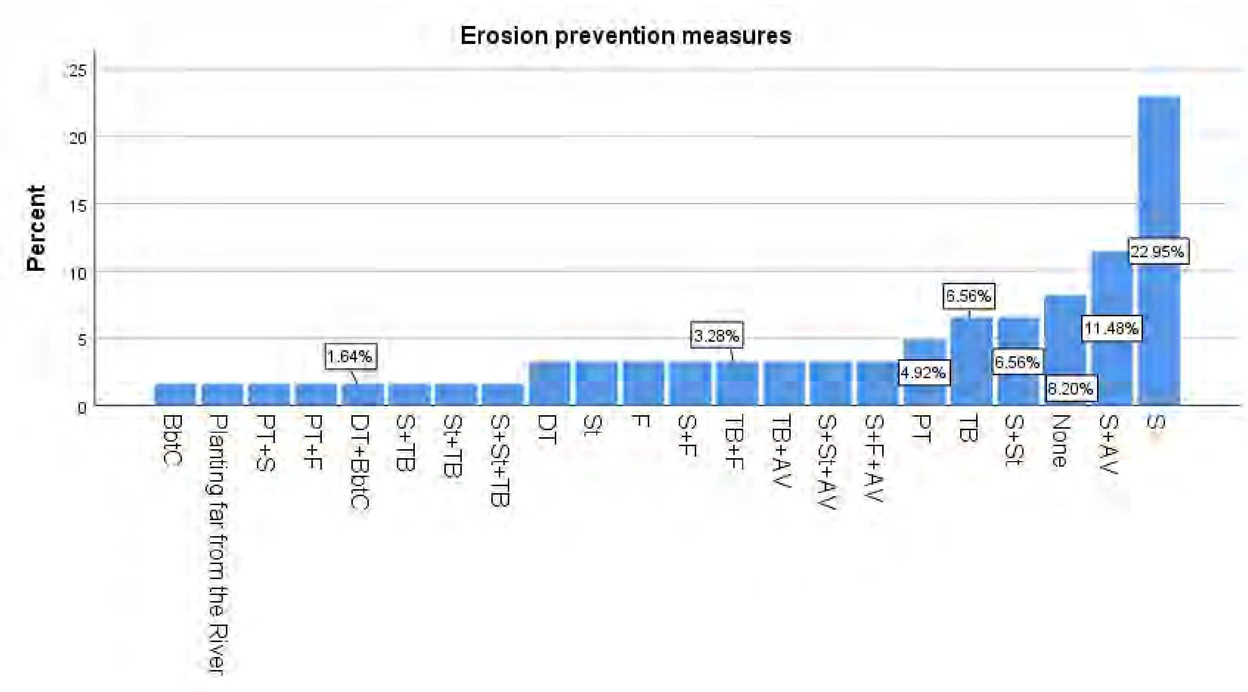

Fig. 44: Graphs representation of the main prevention for erosion. The main prevention measures are subdivided into the following groups: No prevention (None), Planting trees (PT), Ditches and terraces (DT), Planting sisal (S), Using stone (St), Tree branches (TB), Fences (F), Break between the Cultivation plots (BbtC), Planting far from the river, PT+S, PT+F, DT+BbtC, S+St, S+ TB, TB+F, TB+AV, S+ST+TB, S+ST+AV.

Moreover, thanks to the interviews, it was possible to compile a map of extreme drought years, many of which were associated with specific names (Table 14).

Table 14: Scale of the extreme drought years associated with local names and effects.

DRY YEAR	NAME	EFFECTS
1978	*Lokipi*	Any prevention done, just hoping for some help
1984	*Lotirrirr*- America	Many animals died, yield reduced
1994		Rain delay, animal feed tea leaves
1999	*Lopock*	Migration route changed because of a disease's outbreak in the West
2009		Animal died because of diseases, zero crop harvest
2023		Global drought so no need to migrate, rain pattern shifted

Since there is an extreme drought year approximately every 10 years, 88.5% of farmers are implementing prevention measures. The types of drought prevention measures fall into five main categories: Responses regarding pasture establishment, the selection of more resistant crops, and the importance of fodder trees are classified as *Increase Biodiversity*. Answers mentioning paddocking and enclosure are grouped under *Soil Conservation* for drought prevention. Responses involving expanding the grazing land, migration, maintaining a stock of maize and other grasses, and purchasing additional resources are categorized as *Cattle Health*. Type of prevention related to reducing the number of animals and the significance of increasing income are placed within the *Economic Stability* category. Answers emphasizing the importance of building ditches for drought prevention are classified under *Water Harvesting* (Table 15). The Figure 45 outlines the main categories of prevention measures: increasing biodiversity (approx. 14%), soil conservation (approx. 24%), cattle health (approx. 45%), economic stability (approx. 13%), and water harvesting (approx. 1%).

Table 15: List of answers got in the interviews associated with the code used in the statistical analysis through IBM SPSS.

Answers	**Code**
• Pasture establishment, • selection of resistant crop, • introduction of fodder trees	Increase biodiversity
• Paddocking, • enclosing	Soil conservation
• Increase grazing land, • migration, • stock maize, • stock hay • buy grass	Cattle health
• Save or make money, • reducing animal	Economic stability
• Ditches	Water harvesting

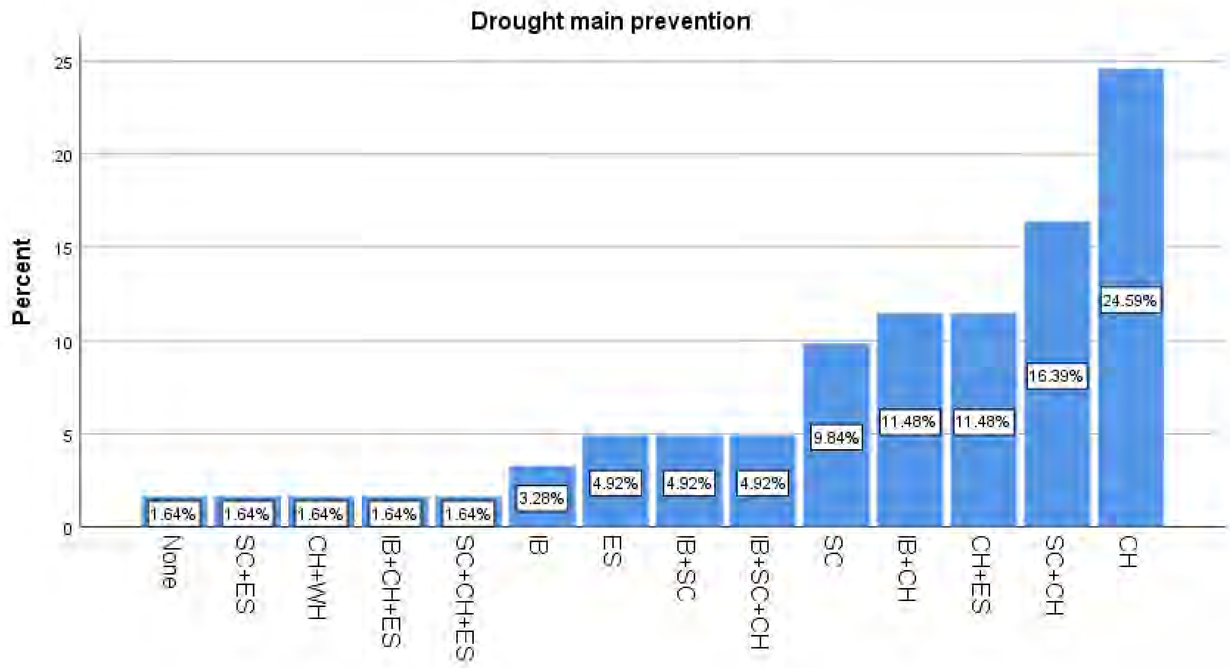

Fig. 45: Graphs on main prevention on drought. The main prevention types are subdivided into groups: Increase biodiversity (IB), Soil Conservation (SC), Cattle Health (CH), Economic Stability (EC), Water Harvesting (WH), No prevention (None), IB+SC, IB+CH, SC+CH, CH+WH, IB+SC+CH, IB+CH+ES.

The drought prevention measures are further analysed in conjunction with the educational level. The graph in Figure 46 clearly shows that there is no linear correlation between the various measures adopted and the level of education. Indeed, the only case of water harvesting is mentioned by an interviewee who completed high school. On the other hand, the sole case of no prevention measures is mentioned by an interviewee who continued studying after high school.

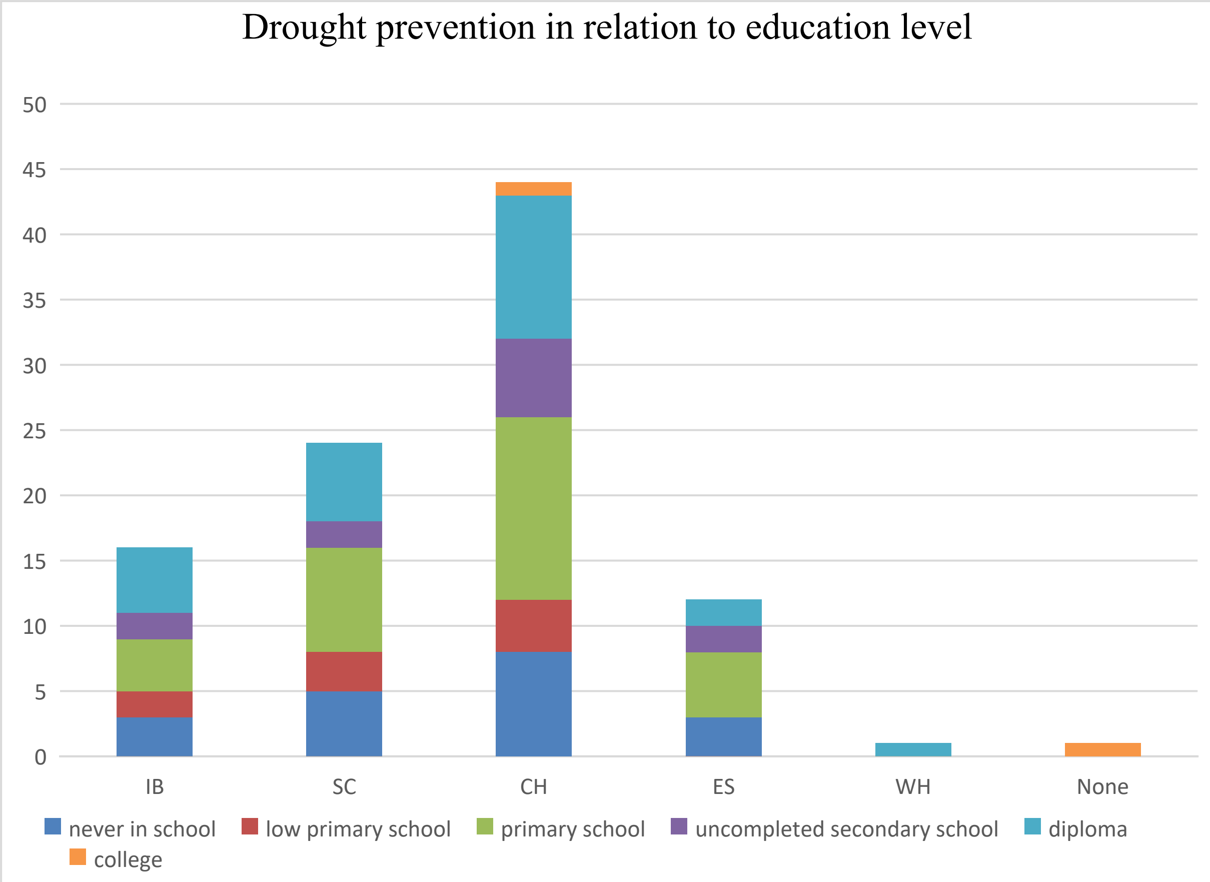

Fig. 46: Histogram that integrates the level of education with the specific drought prevention measures adopted by the interviewers. The main prevention types are subdivided into groups: Increase biodiversity (IB), Soil Conservation (SC), Cattle Health (CH), Economic Stability (EC), Water Harvesting (WH) and No Prevention (None).

Water harvesting practices could play a fundamental role during drought periods and the one mentioned in the interviews are categorized into different groups to facilitate the analysis: Rooftop water harvesting is coded as *Household Consumption*; Practices like ditches, terraces, stone lines, and half-moons are classified under the *Soil Water Harvesting* category; Water pans are included in the *Governmental Construction* category (Table 16). Unfortunately, 67% of water harvesting is done for household consumption through roof-top water harvesting, while only 32.3% is used for soil water harvesting through ditches, terraces, or occasionally stone lines and half-moons (Figure 47).

Table 16: List of answers from the interviewers associated with the coding worlds used in the statistical analysis through IBM SPSS.

Answers	**Code**
• Roof-top water catchment	Household Consumption
• Ditches, • terraces, • stone-line, • half-moons	Soil water harvesting
• Water pan	Governmental construction

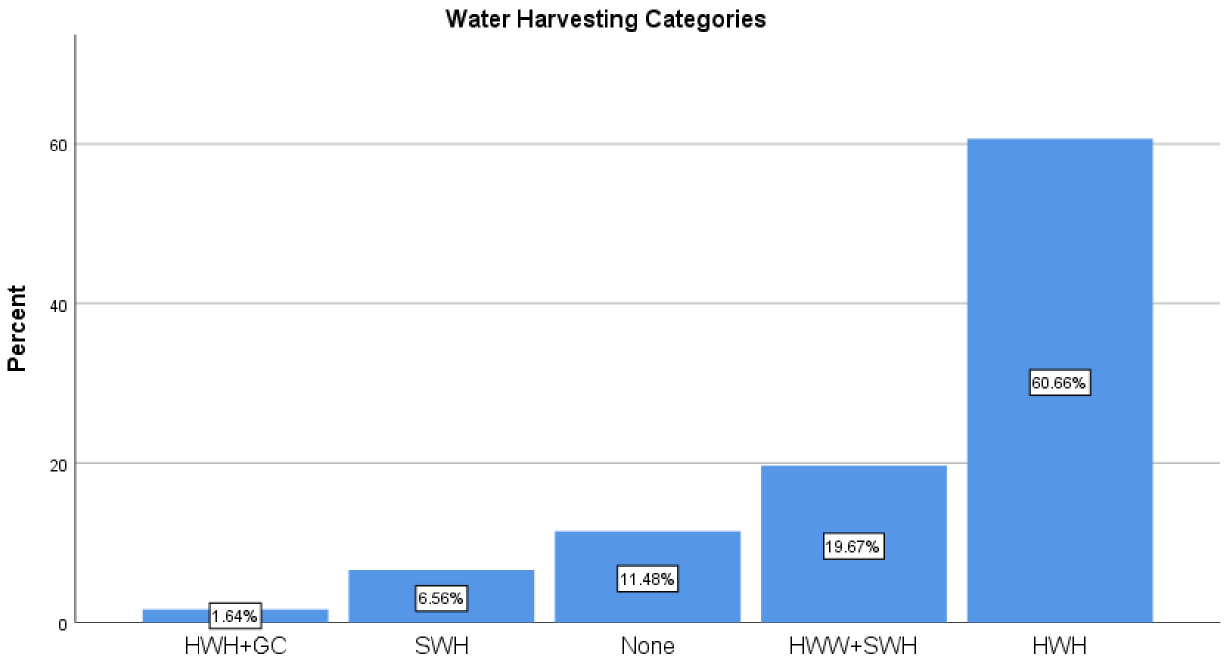

Fig. 47: Graph of Water Harvesting categories. The categories are subdivided into the following groups: No water harvesting (None), Household Water harvesting (HWH), Soil water harvesting (SWH), Governmental Construction (GC), HWH+SWH, HWH+GC.

To consolidate the findings from the interviews, Table 17 presents a summary of the key points.

Table 17: List of relevant questions, results and numbers obtained in the individual interviews.

Question	Results	Number
Land size	Not interconnected with family size	3.5 ha
Herd size	Not interconnected with family size	5 cows, 10 goats, 9 sheep
Suggestions	Related with soil and water conservation	51.9%
Eroded land	Mean of percentage land eroded per each interviewer	11%
Erosion prevention measurement	Most common: planting Sisal	57.4%
Drought years	Approx. every 10 years	’78, ’84, ’94, ’99, ’09, ‘23
Drought prevention measurement	Most relevant: cattle health	approx. 45%
Drought prevention combined with education	No correlation between type of prevention and level of education	-
Water Harvesting practices	Most common: roof-top water catchment for household consumption	67%

4.2.3 Focus Group Discussion

The three Focus Group Discussions (FGDs) shed lights on the community's relationship with the land. The Pokot tribe, an ancient pastoral community, historically possesses vast herds of cattle and led a nomadic lifestyle.

The results of all three FGDs reveals that in the 2000s, community land began to be divided among families to reduce conflicts, thus marking the start of land ownership. In all three FGDs the average land per family cited is around 2ha, but in CL7, there is an exponential decrease in land ownership due to families dividing land among their children.

Another significant change in the area is education. In all FGDs, it emerges that individuals above the age of 30 did not attend school, while for the new generation, completing high school is considered essential. This transformation is possible due to the construction of several schools in the area. Furthermore, education has gradually gained importance within the community, as in the past, only the ‘laziest’ child or the last-born were sent to school, and yet, they were the ones bringing innovative ideas to the family. Consequently, families started fundraising with neighbours and reduced cattle herds to pay for school fees.

The side effect of reducing cattle herds is that families invested more time in activities like agriculture. Sorghum and millet were traditionally the main crops, cultivated even during their nomadic period to complement their carnivorous diet. The introduction of maize, facilitated by Western countries, led to its widespread adoption due to its ease of cultivation, resistance to pests, and versatility in the kitchen. Soon, beans also gained popularity. Kitchen garden plays also an important role in their agricultural system, in CL7 and CL10 around 50% of the household own one kitchen garden, while in CL16 it is very rare due to water scarcity.

In terms of livestock, all FGDs agree on an average of 5 cows per family, while goats and sheep ratios vary across clusters. CL16 has around 5 goats and 5 sheep per family, CL10 has an average of 10 goats and 6 sheep, and CL7 has 10 goats and 15 sheep. This difference in CL7 is due to a specific sheep breed that is more suitable for smaller land, has greater economic value, and produces more nutritious milk.

CL7 and CL10 have shown improvements in land management, especially concerning tree planting and enclosing the rangelands, which has resulted in a cooling climate and increased green production, while reducing problems related to soil erosion. Only CL10 received training from Smart Agriculture in 2022, which focused on improving animal breeds and tree planting; and from 1993 to 1998, VI Agroforestry actively assisted the community of CL10 in controlling soil erosion introducing enclosure systems. Since then, these systems have been widespread among the community of Chepareria ward.

The community is aware of the environmental threat posed by soil erosion. They understand that overgrazing often leads to erosion, but they explain that grazing tends to occur on soil that already has existing problems, making it more susceptible to erosion. Additionally, in some areas, unfavourable topography exacerbates the issue. The soil used for farming, even if it's looser due to tillage or more exposed after harvest, is better protected from erosion due to its improved condition. The community acknowledges that, on average, 60% of their land experiences erosion. To prevent erosion, they implement measures like paddocking, enclosure, and protecting water paths with logs, stones, or erosion-resistant plants like sisal or *Aloe vera*.

To manage soil fertility in their traditional practices, they usually rely on manure. However, in CL7, where the cattle population is reduced, there's less manure available, and the cost of fertilizers and verified seeds is high.

Even though they have fewer cattle and experience less severe droughts because of tree planting, migration is still a crucial way to deal with dry seasons and years. Each cluster has its migration pattern. CL7 has an organized approach: cattle are taken to Trans-Nzoia, a neighbouring county, every year in November when the cultivation season begins. They stay there until December when the land is prepared for agricultural production, after which they move to Uganda. Within a large group of families, they rotate responsibility for cattle migration every two weeks. Most animals are not returned home unless they need to be milked. For CL10, migration occurs directly to Uganda every year during the dry season. In contrast, CL16 migrates to Uganda only in extreme situations during dry years. Some community members prefer to avoid migration and instead implement techniques to increase grass productivity on their land. However, they agree that migration is becoming increasingly dangerous due to cattle rustling and population growth, which are pushing pastoralists further into Uganda, where welcoming communities are scarce. For this reason, they are actively seeking alternative solutions to reduce the need for migration and to expand pasture availability within their own country.

The primary method for storing water is through rooftop catchment, but it's only efficient for household use when containers are available, and when the roof is not made of hay. While it's excellent for domestic consumption, it's less suitable for irrigating plants. The use of ditches, terraces, and half-moons is less common. Among the clusters, CL16 has only 10% using rooftop water catchment, while in CL7, it's 20%, and in CL10, 40% use rooftop water catchment along with 10% employing ditches and terraces.

Overall, the community expresses curiosity and willingness to learn water harvesting techniques and practices to prevent erosion.

To consolidate the findings from the FGDs, Table 18 presents a summary of the key points.

Table 18: List of question and of answers provided by the 3 different FGDs. When the answers of all the groups are the same, the other two cells are removed.

Question	**CL7**	**CL10**	**CL16**
Average land size	2ha		
Education	Under 30years school completed or about to complete, above analphabetic or elementary level		
Herd reduction	Due to payment of school fee, of sedentary life. Consequence: agriculture		
Kitchen Garden	40%	60%	0%
Enclose effects	Improved the area		
Erosion	Induced by overgrazing, tillage and topography. It is perceived 60% of land eroded in the area		
Migration	Every year: Trans-nzoia Nov-Dic, Uganda Dic-Oct	Every year: Uganda	Only in extreme case: Uganda
Water Harvesting practices	20% roof-top water catchment	40% roof-top water catchment and 10% ditches and terraces	10% roof-top water catchment

5. Discussion

5.1 Soil Physical Analysis

5.1.1 Texture Analysis

The study area is predominantly characterized by a high percentage of sand, with 41.6% of the field exhibiting a sandy clay loam soil, followed by 25% with a sandy loam texture, and finally, 33.33% with a loamy sand soil texture. However, the results obtained from the LDSF measurements in 2021 reveal a striking disparity in soil textures within the same area. Specifically, 66.6% of the points exhibit a clay texture, while the remaining 33.3% display a clay loam texture (Table 19). This unexpected shift highlights a significant deviation from the previously observed soil composition in the study area.

Table 19: Table representing the texture of LDSF point taken in 2021 and their distance measured in meters with the closest point of the study area of this research.

LDSF	Sand%	Clay%	Texture	Closest point	Distance (m)
CL7.4	28	56	Clay	CL7G1	176
CL7.9	44	37	clay loam	CL7RM2.3	147
CL10.4	43	35	clay loam	CL10GC3	304
CL10.5	30	53	Clay	CL10D1	301
CL16.5	28	51	Clay	CL16D3	101
CL16.6	32	47	Clay	CL16G1	387

Given that the analyses were conducted with a two-year gap, a plausible explanation for the observed changes lies in the alteration of land composition due to the erosion process. This phenomenon is reminiscent of the findings in Chepil's experiment (Chepil *et Al*,. 1957), where erosion induced by water runoff and wind resulted in the removal of either a substantial or a thin layer of topsoil (Colazo *et Al*,. 2015).

However, attributing the drastic transformation solely to erosion seems insufficient. Another conceivable factor is the rapid variation in soil texture within a few meters. Notably, the sampling points are not identical, with an average distance of 236 meters. Additionally, taking into account the parent rock material, mainly acid metamorphic rock, the emergence of quartz, and subsequently sand, as a result of weathering is plausible (McCall G.J.H. *et Al*., 1964). Indeed, in the surrounding region, quartz stones are often sold. Moreover, the difference in the methods employed adds complexity to the comparison. The LDSF samples underwent analysis using mid-infrared (MIR) spectroscopy at the ICRAF Soil-Plant Spectral Diagnostics Laboratory in Nairobi, Kenya (CIROF-ICRAF, SOP for sample analysis on Bruker Alpha Spectrometer). In contrast, the 2023 samples are analysed using the Bouyoucos method at the University of Nairobi laboratory (Samuel Mwendwa, 2022). It's crucial to note that both sets of samples were collected from the top 20cm of soil.

It is essential to emphasize that all physical analyses are conducted in the same laboratory, under consistent working conditions, and potential limitations. Additionally, the analyses are performed at the same GPS points. Therefore, the most recent soil texture is considered as the reference, ensuring uniformity in the comparative analysis.

5.1.2 Soil porosity

Soil texture significantly shapes soil structure, a characteristic further influenced by management practices (Ghosh *et Al.*, 2020). Soil structure is an indicator of how sand, silt, and clay particles bind together in the soil (Local Land Services, 2020). Porosity emerges as a crucial marker of soil structure, representing the fraction of the total soil volume occupied by pore spaces, essential for facilitating air and water movement within the soil environment (Thangavel Ramesh *et Al.*, 2019).

In Chepareria, soil physical analysis are conducted across four land regimes (P, D, GC, G). The soil is classified based on its texture into three groups: sandy clay loam, sandy loam, and loamy sand. The sandy clay loam category is more representative, as it includes all land regimes. An observation reveals that the degraded land regime consistently shows the lowest porosity values, while the G+C regime exhibits the highest. The project plot has values that place it between the two grazing regimes. A similar study conducted in an Ethiopian watershed highlights how areas with higher biological management exhibit higher porosity (Sultan, D *et Al.*, 2018). G+C, G, and P land managements are all characterized by discrete vegetation.

In sandy loam, where only P and G+C are identified, there is a similar trend in mean porosity percentage. However, the standard deviation is observed to be higher in the G+C regime, resulting in less uniform porosity across the entire area. Similar results were observed in the West African Savanna, where fallowed plots exhibited higher porosity stability across the entire area than the plots under cultivation (Sunday E. Obalum *et Al.*, 2014).

Conversely, in loamy sand, a clear and explicable trend between different land management practices is not discernible. The sole information here is that all values are consistently lower than those in the other two soils with lower sand content. In sandy soils, porosity tends to be smaller compared to clay soils, as the latter possesses a greater quantity of micro-pores (Local Land Services, 2020).

5.1.3 Soil moisture

To assess soil water content, two primary methods can be employed: one utilizing satellite images and the other conducted in the field. In the field, various tools and methods are available, with the most common being the tensiometer and the gravimetric method—the latter being the approach adopted in this research. Soil water content is a crucial parameter, revealing the amount of water retained in the soil. In semi-arid environments, this information is vital not only due to prevalent rain-fed agriculture but also for assessing erodibility risks, potential flood events, predicting groundwater recharge, and gaining insights into evapotranspiration losses (Brevick *et Al.*, 2006). Soil moisture is influenced by factors such as soil texture, structure, land topography, vegetation, land management practices and environmental factors (Schneider *et Al.*, 2011).

In the DTR project, soil moisture sampling is conducted three times in 2023. These values obtained are closely tied to land management practices, soil texture, and precipitation amounts. The most representative results should be those presented in sandy clay loam soils, where four different land management practices with the same texture are compared. The values of grazing land regimes exhibit significant variability over the three months, while for D, G+C and P land management practice the line is stable. Therefore, discerning the impact of land use on soil moisture seems challenging. A similar difficulty is experienced by William A.G. (William A.G. *et Al*., 2003) in a semi-arid region of Spain.

Moreover, in sandy loam soils, the two land regimes present (P, G+C) are located in the same cluster under the same environmental conditions. The highest and most uniform values for three months are identified in the project plots, except for the month of June when G+C experiences a surprising increase. Given the net moisture reduction in every cluster during the month of June, the elevated value of G+C can likely be attributed to some intervention implemented by the farmer in that month, such as manual irrigation, in response to the prevailing drought conditions. The P results of May and July serve as an evidence of water harvesting effectiveness, where micro-catchment systems better store rainwater in the soil, as already demonstrated in Palestine (Al-Seekh *et Al*., 2009).

Finally, in loamy sand, the highest values are predominantly found in the more vegetated area ,G+C regimes, except for May when they are observed in the degraded land regime. Notably, the degraded area, nearly bare, displays higher moisture content than the grazed area for all three months. This could be attributed to farmers avoiding overgrazing in the degraded area due to the visible poor condition of the land. For instance, in overgrazed rangelands where the soil is completely bare, higher heat exposure results in increased evaporation losses (Zhao *et Al*., 2011).

5.1.4 Saturated hydraulic conductivity

To understand how water moves into the soil under saturated conditions and penetrates in normal circumstances, two crucial parameters are analyzed: Saturated Hydraulic Conductivity and Infiltration Velocity. Both play a vital role in soil investigation, aiding in predicting erosion and nutrient leaching (Metergroup).

Ksat is equivalent to hydraulic conductivity in saturated conditions and provides insights into how the soil responds during storm events (Upstream Technologies). It is closely tied to soil texture, structure, vegetation type, and soil management practices (Surya Gupta *et Al*., 2023). In Cheperareria, degraded land exhibits the lowest Ksat in May. Similar results were observed in the Land Rehabilitation project of Turan Yüksek in Turkey in 2011. In both soil sites, the rehabilitated land consistently showed more constant Ksat values, categorized in this study as moderate. Interestingly, grazing land displayed a higher Ksat than the G+C area, possibly due to the variety of grasses in the grazed area compared to the limited variety in G+C. Ksat is also influenced by climatic factors; indeed, in July, shortly after heavy rainfall, Ksat values increased compared to May. However, the rehabilitated land maintained a constant Ksat value: moderately rapid. In conclusion, a definitive resolution is challenging to discern due to the variability of Ksat over the two months, which does not offer a conclusive explanation. This scenario is also well-described by Li *et Al*. (2018) in their experiment conducted in China.

5.1.5 Infiltration velocity

The infiltration rate refers to the speed at which water penetrates the soil. In Chepareria, the infiltration velocities values consistently surpass the FAO standard for infiltration velocity (Infiltration rate, Fao), primarily due to heightened evapotranspiration in arid regions, which significantly contributes to water loss during the test (Weldemichael A. Tesfuhuney *et Al*., 2015).

In loamy sand soils only the grazed area exhibits a high infiltration velocity, while other areas (D, G+C) present considerably lower values, especially compared to soils with less sand content. This indicates a high risk of erodibility (Jeffrey D. Walker *et Al*., 2007).

Among the sandy loam soils, CL7P3 records the highest infiltration velocity, demonstrating high lateral infiltration even beyond the ring placement. This is attributed to the excellent soil structure highly influenced by the root system (Changkun Xie *et Al*., 2020). On the other hand, CL7P4, also sandy loam, consistently displays the lowest value, likely due to its location just after a contour bund, making it the only area isolated by water harvesting interventions.

In sandy clay loam soil, grazing land exhibits the highest values, with the degraded land showing a low value due to bare land and soil water repellence (Pedro Hervé-Fernández *et Al*., 2023).

5.1.6 Effects of soil water conservation techniques

In summary, a definitive and unequivocal positive outcome regarding the efficacy of soil and water conservation implementation is not apparent. This ambiguity can be attributed to the limited field activity and the few samples collected (William A. G., et al., 2003), coupled with diverse environmental factors such as uneven rainfall distribution around the Chepareria ward (Table 9-10-11), as well as the impact of evaporation and wind during the infiltration test. Another crucial point is that the interventions have been applied only since 2022, and the sample collection is occurring after just one year of implementation, making it challenging to observe comprehensive ecosystem restoration (Verdoodt A. *et Al*., 2009). Moreover, the results are influenced by fieldwork constraints, including the unavailability of the ring in June, laboratory imprecision, and the travel time of samples to Nairobi. Only a few isolated results, such as the high infiltration value of CL7P3 or the consistent moisture and Ksat values over the two months, offer some insight into the visible effectiveness of LCa (Figg. 48-49). These values can provide a more comprehensive understanding only in the subsequent years, considering the initial state of high degradation in the LCa. Other successful restoration projects in Kenya , that offer valuable benchmarks for comparison, conducted soil analysis after a minimum of three years within enclosed systems, as observed in the study by Mureithi

S.M et Al. (2014).

Fig. 48: Ferdinand Anyka-soil physics technician at the UoN and Maria Virginia Bile student Unifi while collecting soil samples in the LCa (M. Virginia Bile, June 2023).

Fig. 49: Ferdinand Anyka-soil physics technician at the UoN and Maria Virginia Bile student Unifi while collecting soil samples in the degraded land regime just behind the LCa. This was the original status of the LCa before the restoration was initiated (M.Virginia Bile, June 2023).

5.2 Socio-economic analysis

5.2.1 Individual interviews

To gain a deeper understanding of the community's perception regarding the research topic, individual and group interviews are conducted with a participatory approach. Socioeconomic factors are crucial for comprehending local dynamics, understanding community perspectives, and providing insights into the feasibility and viability of adopting, utilizing, and maintaining the new techniques proposed by the research community (Mirza Md Tasnim Mukarram *et Al*., 2023). The first investigation done is concerning the land size per family size and the number of various livestock species owned by a family. The family size doesn't influence the land size nor the herd size. An emblematic example can be drawn from families that own 4 ha of land. They have a range from 1 to 16 children. It means that the harvest from 4ha of land have to be shared within 16 brothers. Furthermore several studies have highlighted the risk of loss of African land due to population growth: an increase threat more dangerous than climate change that affects food security(Derek D. Headey *et Al*., 2014; Gulliver, P.H. 1961). For herd size, there isn't a clear linear correlation with family size, yet among agro-pastoralist Pokot, the herd symbolizes social status. The number of cattle not only determines the number of wives for a man but also influences his children's education level (Cirani M., 2019).

Moreover, these communities face a significant information gap (Silvestri *et Al*., 2012). In West Pokot County, Wi-Fi is non-existent, and the cost of internet data is prohibitive. Access to smartphones and television is limited, while rechargeable radios, powered by solar panels, provide a primary source of information. As a result, in these regions, communication and observation stand out as the most accessible means of acquiring information.

In line with this, Lev Vygotsky underscores the significance of collective learning: "Learning is a social process achieved through sharing experiences with others and making meaning through communication." Consequently, to assess the community's perspectives on soil and land conservation practices, the initial question probes the impact of agricultural-related suggestions or observations. A notable 26.67% of responses indicate an interest in implementing soil water harvesting after hearing friends' suggestions, while 23.4% express an inclination toward soil preservation as a strategy. In contrast, only 6.7% prioritize increasing economic stability without considering the feasibility of soil water conservation. This outcome is significant, with half of the community expressing interest in the research topic.

Moreover, they are aware of the challenges posed by soil erosion. A 20-year-old woman shared her experience of losing 0.5 hectares of land this year shortly after maize plantation due to river diversion. Considering the insights gained from individual interviews, approximately 11% of their land is eroded. They attributed land degradation to overgrazing, tillage, and topography, aligning with the explanation provided by Karuku George in the article published in 2018 titled "Soil and Water Conservation Measures and Challenges in Kenya" and aligning the results of FGDs in Kibwezi Sub-County conducted by K. Z. Mganga1 (*et Al*., 2015). Actively seeking solutions, pokots have embraced various techniques to mitigate erosion impacts. NGOs have advised planting sisal or *Aloe vera*, believed to stabilize the soil with their root systems (Fig. 50). A woman from the Pokot highlands introduced the concept of stone lines to her neighbourhood. Additionally, traditional methods involve placing stones and tree branches inside gullies, which locally is called *kara*. All of them are perceived as efficient solutions for long-term results. These examples illustrate how the Pokot communities has proactive approach to problem-solving.

Fig. 50: On the right example of Sisal stabilizing high erodible soil; on the left example of stone-lines in sloppy terrain (M. Virginia Bile, July 2023).

Thanks to the interviews, a historical scale on drought years emerged. The community faces drought approximately every 10 years, causing cattle losses due to disease, to cattle rustling or to famine, migration, human hunger, and the need to travel great distances for water (Gebremedhin Gebremeskel Haile *et Al*., 2019). Recounting the hardships of ‘84, a man described how many times he and his brothers were boiling a poisonous fruit to render it edible. Unfortunately, the year 2023 has not started well in their perception as reported in the Humanitarian Action the fourth September 2023, too. Meteorological data from Nasukuta Station reveal the precipitation trends since 2004. The driest year in the last two decades was 2009, with only 630.7 mm/y. While 2019 was frequently mentioned in interviews, it did not match the severity of 2009 in terms of total water, although the sum until July was insufficient, coinciding with the critical growth period for crops. Regrettably, the precipitation in 2023 until July appears unfavourable, measuring only 288.8 mm/y. This shortage explains the reported poor maize production, compared to "onions" by interviewees (Figg. 51-52). Furthermore, a study conducted by Kalisa *et Al*. (2020) unveiled the sequences of drought years in East Africa through SPI analysis. The drought years reported by the Pokot align with those in the study, albeit with slight variations, acknowledging that general analyses may fluctuate in different regions. The study specifically identifies 1979, 1984, 1994, and 2001 as the most significant drought years.

Fig. 51: Rain-fed agriculture under water scarcity condition in CL10GC(M.Virginia Bile, June 2023).

Fig. 52: Rain-fed agriculture under water scarcity condition in CL16GC (M. Virginia Bile, July 2023).

Certainly, the implementation of preventive measures becomes imperative to ensure security during the dry season and dry years. Among the most common techniques is the practice of storing maize crop residue on tree tops, ensuring feed for animals. In fact, approximately 45% of drought prevention focuses on guaranteeing cattle health, while 13% aims to increase economic stability by opting to harvest sand, burn charcoal, or mine gold (Fig. 53). Contrarily, only 24% of them is dedicated to soil preservation. The two practices of soil preservation, enclosing and paddocking, offer protection to grazing land, preserving cattle health while safeguarding the soil from overgrazing (Mureithi S.M *et Al*., 2014). Surprisingly, only 2.3% apply water harvesting techniques for drought prevention, indicating a minimal adoption of such methods.

Fig. 53: The desperate farmers mining gold in Mtelo, West Pokot, due to the strict drought of 2023 (M. Virginia Bile, July 2023).

An additional analysis considers the level of education in relation to the type of prevention adopted. The obtained results are quite remarkable, revealing that the level of education does not significantly influence the choice of prevention methods. For instance, in CL10, a woman who never attended school managed to establish a productive orchard and even create an ornamental garden. An essential detail about this woman is that her husband had a stable job, providing the family with a monthly income. Despite the presence of innovative ideas and a deep understanding of information, their implementation is often hindered by a lack of economic resources, as highlighted in the study conducted in the Morogoro Region of Tanzania (Yahya *et Al*., 2014). Moreover, as resulted in the FGDs various governmental and non-governmental institutions have organized training sessions in these areas. As demonstrated in another study in West Pokot (Mandila *et Al*., 2023), information primarily spreads through farmer-to-farmer communication. Consequently, the techniques learned tend to become commonplace through community discussions. It's noteworthy that although the Pokot community does not explicitly mention water harvesting as a drought prevention measure, its implementation is evident in the usage and in the number of suggestions related to it.

Given the community's frequent encounters with drought, the next question delves into their awareness of water harvesting. Indeed, they are conscious of it. The predominant method is roof-top water catchment, utilized by 82% of the community primarily for household consumption (Fig. 54). Merely 26.3% engage in water harvesting practices benefiting soil water retention, such as terraces known as *törömö*, breaks termed *pörech*, and ditches called *fanya chini* in kiswahili (Karuku George, 2018; Sultan, D. *et Al*., 2018). Notably, two interviewees, having undergone DTR training, proudly adopted the half-moons. Unfortunately, government intervention is minimal, benefiting only 1.6% of the community.

Fig. 54: Example of roof-top water harvesting where the pipe under the roof collects water and drives it into a container (M. Virginia Bile, June 2023).

Every interview concludes with sincere expressions of willingness to learn more about water harvesting. In most households, final greetings are accompanied by numerous thanks and prayers for assistance in improving their quality of life.

Interestingly, interviews are considered a form of training (Fig. 55). In fact, discussing specific topics provides insights for the interviewees (Husband *et Al*., 2020). They reflect on soil water conservation and express keen interest in the topic, recognizing its significance to their livelihoods and the fundamental role it played in their transition from pure pastoralism to agro-pastoralism.

Fig. 55: The owner of CL10D after being interviewed has started to put bags and tree branches to reduce land erodibility (M. Virginia Bile, July 2023).

Interviews also shed light on gender differences, aligning with the findings of the study by Asfaw and Admassie in 2004, which indicates that Pokot men have clearer business ideas, while Pokot women are more concerned about land improvement, given their role in farming (Nhemachena and Hassan, 2007). The Pokot society is notably patriarchal. It was sad to encounter two women whose polygamist husband had yet to permit them to implement soil water conservation techniques, as decisions of this nature require his consultation. However, he had been absent for a while.

Despite these insights, there are some limitations arising from the fact that the interviews were conducted by a young white lady, which may evoke various reactions such as excitement, fear, or curiosity. Interestingly, this aspect has sometimes facilitated positive outcomes, as the white skin colour is often associated with efficacy and seriousness. Additionally, it encourages openness in sharing their traditions with a foreigner. Another limitation involves engaging with men, as it was challenging to find them available during the day, with many spending their time consuming the local fermented alcoholic drinks. Alcoholism is a significant issue in rural areas of Kenya (Nancy Muturi, 2014). Some man appearing for interviews seemed to be prompted by someone who informed them about the project's acknowledgment. A crucial limitation is that discussions conducted in another language may result in the loss of information or details. Additionally, not everyone disclosed their cattle amount due to its private nature.

5.2.2 Focus Group Discussions

Focus Group Discussions (FGDs) offer an unintended benefit by providing insight into the dynamics of Pokot society. While they have yielded various outcomes, this discussion focus on those most relevant to the research questions. First and foremost, the initial consequence of drought is emphasized: migration. Migration is also influenced by reduced land availability due to erosion and demographic growth (Walter Leal Filho *et Al*., 2020; Gulliver, 1961). Erosion is indeed considered a significant threat, with a perceived land erosion rate of 60%. This figure starkly contrasts with the average erosion rate calculated for each household during the individual interviews conducted. Secondly, the dietary shift during the transition from a nomadic to a sedentary lifestyle is highlighted. Previously, their diet consisted of meat and wild fruits, along with yogurt, milk, and blood (Fig. 56). Women attempted to cultivate millet and sorghum, resulting in a meagre diet (Bostedt, G *et Al*., 2016). Nowadays, they primarily cultivate maize, along with small amounts of millet, sorghum, and beans (Fig. 57). Despite their focus on growing kitchen gardens, water scarcity often impedes their efforts. All their agriculture relies on rain-fed conditions. Considering the necessity of migration due to extensive land erosion and the demand for water, it appears that a drastic intervention is needed to improve soil and water conservation.

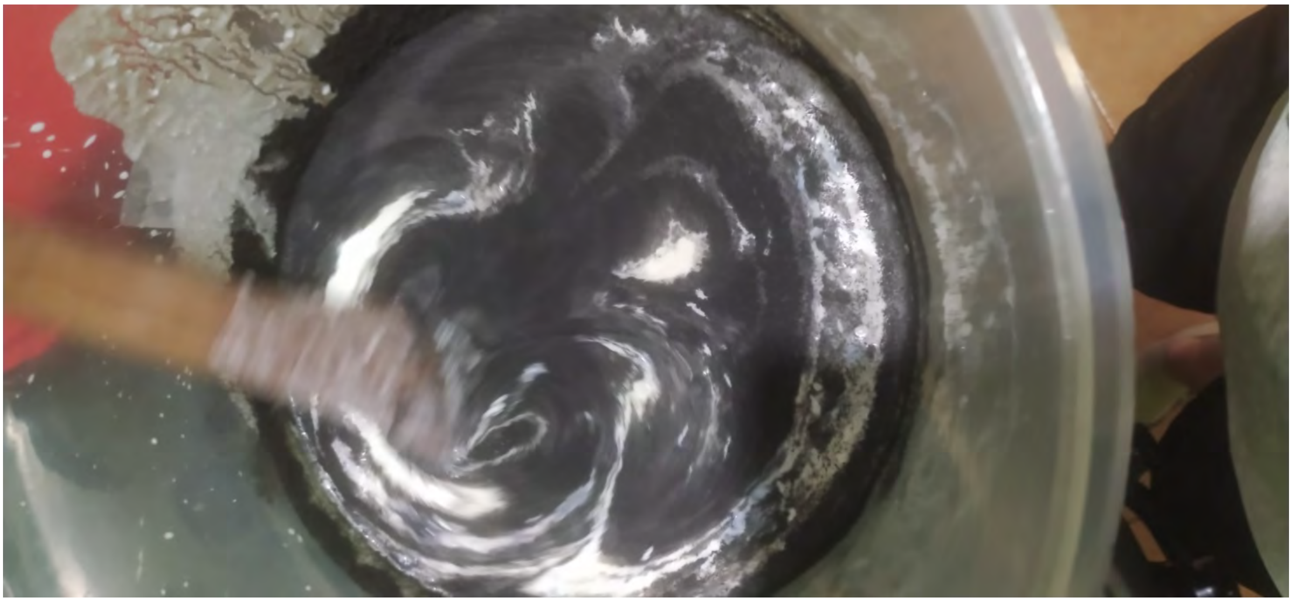

Fig. 56: Local yogurt mixed with charcoal derived from a sacred tree (M. Virginia Bile, July 2023).

Fig. 57: Household of a woman near CL7 captured while drying beans with her children before being interviewed for DTR (M. Virginia Bile, July 2023).

Another consideration stems from the increasing importance families place on education. While previously not deemed essential, the Pokot now recognize the effects of education. They eagerly await innovations from their educated children (Bouhajeb., 2018). It is a clear example of openness to new ideas despite the conservative nature of Pokot culture.

Lastly, observations reveal that FGDs conducted in CL7 and CL10 yield more substantial results than in CL16. In CL7 there's a preference for specific, more productive sheep breeds and the possession of a detailed migration path. The discussion took place a short distance from LC and 2 km from LCa, demonstrating how the presence of a sharing hub brings new insights into the community. CL10 enjoys a strategically advantageous location, being in close proximity to a well-maintained tarmac road and a market center. This prime positioning facilitates efficient information flow. Furthermore, the area boasts enhanced infrastructure, including an increased number of roof-top water catchment systems, ditches and terraces, and a notable prevalence of kitchen gardens.

CL7 stood out as a group where participation was total, everyone had time and space to speak, and everyone wanted to share their experiences. In contrast, participation of women in other FGDs was limited due to the respect given to older men and the responsibility of caring for children. (Karmebäck, V.N. *et Al.*, 2015). Culturally, women and men sit on opposite sides, remarking the gender difference. Unfortunately, the discussion's organization was entrusted to someone with strong neighbourhood connections, often making it impossible to achieve the ideal gender and number balance (4 women and 4 men). Additionally, since the discussion was facilitated in Pokot, the translation moments occasionally interrupted the conversation or omitted important information not considered relevant by the facilitator (Sina K. *et Al.*, 2020).

After all the interviews and after having adopted an ethnography approach in the three months of data collection (Kimber *et Al*., 2023), it results clear how the community is aware of the role of soil and water conservation practices implementation, and they even implemented some. However, they express a need for further demonstration and motivation. The research begins with a significant question: *Can solutions be found to help the Pokot community increase productivity while addressing the challenge of water scarcity and land degradation?* After all the analysis, the answer is affirmative. Solutions such as the ones implemented under the direction of DTR are efficient and easily applicable for the community since they consist of enclosing the lands, creating contour bunds, building half-moons, adding manure, and establishing pasture. The farmers just need demonstrations and the distribution of seeds.

6. Conclusion

After three months of socio-economic and field analysis, the results obtained provide clear evidence of the importance of water harvesting techniques within the Pokot community.

The Pokot community is consistently seeking new and effective techniques to reduce soil erosion and enhance agricultural productivity. The interviews reveal the vulnerability of their livelihoods as they heavily depend on natural resources. This leaves them in a precarious economic situation, compelling them to engage in activities such as sand harvesting, charcoal burning, or mining for a steady income (Fig. 58). Unfortunately, these activities pose significant risks to human security and to the environment. Consequently, they have shown a keen interest in acquiring new knowledge related to soil water conservation practices, as demonstrated by their active engagement.

Furthermore, the Livestock Café and the Livestock Café annex emerge as crucial hubs for sharing information and knowledge, especially in these areas where such resources are scarce. The experiments conducted serve as visible examples of significant and diverse productivity, and physical analysis provides some explanatory insights. However, it's important to note that three months of field analysis may not be adequate for a comprehensive assessment of the effectiveness of water harvesting implementation. A more thorough understanding that complements this study could be obtained through additional fieldwork in the subsequent years, in order to have a more evident ecosystem restoration.

In conclusion, the isolation and insufficient infrastructure characterizing West Pokot County underscore the importance of the hub established by Drylands Transform. This hub operates as a central platform for reducing food insecurity within the community. Given the escalating challenges posed by climate change and population growth in the drylands, there is a compelling suggestion to prioritize investments in projects that improve livelihoods, with a special focus on implementing water harvesting techniques. These initiatives hold the potential to make substantial contributions to the sustainable development and resilience of the agro-pastoral Pokot community.

Fig. 58: Pokot pastors mining copper in Mtelo, West Pokot, to face the intense drought of 2023 (M. Virginia Bile, August 2023).

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