Characterisation of *Maasai Alalili* Silvo-Pastoral Conservation Systems of Northern Tanzania

Project Team:

Mr. Elkana Hezron Misana (Team leader)
Prof. Linus K. Munishi (Supervisor)
Dr. Issakwisa B. Ngondya (Supervisor)
Mr. Neovitus Siang'a
Mr. John Erasto Sanare
Mr. Kilelenjo Mereso

Funding:
Funded by the Rufford Foundation

November, 2023

Executive Summary

Alalili is a traditional conservation system indigenous to Maasai pastoral communities through which certain portions of rangelands are conserved during wet season for grazing during dry seasons. Regardless of their ecological and economic significance, rangelands including *Alalili* systems have been affected by unsustainable land use operations such as overgrazing, extension of crop lands and settlement areas with respect to impacts of climate change. Such drivers including negligence have led to poor health condition of grazing lands hence inadequate fodder for both livestock and wildlife. Therefore, this study aimed at providing the information useful to address these pressures in regions of northern Tanzania through characterization of *Maasai Alalili* systems. The documentation and understanding of their current status can be used as a potential pathway to promote sustainable conservation of rangelands, biodiversity, community resilience, and livelihoods development. The presented results have indicated that *Maasai Alalili* silvo-pastoral conservation systems are still persuaded although their sustainability is highly at risk, especially in private and village land areas. The fodder species in *Alalili* systems are endangered by inadequate soil fertility, climate change, woody encroachment, and herbivory intensity, which leads to an enormous degradation of rangelands in the near future and loss of healthier fodder productivity. Therefore, the inclusion of *Alalili* practices into core pasture production and management areas, facilitating their reinforcement into policy and practices will boost their survival, suitability and sustainability.

Acknowledgements

I would like to express a special gratitude to my supervisors Prof. Linus K. Munishi and Dr. Issakwisa B. Ngondya for their support received through their constructive comments and critiques towards accomplishment of this work. Many thanks are forwarded to my employer, the Nelson Mandela African Institution of Science and Technology (NM-AIST) for granting me a study leave and the permission to conduct this research work. I'm grateful for the financial support from Rufford Foundation in facilitation of this work, also COSTECH, TAWIRI, TAWA, NCAA, and Local government authorities of each district for allowing access to *Alalili* systems within rangelands throughout the study area. Further appreciation is expressed to all stakeholders whose views and insights during various meetings and surveys have been so helpful in accomplishing this work. I would also like to acknowledge the field support team - Mr. Emmanuel Mboya, Mr. John Erasto Sanare, Mr. Neovitus Siang'a, Mr. Kilelenjo Mereso, Ms. Catherine Maembe, Mr. Emmanuel Lorru, Mr. Nganana M. Papalay, Mr. Lomayani Lukumay, Mr. Birikaa R. Olesikilal, Mr. Danstan Mndolwa and Mr. Mamus Toima for their support.

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1. Introduction

Alalili is a traditional conservation system indigenous to *Maasai* pastoral communities through which certain portions of rangelands are conserved during wet season for grazing during acute dry seasons (Selemani, 2020; Sangeda & Maleko, 2018; Nelson, 2012; Mapinduzi et al., 2003). The system came into practice long before 1940s by *Maasai* communities residing across the northern regions of Tanzania and southern part of Kenya (Olekao, 2017; Goldman & Riosmena, 2013). These indigenous conservation systems integrate between livestock and wildlife resources of the northern circuit with regard to an availability of forage species (Mpondo et al., 2021; NTRI, 2019). They are giving economic and socio-ecological potentials to *Maasai* pastoralists, and the surrounding communities as reflected by increased livestock productivity, habitat, biodiversity conservation and tourism services especially in the rural areas of the Northern semi-arid parts of Tanzania (Wiethase et al., 2023; Tutunga, 2021; Goldman, 2011; McCabe et al., 2010).

Regardless of their ecological and economic significance, rangelands of northern Tanzania including *Alalili* systems have been affected by unsustainable land use operations such as overgrazing, extension of crop lands and settlement areas with respect to impacts of climate change (Wiethase et al., 2023; Kariuki et al., 2021; Babune & Mshuda, 2020; NTRI, 2019). Such drivers including negligence have led to poor health condition of grazing lands hence inadequate fodder for both livestock and wildlife (Malunguja et al., 2020; Schallner et al., 2020; Homewood et al., 2009). Moreover, *Maasai Alalili* systems are faced with an extinction threat considering that Maasai communities of northern Tanzania and southern part of Kenya are in transition due to continuous socio-cultural transformation, increased population, as well as changes in land use (LU) and climate (Kariuki et al., 2021; NTRI, 2019). These disruptions and impacts call for adoption and strengthening indigenous conservation practices for enhanced resilience and sustainability of rangelands with respect to the associated ecosystem goods and services including pastures for livestock and wildlife (Selemani, 2020; TPW, 2020; Nelson, 2012).

However, studies which justify the promotion of indigenous pastoral conservation as pathways for sustained biodiversity conservation and resilience intensification in combating impacts of climate change are limited to *Ngitili* (Malunguja et al., 2020; Mwilawa et al., 2008). On this regard, *Alalili* systems were essentially studied for documentation and understanding their current status that can be used as a potential pathway to promote both sustainable conservation of biodiversity, community resilience and livelihoods development. Specifically, this study aimed at documentation of the types, size, location (elevation and landforms), and distribution of *Alalili* systems in different LU systems through mapping. We further aimed at describing the soil properties, water sources, climatic factors and status of fodder species composition featuring these *Alalili* systems across the rangeland of northern

Tanzania. The study extracted key ecosystem goods and services pertaining to supporting, provisional, regulating, cultural and aesthetic values obtained from *Alalili*. Ecological roles such as fodder potential to livestock and wildlife, peaceful co-existence and the socio-economic potentials for household income generation was also recorded. The characterization is regarded as a pathway to guide communities and other stakeholders towards preservation and practice of this important heritage and how these can be sustained in the rapidly changing and uncertain world of Anthropocene.

2. Methods

2.1 Study site

The study was conducted in Arusha and Manyara regions of northern Tanzania (Fig 1).

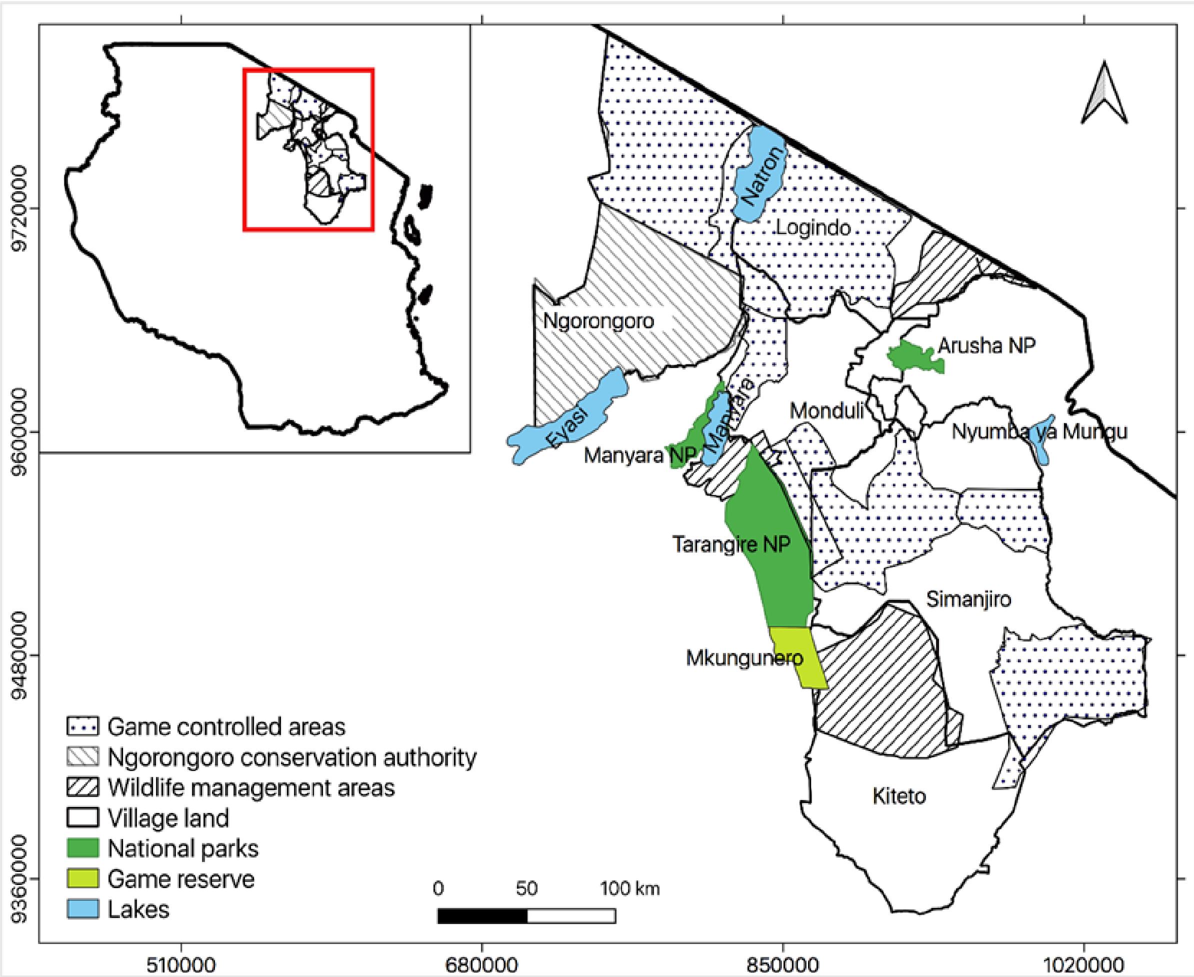

Figure 1: A map portraying different land use categories in rangelands of northern Tanzania where the study was conducted.

The Arusha region is located between 3°23'12.9300' S and 36°40'58.7820" E. The region lies between 1100 and 4566 meters above sea level (masl) from the foothills to the peak of Mount Meru (Olarinoye et al., 2020). It is bordered by Kilimanjaro region to the east, Kenya to the north, Mara and Simiyu regions to the west, Manyara and Singida regions to the south (URT, 2018) (Mwalyosi, 1992). On the other hand, Manyara region is located between 4°41′20.40″ S and 36°24′39.60″ E. The region lies at an elevation ranging between 659 and 2,123 masl. It is bordered to the north by Arusha region, to the north east by Kilimanjaro region, to the east by Tanga region, to the southeast by the Morogoro region, to the south by Dodoma region, to the southwest by the Singida region, and to the northwest by the Simiyu region (Manning, 2020) (Mbinile et al., 2020). According to the 2022 Tanzania National Census, human population of the Arusha region was 2,356,255 with a total area of 34,526 km² and that of Manyara region was 1,892,502 covering a total area of 50,819 km² being dominated by the Maasai ethnic group who are key inhabitants of the two regions (URT., 2022). Generally, the study site features potential wildlife resources that are being managed by the Ministry of Natural Resources and Tourism. Such resources include national parks, Ngorongoro conservation area, game reserves, game-controlled areas and wildlife management areas from which there is a peaceful co-existence between *Maasai* pastoral communities, livestock and wildlife with a significant support contributed by *Alalili* systems.

2.2 Research design and sampling techniques

Before data collection, we conducted a reconnaissance survey to confirm the availability of *Maasai Alalili* systems within proposed districts of the study regions. A cross-sectional research design coupled with both purposive and stratified random sampling techniques were applied. Administrative boundaries of the Arusha and Manyara regions were marked through Quantum Geographical Information System (Q-GIS) software to enhance sampling process of the *Maasai* land with an assistance of shape files collected from Tanzania Wildlife Research Institute (TAWIRI). We purposively sampled five districts from the two regions targeting pastoral and agro-pastoral *Maasai* communities. The sample districts were Kiteto and Simanjiro districts for Manyara region as well as Longido, Monduli and Ngorongoro districts for Arusha region. The existing land use practices in Arusha and Manyara regions were used for stratification of the study area (Land Act, 1999; The Local Government (Urban Authorities) Act, 1982; Leader-Williams et al., 1996). Six types of land use strata were plotted through Q-GIS and distinguished using the topographic map of sampled regions. The land use strata were national parks, game-controlled areas (GCA), game reserves, Ngorongoro conservation area (NCA), wildlife management areas (WMA), and village lands. National parks and game reserves were not accounted for mapping of *Alalili* as *Maasai Alalili* silvo-pastoral conservation systems are not allowed in the national parks and game reserves.

Key informant interviews were conducted in each district for the purpose of identifying villages that have *Alalili* systems within land use strata. Key informants included district game officers (DGOs), rangeland management officers (ROs), ward/village executive officers (VEO/WEO), and members of village rangeland management committee. A total of 298 *Alalili* systems were identified from which 40% (119 *Alalili* systems) was sampled through randomization technique with adoption of random number tables. Empirical evidence-based method (Ground-truthing technique) was applied to verify the exact land use practices found in the study area.

2.3 Data collection

2.3.1 Classification and distribution of *Alalili* systems

All *Alalili* samples were visited in each sample village and their respective coordinates recorded with a GPS to enhance mapping of their distribution across land uses and types through Q-GIS platform. The types of *Alalili* were identified and described through key informant interviews conducted in each sample village (Fig. 2).

Figure 2: Field survey and key informant interviews with; (A) Members of village rangeland management committee (B) WEO/VEO and DGO/RO

2.3.2 Characterization of *Alalili* systems

2.3.2.1 Size and location

The size across *Alalili* systems were determined by measuring an actual radius through ground truthing and digitization process under Google background image in Q-GIS environment with the help of Q-GIS platform. The two values were compared, and the average was taken into consideration to decide the actual area covered by each *Alalili* system. An area below the mean range (mean ± SE) was considered small, an area within a mean range was considered medium and those with above mean range were regarded as large. The topographical information collected included both landforms (mountains, hills, plains, and valleys) and the elevation at which *Alalili* systems are located. Data regarding landforms were gathered based on their morphology as described by Mlingano Agricultural Research Institute (URT, 2006). The elevation of the landscapes for each *Alalili* was recorded by a GPS whereby all *Alalili* systems located below the mean elevation (mean ± SE) were considered low-lands, *Alalili* systems located within a mean range were considered mid-lands and those located above mean range were regarded as high-lands.

2.3.2.2 Climate data and vegetation index

Data on temperature and precipitation characterizing the *Alalili* systems were obtained from the Tanzania Meteorological Agency (TMA). Time series analysis through Landsat TM (Thematic Mapper) imagery with a 30-m spatial resolution coupled with Normalized Difference Vegetation Index (NDVI) was used to determine seasonal vegetation differences between *Alalili* systems for years 1990, 2000, 2010 and 2020 (Borges et al., 2022).

2.3.2.3 Soil sampling and laboratory analysis

Soil samples were collected systematically using an Edelman auger at a depth of 15 cm surface soil layer (Meya et al., 2020) from five points (i.e., center of the quadrat and from its four corners) of the 20x20m quadrats laid down at the center of each *Alalili*. The collected samples were mixed to form a soil composite of each sample *Alalili* system (Mkoma, 2015) before transporting them to a soil laboratory at the Nelson Mandela African Institution of Science and Technology (NM-AIST) for determination of top soil properties. Physical properties analyses covered two parameters only, i.e., soil texture and colors while chemical properties analyses covered four parameters only, i.e., soil pH, organic carbon (OC), Nitrogen (N) and phosphorus (P). The selected soil properties was analyzed by using analytical procedure as described in soil analysis manuals by Brown and Dahnke (1998), Okalebo et al. (2002) and FAO (2020a, 2020b, 2021). Soil texture and its particle size distribution was determined by using Hydrometer method and USDA textural class triangle whereby determination of sample soil color was done through Munsell soil color chart. A pH meter through a soil to water ratio of 1:2.5 was used for measuring soil pH. The determination of soil OC was done based on the Walkley and Black wet oxidation method. The available soil N and P were determined following the Kjeldahl wet digestion-distillation and Bray-1 methods respectively.

2.3.3 Fodder plants composition across vegetative taxa and lifeforms

Fodder species composition was estimated as an abundance or richness (number of observed species within a particular genus and family group) (Tutunga, 2021; Malunguja et al., 2020; Egeru et al., 2014; Gotelli & Chao, 2013). Determining fodder plants composition involved the use of nested quadrats of 20x20m, 5x5m and 1x1m for trees, shrubs and herbaceous respectively (Giupponi & Leoni, 2020; Kisoza, 2013) that were established at the center of each sample *Alalili*. Two main classes of fodder plants were established for identification and counting, i.e., herbaceous plants (grass and forbs) and woody plants (shrubs and trees). All fodder species were identified *in-situ* with the help of a botanist (Fig. 3) whereas voucher specimens of species that were not readily identified, were sent to Tanzania Plant Health and Pesticides Authority (TPHPA) for identification (Malunguja et al., 2020; Egeru et al., 2014).

Figure 3: *In-situ* fodder species identification (A) Herbaceous species (B) Woody species.

2.3.4 Ecological potential, socio-cultural and economic roles of *Alalili* systems

Data were collected through participatory field visits and semi-structured interviews (SSI) coupled with focused groups, questionnaires for household surveys and key informant interviews. Ecological roles such as fodder potential to livestock and wildlife, peaceful co-existence and emerging conflicts and the socio-economic potentials for household income generation was also recorded. Key ecosystem goods and services pertaining to supporting, provisional, regulating, cultural and aesthetic values obtained from *Alalili* were recorded. Social-cultural values and economic contribution or importance obtained from *Alalili* systems by pastoralists and agro-pastoralists were documented.

2.3.5 Community Empowerment and Conservation Training

The importance of *Alalili* systems was explained back to communities as one among significant indigenous conservation knowledge to raise their awareness on ecological values and socio-economic significance through village meetings. The training sessions through village assembly were conducted in each sample village. Villagers were empowered with a hybridized conservation knowledge on how to integrate beekeeping and *Alalili* systems to sustain their livelihood while conserving biodiversity and rangelands from degradation (Fig. 4).

Figure 4: Community Empowerment and *Alalili* Conservation Training through; (A) Village Assembly (B) Village rangeland management committee.

2.4 Data analysis

Mapping of the spatial distribution of *Alalili* system across *Alalili* type, size, and land use categories was done in Q-GIS. Chi-square test was used to understand the variation of abundance and distribution of the surveyed *Alalili* systems across land uses, topographic parameters and selected physical soil properties. It was also used to understand the variation in *Alalili* proportions across different parameters of the surveyed social-economic benefits and ecological values gained by *Maasai* pastoral and agro-pastoral communities from using *Alalili* systems. Independent sample t-test was used to understand the variation in size (area) of *Alalili* systems, climatic and vegetation cover changes and the selected soil chemical properties across types of *Alalili* systems. It was also used to understand the variation in fodder species composition and income generation across types of *Alalili* systems. Analysis of variance (ANOVA) was used to understand the variation in size (area) of *Alalili* systems, climatic parameters, vegetation cover changes and the selected soil chemical properties across land use categories. It was also used to understand the variation in fodder species composition across life forms and land uses as well as the variation in income generation across land use categories. Prior to analysis, the data were tested for both normality and homogeneity of variance through Shapiro-Wilk test and Levene's test respectively. A generalized estimating equations (GEE) model was applied to analyzing the effect of land use and types of *Alalili* on the size of *Alalili* systems through R version 4.2.3. A p-value of $p < 0.05$ was considered significant.

2.5 Ethics statement

This work received an approval from the Tanzanian Commission for Science and Technology (COSTECH) (permit number 2022-222-NA-2022-005 dated 20th April, 2022), Ministry of Natural Resources and Tourism through Tanzania Wildlife Research Institute (TAWIRI) (permit number TWRI/RS/22"G"/21 dated 22nd April 2022), Tanzania Wildlife Management Authority (TAWA) (permit number AE.542/712/01 dated 10th May 2022), and the Ngorongoro Conservation Area Authority (NCAA) (permit number BD.158/711/01-B/100 dated 09th May 2022). Permission for research in communities was obtained from relevant local and district authorities.

3. Results

3.1 Classification and distribution of *Alalili* systems

Generally, two types of *Alalili* systems were identified in the *Maasai* pastoral communities across rangelands of Arusha and Manyara regions named as private and communal enclosures. The two types of *Alalili* are spatially distributed in the study area featured with different land uses (Fig. 5).

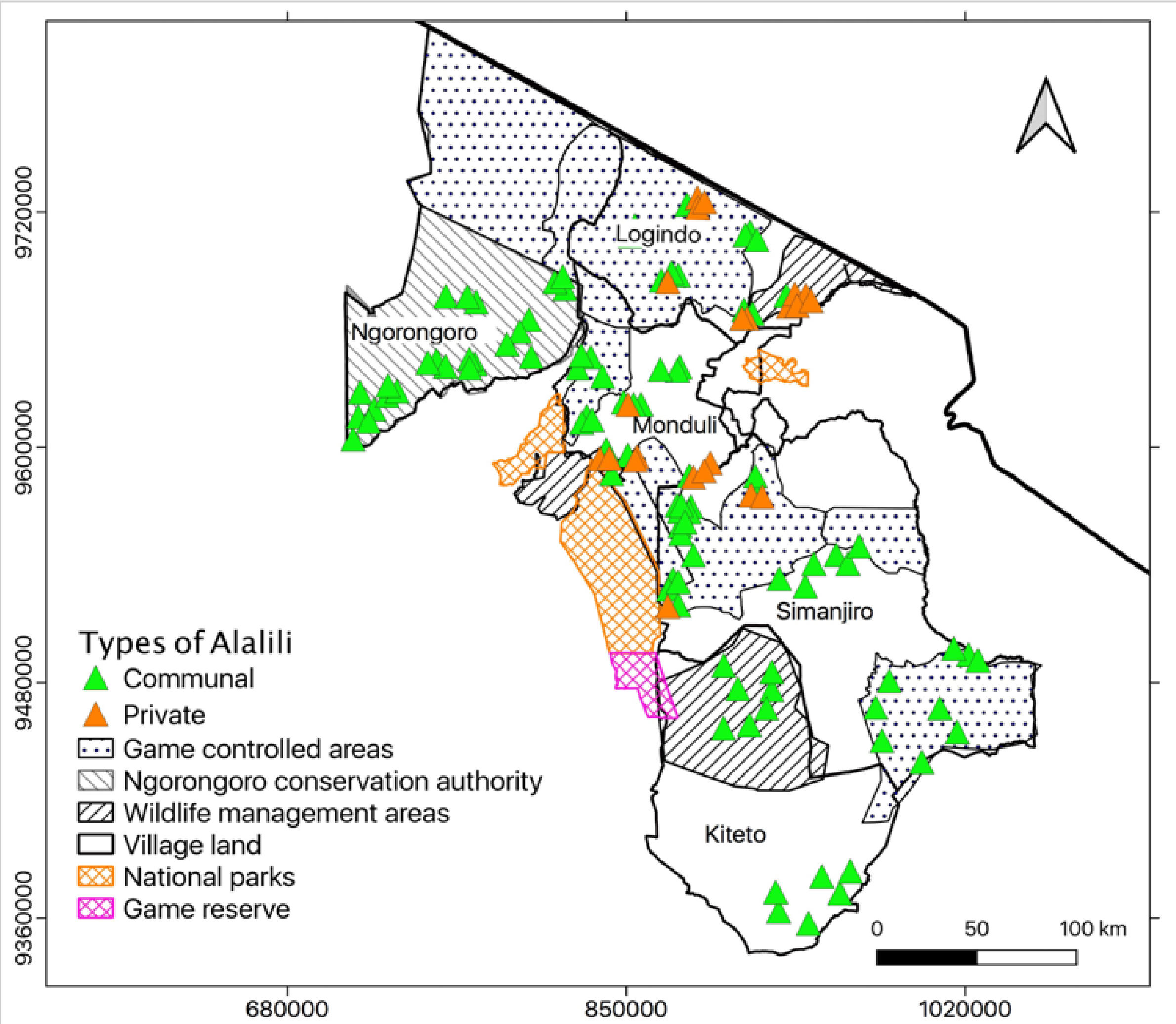

Figure 5: Types and distribution of *Alalili* systems across land uses of northern Tanzania.

3.1.1 Communal *Alalili*

Communal *Alalili* enclosures are silvo-pastoral systems owned and managed by a village or a village section for the purpose of providing fodder/forage to livestock during acute dry season featured with forage scarcity to livestock. Many of them (74%) are far from the settlement areas, usually out of the residential village land. More than 50% of these were described as old, ranging between 50 and 90 years of age whereas some few were reported to be recently established having a range of 10 to 15 years old. These silvo-pasture resources are aimed at providing fodder to livestock during dry season only whereby between 50-450 herds are allowed to graze with respect to the size of *Alalili* system in place. They are found in the wilderness (either in high or low land), protected areas and are not fenced (bounded by a wall), thus are utilized as shared grazing resources between livestock and wildlife (Fig. 6).

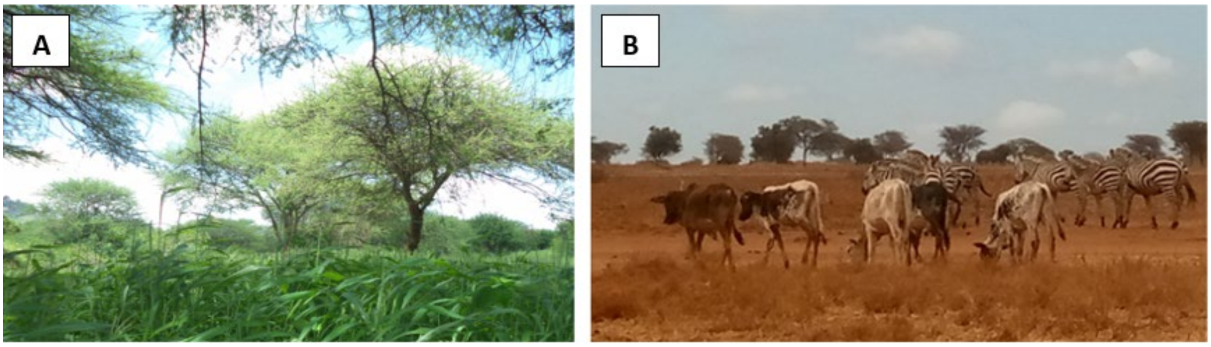

Figure 6: (A) A communal *Alalili* at the end of rain season (B) Wildlife and livestock grazing in communal *Alalili* amidst of dry season.

3.1.2 Private *Alalili*

Private *Alalili* enclosures are silvo-pastoral systems that are owned and managed by an individual family, household or a clan referred to as a *Boma* residing within a particular village. They are also not necessarily being owned by a household because some are privately-owned by investors who aim at high producibility of livestock products and services. They provide fodder to calves, weak and/or sick, as well as lactating livestock whereby the number of livestock allowed for grazing is limited from 30-150 herds only and no definite season for grazing. The majority (94%) are located around the settlement areas, far from the wilderness and some of them were confined with a live or local fence for protection against wildlife encroachment and depredation (Fig. 7). More than 50% of these were described as younger as recently established within 30 years ago while less than 20% were old up to 70 years of age.

Figure 7: One of the confined private *Alalili*; (A) Live fence (B) Grazing area.

3.2 Characterization of *Maasai Alalili* systems

3.2.1 Size categorization and abundance of *Alalili* systems

In this study, three categories of *Alalili* systems were classified based on their size variability, i.e., large, medium and small *Alalili* whereby area coverage varied significantly ($F = 27.175$, $df = 2$, $p = 2.76e^{-10}$) across size categories (Fig. 8). On the other hand, the size varied significantly ($t = 4.4646$, $p = 1.988e^{-05}$) across types of *Alalili*, whereby, communal *Alalili* systems had a largest mean area coverage compared to that of private *Alalili* (Fig. 8). Furthermore, the size of *Alalili* systems varied significantly between GCA and other land use categories ($F = 3.806$, $df = 3$, $p = 0.0123$), whereby, *Alalili* in GCA had the largest mean area followed by those in WMA, NCA and village land (Fig. 8).

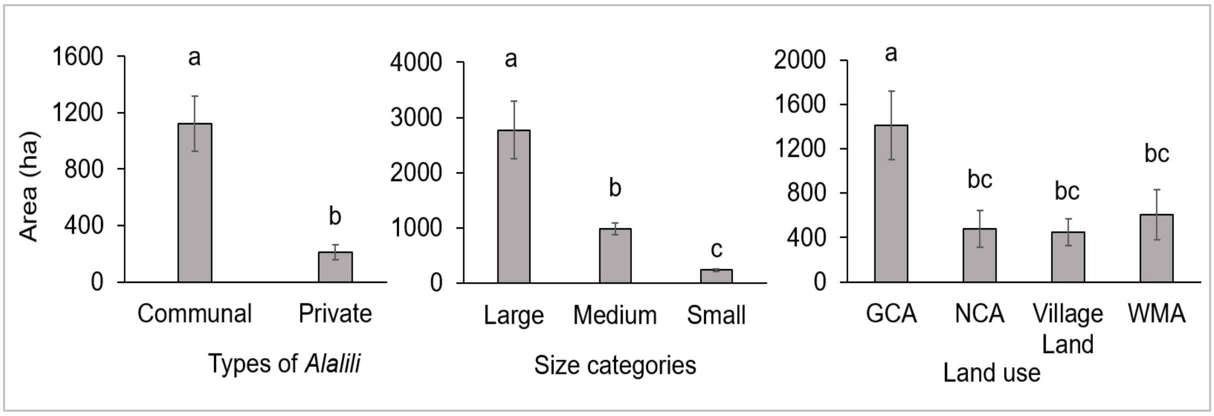

Figure 8: Size variation of *Alalili* across: types, size categories and land use

The surveyed *Alalili* systems depicted a spatial distribution considering a significant variation ($\chi^2 = 47.3$, $df = 1$, $p<0.001$) in abundance between communal and private categories. The communal category had the highest abundance encompassing 82% of all surveyed *Alalili* systems compared to 18% encompassed by private category (Fig. 9). On the other hand, the abundance of *Alalili* varied significantly ($\chi^2 = 39.2$, $df = 3$, $p<0.001$) from GCA to other land use categories whose distribution followed a sequence of GCA>NCA>village land>WMA corresponding to 50%>20%>16%>14%.

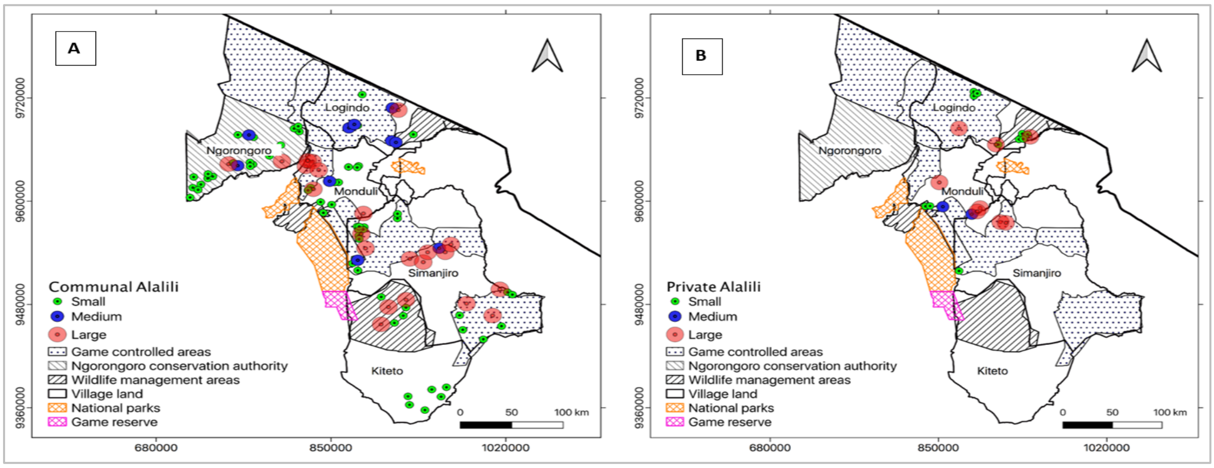

Figure 9: Abundance of *Alalili* systems across land use and size: (A) Communal (B) Private.

3.2.2 Topographical distribution of the surveyed *Alalili* systems

There was a significant variation between proportions of communal and private *Alalili* across landforms (χ^2 = 589, df = 1, $p<0.001$) and elevation (χ^2 = 154, df = 1, $p<0.001$). Communal *Alalili* systems depicted higher proportion of their existence in valleys corresponding to their location with high proportion in the low-lands compared to private *Alalili* that was highly distributed on hilly landforms elevated at low-lands (Fig. 10). Additionally, the proportion of *Alalili* systems subjected in the identified landforms and elevation varied significantly across land use categories, i.e., (χ^2 = 18.9, df = 9, $p=0.026$) and (χ^2 = 46.4, df = 6, $p<0.001$) respectively. Village lands encompassed more *Alalili* systems on hilly and valley landforms being elevated at low land followed by WMA and GCA. In contrast to other land use categories, NCA depicted a highest proportion of *Alalili* systems located on plain and hilly landforms whose elevation was more than 80% highlands (Fig. 10).

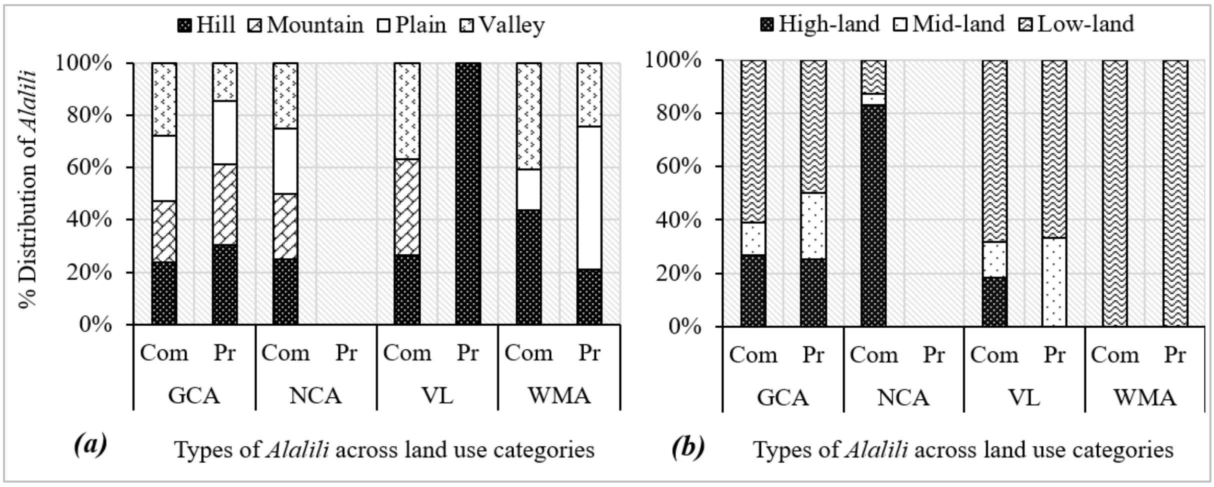

Figure 10: Topographic distribution of *Alalili* systems across: *(a) Landforms (b) Elevation*. * Abbreviations: Com=Communal *Alalili* systems; Pr=Private *Alalili* systems; VL=Village lands

3.2.3 Climate and vegetation changes of the surveyed *Alalili* systems

3.2.3.1 Temperature changes

Temperature in *Alalili* systems varied significantly across land uses ($F_{(3)}$ = 18.66, p = $9.13e^{-12}$), grazing seasons (t = -6.5085, p = $1.23e^{-10}$) and the years ($F_{(3)}$ = 9.237, p = $5.03e^{-06}$) from 1990 up to 2020. The mean annual temperature levels across years followed a sequence of GCA>WMA>village land>NCA. Moreover, wet season depicted higher mean temperature compared to dry season although there was a gradual increase in mean temperature from 1990 to 2020 (Fig. 11).

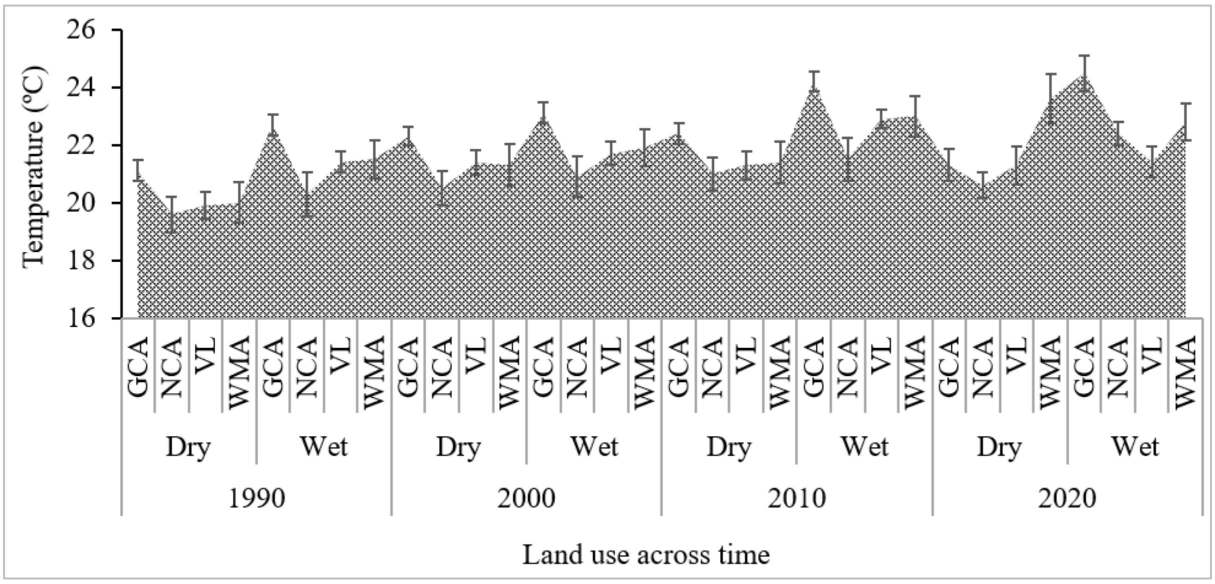

Figure 11: Temperature variation across land use categories, grazing seasons and years

3.2.3.2 Precipitation changes

The mean values of precipitation in *Alalili* systems varied significantly across grazing seasons ($t = -39.361$, $p = 2.2e^{-16}$) and years ($F_{(3)} = 30.43$, $p = 2e^{-16}$) since 1990 up to 2020 but did not show significant difference across land uses ($F_{(3)} = 1.256$, $p = 0.288$). Wet seasons depicted a higher amount of precipitation than the dry seasons although there was an uneven decrease in precipitation from 1990 to 2020. Though it was not significant across land use categories, the relative difference of precipitation followed a sequence of WMA>village lands>GCA>NCA (Fig. 12).

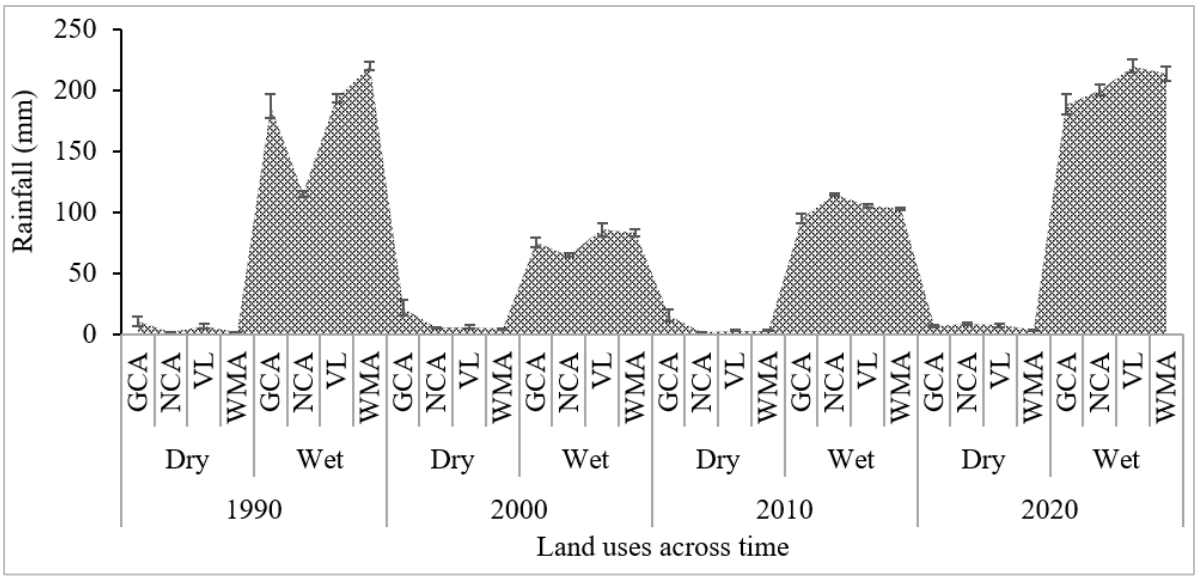

Figure 12: Rainfall across land use categories, grazing seasons and years.

3.2.3.3 Vegetation cover changes

NDVI values varied significantly between types of *Alalili* systems ($t = 13.951$, $p = 2.2e^{-16}$), whereby, communal *Alalili* had higher values than private *Alalili* systems over the course of time. Similarly, the NDVI values varied significantly between seasons ($t = 33.201$, $p = 2.2e^{-16}$) and years ($F_{(3)} = 14.91$, $p = 1.72e^{-09}$) from 1990 up to 2020. Dry seasons were characterized by higher NDVI values than wet seasons. However, a gradual decline in vegetation cover within *Alalili* systems was spotted to take place across years from 1990 up to 2020 with an irreversible decline gradient observed in the private *Alalili* systems compared to that of communal (Fig. 13).

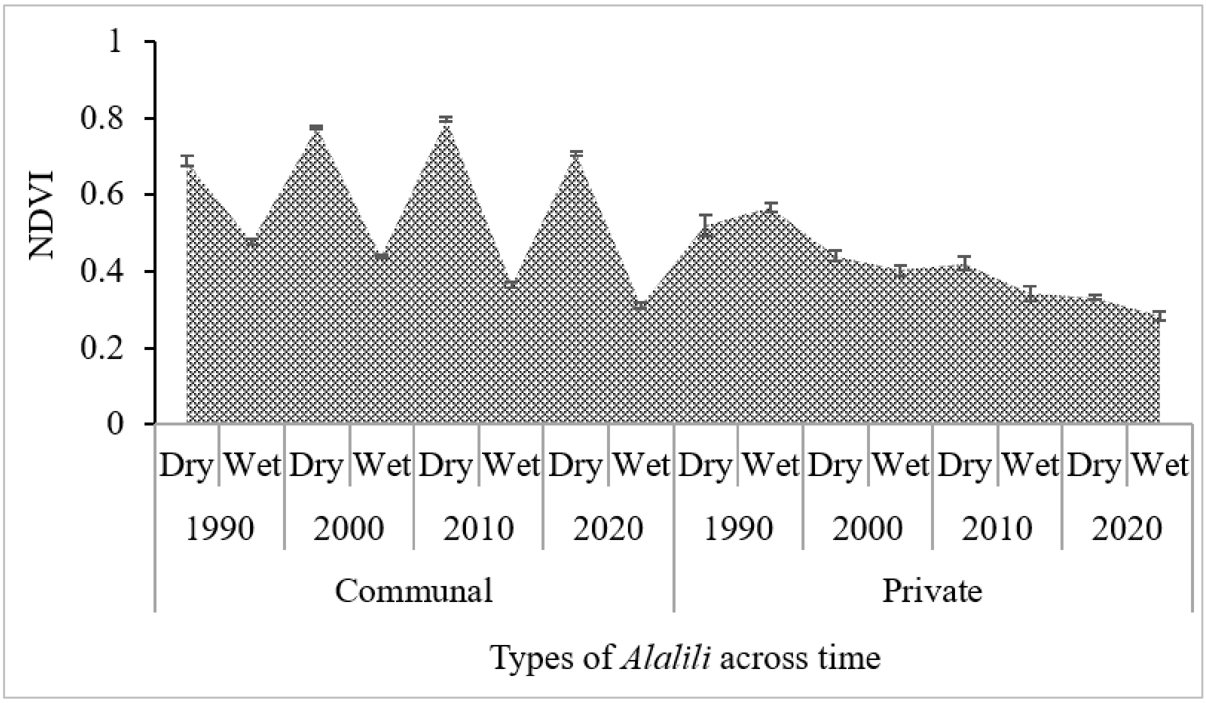

Figure 13: Vegetation cover changes across types of *Alalili* and time.

NDVI values of the surveyed *Alalili* systems varied significantly across land uses ($F_{(3)} = 3.346$, $p=0.0186$) over the course of time with a variability sequence of NCA>GCA>village lands>WMA. Similar to the types of *Alalili* (Fig. 13), the gradual decline in vegetation cover was detected for each land use category over the course of time (Fig. 14).

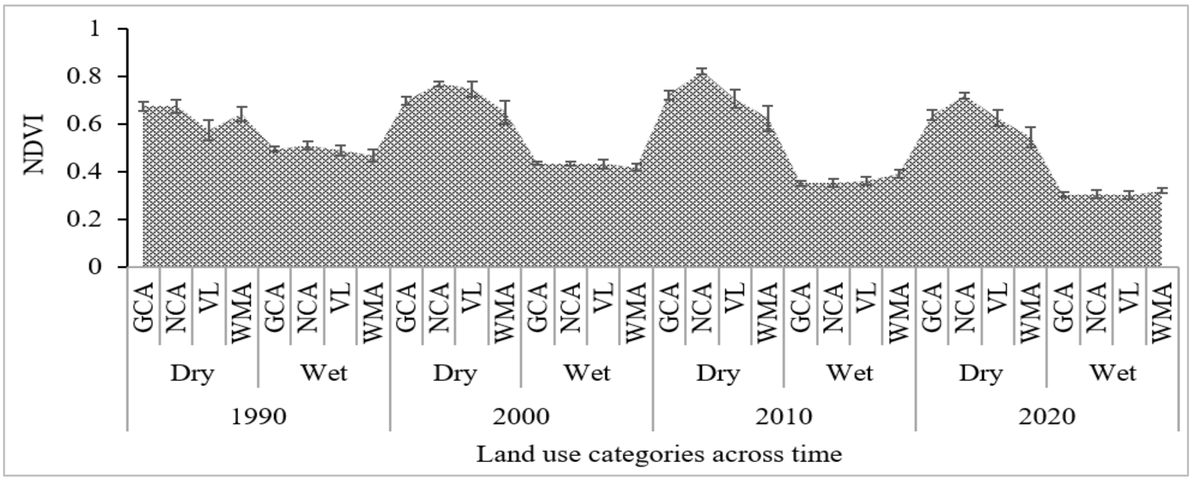

Figure 14: Vegetation cover changes across land use categories and time.

3.2.4 Selected soil properties of the surveyed *Alalili* systems

3.2.4.1 Selected physical properties

The proportions of *Alalili* systems varied significantly (χ^2 = 9.03, df = 3, *p<0.001*) across soil textural classes. The highest proportion of communal *Alalili* systems was characterized by Sandy clay loam soils followed by Clay loam and Sandy loam in contrast to private *Alalili* systems that were dominated by Sandy loam soils. However, both communal and private *Alalili* systems were rarely characterized by Sandy clay soils. The proportion of *Alalili* systems characterized by the identified soil textural classes did not vary significantly (χ^2 = 9.82, df = 9, *p=0.365*) across land use categories, though, most *Alalili* systems were characterized by Sandy clay loam and Sandy loam soils. The highest proportion of *Alalili* systems were characterized by grayish brown and reddish brown with rare reddish and dark gray soils.

3.2.4.2 Selected chemical properties

3.2.4.2a Soil pH

The soil pH did not vary significantly across types of *Alalili* systems (t = -0.71153, *p = 0.482*) as well as across land use categories ($F_{(3, 46.1)}$ = 1.536, *p = 0.218*). Although, private *Alalili* systems had a relatively higher soil pH range (6.7 – 9.1) compared to that of communal *Alalili* (6.5 – 8.1) while *Alalili* in WMA had relatively higher soil pH range (6.5 – 9.1) compared to other land use categories (Table 1).

Table 1: Summary of chemical properties featuring topsoil of surveyed *Alalili* systems.

Land use categories	Top soil characteristics (15 cm surface layer)					
	Types of *Alalili*	**Soil pH (H_2O 1:2.5)**	**OC (%)**	**P (mg/kg)**	**N (%)**	**C:N**
GCA	Communal	7.8 ± 0.3	2.2 ± 0.1	27.9 ± 3.7	0.17 ± 0.01	12.7 ± 0.3
	Private	7.1 ± 0.4	2.2 ± 0.2	29.3 ± 6.7	0.18 ± 0.02	12.5 ± 0.7
NCA	Communal	7.3 ± 0.2	2.4 ± 0.1	25.5 ± 2.6	0.22 ± 0.01	11.3 ± 0.4
	Private	n.a	n.a	n.a	n.a	n.a

Village land	Communal	6.9 ± 0.3	1.9 ± 0.2	23.1 ± 4.0	0.16 ± 0.02	12.2 ± 0.7
	Private	7.5 ± 0.6	2.3 ± 0.2	23.7 ± 6.7	0.15 ± 0.01	15.2 ± 1.0
WMA	Communal	6.8 ± 0.3	1.5 ± 0.2	17.6 ± 4.4	0.13 ± 0.02	11.9 ± 0.7
	Private	8.7 ± 0.4	1.8 ± 0.3	19.8 ± 13.9	0.14 ± 0.02	13.2 ± 1.1

* Abbreviations: OC, Organic carbon; P, Phosphorous; N, Nitrogen; C:N, Carbon to Nitrogen ratio; n.a, not applicable

3.2.4.2b Soil Organic Carbon (OC)

While the proportion of OC depicted non-significant variation ($t = 0.10729$, $p = 0.915$) across types of *Alalili* systems, it varied significantly ($F_{(3, 42.3)} = 5.256$, $p = 0.004$) in *Alalili* systems across land use categories. Even though communal *Alalili* systems had a relatively higher proportion of soil OC compared to that of private *Alalili* whereas *Alalili* in NCA depicted a relatively higher proportion of OC compared to other land use categories (Table 1).

3.2.4.2c Available plant Phosphorus in soil

The amount of P available in the soil depicted no significant variation across either type of *Alalili* ($t = -0.00267$, $p = 0.998$) and land uses ($F_{(3, 45.6)} = 0.799$, $p = 0.501$). However, private *Alalili* systems had a relatively higher content of P available in the soil compared to that of communal while *Alalili* in GCA depicted a relatively higher content of P available in the soil compared to other land use categories (Table 1).

3.2.4.2d Soil Nitrogen content

Additionally, the level of N was not significantly different ($t = 0.90046$, $p = 0.374$) across types of *Alalili* systems, but it varied significantly ($F_{(3, 41.2)} = 6.208$, $p = 0.001$) in *Alalili* systems across land use categories. Communal *Alalili* systems had a relatively higher level of N compared to that of private while *Alalili* in NCA depicted a relatively higher level of N compared to other land use categories (Table 1).

3.2.4.2e Soil Carbon to Nitrogen ratio

Lastly, the level of C: N was not significantly different ($t = -1.58622$, $p = 0.124$) across types of *Alalili* systems, but it depicted a significant variation ($F_{(3, 40.4)} = 2.746$, $p = 0.05$) in *Alalili* systems across land use categories. Even though, private *Alalili* systems had a relatively higher level of C:N ratio compared to that of communal *Alalili* while *Alalili* in NCA depicted a relatively higher level of C:N ratio compared to other land use categories (Table 1).

3.2.5 Water sources near surveyed *Alalili* systems

About 70% of *Alalili* systems face water scarcity being far from water ponds which are however temporary sources of water for livestock and the general community. Some few drilled wells and water ponds that also get drained in the acute dry season are distantly located from the *Alalili* systems (about 20 to 30 km walking distance). That being the case, herders tend to collect water with containers from these scarce resources and supply it to their livestock camped near the *Alalili* avoiding weakening of their herds due to long distance walking (Fig. 15).

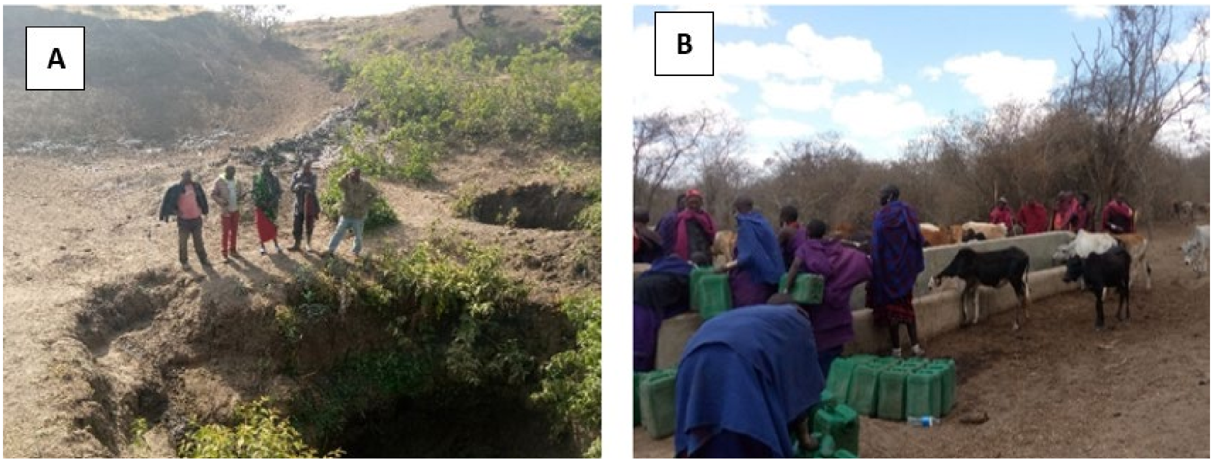

Figure 15: (A) Temporary water ponds dug as water sources closer to *Alalili* systems (B) Herders gathered at a drilled well for water collection.

3.3 Fodder species composition

Woody fodder species depicted a highest composition under families *Fabaceae* (26 tree species and 9 shrub species), *Malvaceae* (2 tree species and 8 shrub species), *Capparaceae* (4 tree species and 5 shrub species), *Burseraceae* (5 tree species), and *Boraginaceae* (1 tree and 4 shrub species). Herbaceous fodder had low species composition compared to woody species whereby, Grasses comprised two families: *Poaceae* (28 species) and *Cyperaceae* (2 species) while forbs had relatively high fodder species composition in families *Acanthaceae* (8 species), *Asteraceae* (6 species), *Fabaceae* (6 species) and *Lamiaceae* (5 species). Fodder species composition varied significantly ($t = 4.18$, $p < 0.05$) between communal and private *Alalili* systems as well as across land uses ($F_{(3)} = 3.5$, $p = 0.04$). Communal *Alalili* systems had the highest number of grasses, forbs, shrubs and trees compared to that of private *Alalili* systems. While private *Alalili* were dominated by forbs, communal *Alalili* were dominated by trees. On the other hand, *Alalili* systems in GCA had the highest number of forbs, grasses and shrubs whereas the lowest number were observed in NCA but, *Alalili* systems in village lands had higher trees composition compared to other land uses. The most appearing woody fodder species included *Balanites aegyptiaca*, *Commiphora africana*, *Maerua triphylla*, *Dichrostachys cinerea*, *Solanum incanum*, *Grewia* sp., *Zanthoxylum chalybeum*, *Ximenia caffra*, *Acacia tortilis*, *A. nilotica*, *A. drepanolobium*, *Sclerocarya birrea*, *Albizia* sp., *Lonchocarpus eriocalyx*, *Lippia javanica*, *Ormocarpum kirkii*, and *Combretum mole*. Common fodder grasses were *Cenchrus ciliaris*, *Cynodon* sp., *Themeda triandra*, *Panicum maximum*, *Cyperus* sp., *Pennisetum mezianum*, *Aristida* sp., *Chloris* sp., *Setaria pumila*, *Eragrostis cilianensis*, and *Brachiaria deflexa*. The most common forbs included *Dyschoriste hildebrandtii*, *Tribulus terrestris*, *Justicia* sp., *Barleria eranthemoides*, and *Achyranthes aspera*.

3.4 Ecological values of *Alalili* systems

3.4.1 Ecosystem services from *Alalili* systems

A total of 22 ecosystem services categorized into four main groups were identified by the *Maasai* pastoral communities: provisioning (5), cultural (8), regulating (4) and supporting (5). Cultural services were perceived as the most important group (33.9%) among the pastoralists, followed by provisioning (31.3%), supporting (19.4%) and regulating (15.4%) services. Pastoralists in NCA depicted a relatively high percentage weight in identification of cultural and provisioning services compared to those in GCA, village land and WMA while pastoralists in GCA depicted a relatively high proportion in identification of regulating and supporting services compared to NCA, village land and WMA. However, female respondents depicted a relatively high percentage weight of identifying cultural services than male respondents in contrast to provisioning services whereby male individuals had a relatively high proportion compared to female respondents.

3.4.2 Contribution of *Alalili* systems in wildlife conservation

More than 70% of the respondents suggested that *Alalili* systems offer a significant contribution ($\chi^2=360$, df=5, $p<0.001$) in wildlife conservation through provisioning of habitats, prey (for carnivores), fodder or forage (for herbivores), water, and breeding sites. Regardless of all being considered significant ($p<0.001$), habitats to wildlife were the leading attribute in preference to food (fodder and prey), water sources and breeding sites with respect to their proportion weights (Fig. 16).

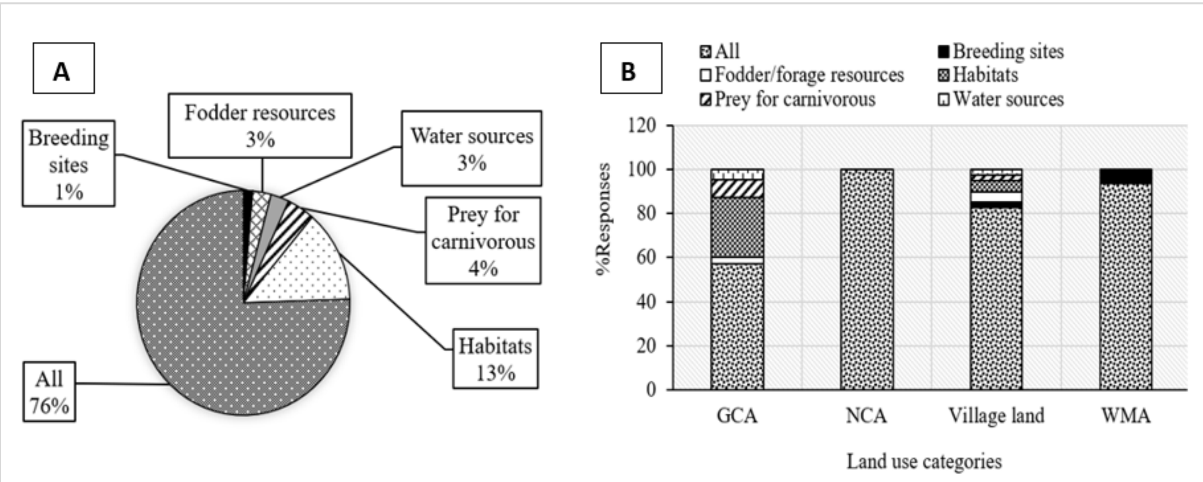

Figure 16: Roles of *Alalili* systems in wildlife conservation; (A) General proportion (B) Across land use categories.

Similarly, pastoralists from all land use categories significantly ($\chi^2=34.7$, df=15, $p=0.003$) agreed that *Alalili* systems are playing all useful roles in wildlife conservation whereby respondents in NCA had the leading proportion followed by those in WMA, village land and GCA. On the other hand, apart from being useful to all wildlife resources, pastoralists in GCA depicted a relatively high suitability of *Alalili* systems in providing useful habitats to wildlife while WMA demonstrated suitability in providing useful breeding sites to wildlife.

3.4.3 Wildlife species inhabiting, visiting or crossing through *Alalili* systems

It has been realised that *Alalili* systems contributes to ecological functions by providing refuge to wildlife species and safer breeding sites for them to multiply outside the boundaries of protected area (Fig. 17). It is regarded safer because, carnivores that can consume the infants and eggs are less dispersed into *Alalili* systems.

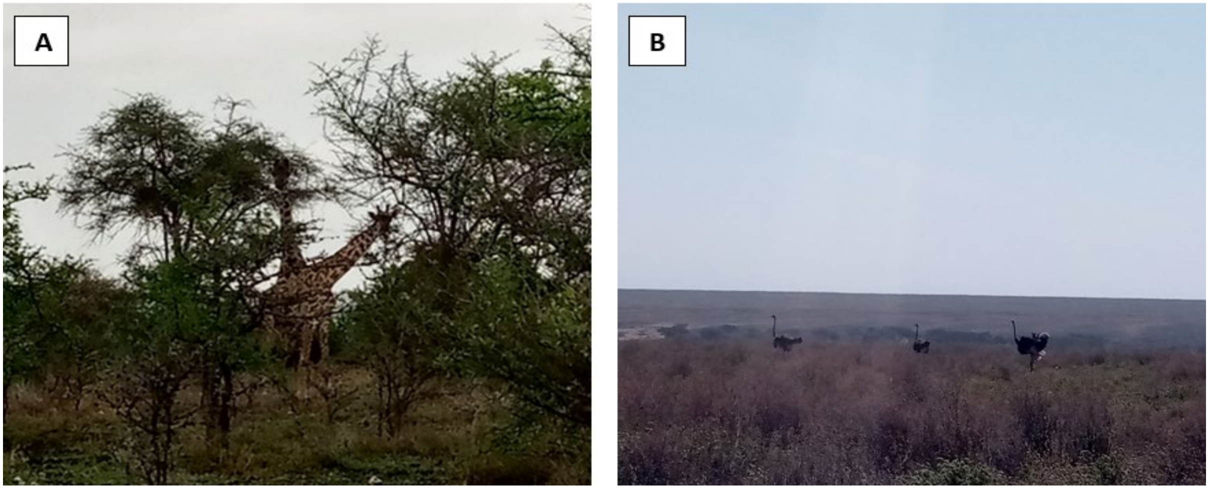

Figure 17: Some breeding sites identified in *Alalili* for: (A) Giraffe (B) Ostrich.

About 25 species of wild animals were identified to either inhabit, visit or pass through *Alalili* systems on their way to adjacent protected areas (Fig. 18). The proportion of identified wildlife varied significantly (χ^2=423, df=24, $p<0.001$) across individual species whereby both Guinea Fowl and Dik-dik constituted the highest frequency of 7.35% and 7.27% respectively. Other species that constituted a relatively high frequency were Francolin, Zebra, Elephant, Giraffe, Leopard, Eland, Hyena, Gazelle, and Ostrich. The proportion of wildlife inhabitation and visits varied significantly (χ^2=648, df=1, $p<0.001$) between communal and private *Alalili* systems which comprised of 84.9% and 14.1% respectively. *Alalili* systems in GCA were highly visited by identified wildlife animals whereby its percentage frequency was 43.8% followed by *Alalili* systems in village lands, NCA and WMA corresponding to 22.3%, 20.2% and 13.7%. Thus, there was a significant variation (χ^2=272, df=3, $p<0.001$) in wildlife visits across the studied land uses.

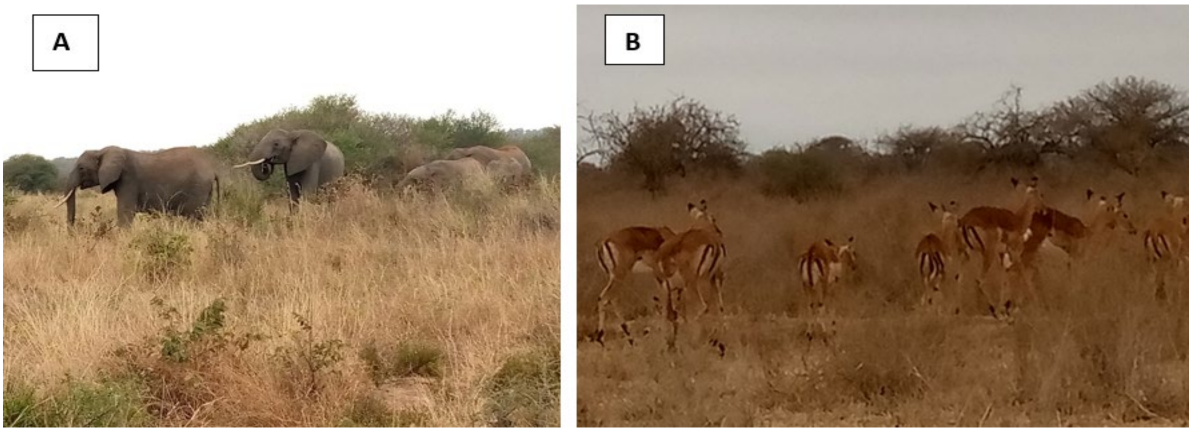

Figure 18: Wildlife found grazing in the *Alalili*; (A) Elephants (B) Gazelle.

3.5 Socio-cultural and Economic Significance of *Alalili* systems

More than 80% of respondents proposed that *Alalili* systems provide useful socio-economic benefits whereby, 44.1% suggested that many benefits are earned at village level followed by household levels (37.8%) and individual levels (18.1%). Four major economic benefits identified include milk sales, fodder sales for *in-situ* grazing obtained through renting of *Alalili* systems, profit gained from livestock fattening activities and penalties collected from illegal grazers. The fattening profit depicted the highest value that ranged from USD 12,156 to 13,837 per household when fattened livestock are sold after an average of five months. Milk sales was the second attribute in terms of economic value whereby its income gain ranged from USD 122 to 135 per household at an average of three months of grazing in *Alalili* systems. This was followed by fodder sales whereby its income gain ranged from USD 57 to 62 per household when the *Alalili* systems are opened for grazing activities. Penalties contributed to an income that ranged from USD 33 to 37 per village that implements charges to illegal grazers. Other benefits identified were beekeeping opportunities, harvesting fuelwood, traditional medicine extracted from medicinal plants, recreation and eco-tourism. They were also useful in maintenance of social-cultural norms, customs and rituals done through religious and spiritual practices within *Alalili* systems whereby their black gods who are said to bring rain and thunders are worshipped for replenishing their grazing land (Fig. 19).

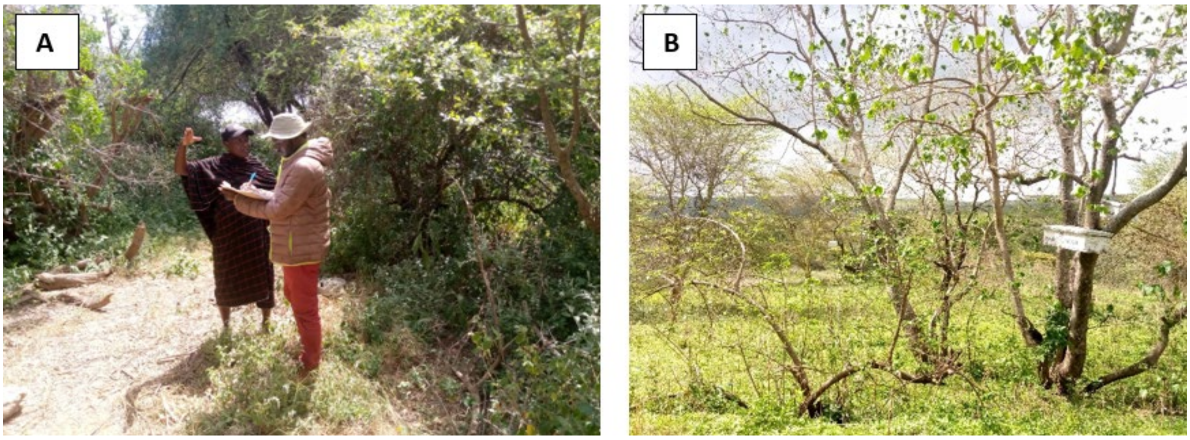

Figure 19: (A) A place for *Maasai* religious practices in the *Alalili* (B) A sample apiary set-up in *Alalili* for beekeeping.

4. Discussion

This study identified two types of *Alalili* silvo-pastoral conservation systems or indigenous enclosures, i.e., private and communal, across different land use categories of northern Tanzania. These systems are still considered as strong traditionally managed pasture conservation strategies playing multiple roles at the same time, i.e., feed reserves, environmental conservation, economic development, mitigating impacts of global climate change as well as giving ecosystem values. This was similarly reported by Mpondo et al. (2021), Selemani (2020) and Goldman (2011) who added that *Alalili* systems provide shared refuge to human, livestock and wildlife considering that most of them are resided along or within protected areas. However, a highest abundance and distribution of communal *Alalili* than that of private suggest on the airmarked negligence over private *Alalili* that will contribute to gradual loss of these useful traditional heritage among the *Maasai* pastoral and agro-pastoral communities as reported by Wiethase et al. (2023), Woodhouse & McCabe (2018) and Nelson (2012). Furthermore, the results section depicts that the soils in surveyed *Alalili* systems are highly alkaline exceeding a recommended pH ranges for pastures (6.5 to 7.0) and inappropriate proportions of OC, N and P contents as well as C:N ratios which endangers the soil fertility and healthier fodder productivity. Such soils have a highest possibility of accumulating salts and sodium carbonates at a toxic concentration thus altering a soil structure of *Alalili* systems resulting into root growth difficulties of fodder plants (URT, 2006). This might also be associated with a reduced vegetation cover over the course of time (Fig. 13) as well as an increased woody fodder species composition encountered in *Alalili* systems compared to less herbaceous fodder species composition. Such observations are suggesting on the possible effects of woody encroachment that will further contribute to a lowered production of herbaceous fodder species. An observable change of pasture lands to crop cultivation associated with heavy grazing and high stocking density across studied *Alalili* systems (Fig. 20) are considered as factors that leads into pasture decline with regard to reduced size of a grazing land and rangeland encroachment (Homewood et al., 2009; Archer et al., 2017). This is also supported by about 54.6% of respondents who proposed that benefits from *Alalili* systems are currently declining compared to the situation in the past 20 years. This will further jeopardise the sustainability of rangelands with respect to effects of social-cultural changes, climate change, LULCC and population growth.

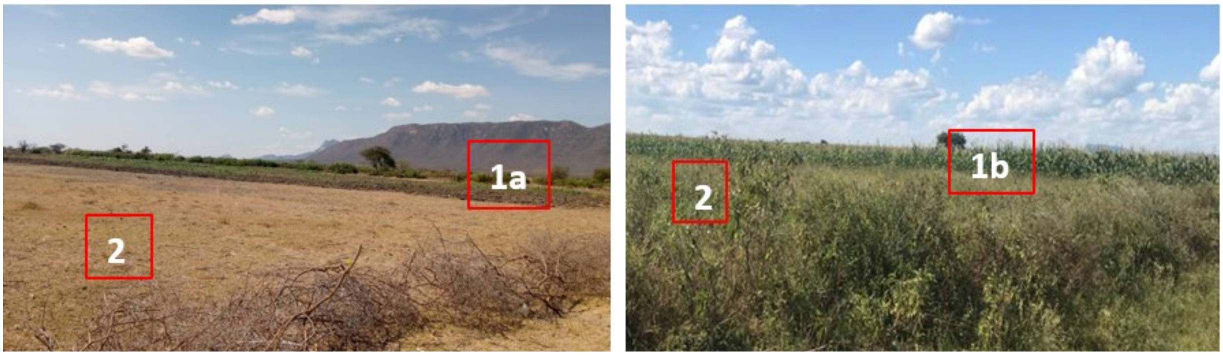

Figure 20: Private *Alalili* encroached; (1a) Part of *Alalili* changed into Onion Garden (1b) Part of *Alalili* changed into Maize plantation (2) The remaining portion of *Alalili* for grazing.

Additionally, some illegal anthropogenic activities such as deforestation and charcoal burning for fuel wood were found to be practiced thus degrading *Alalili* systems while reducing fodder productivity in terms of quantities and qualities for grazing purposes (Fig. 21).

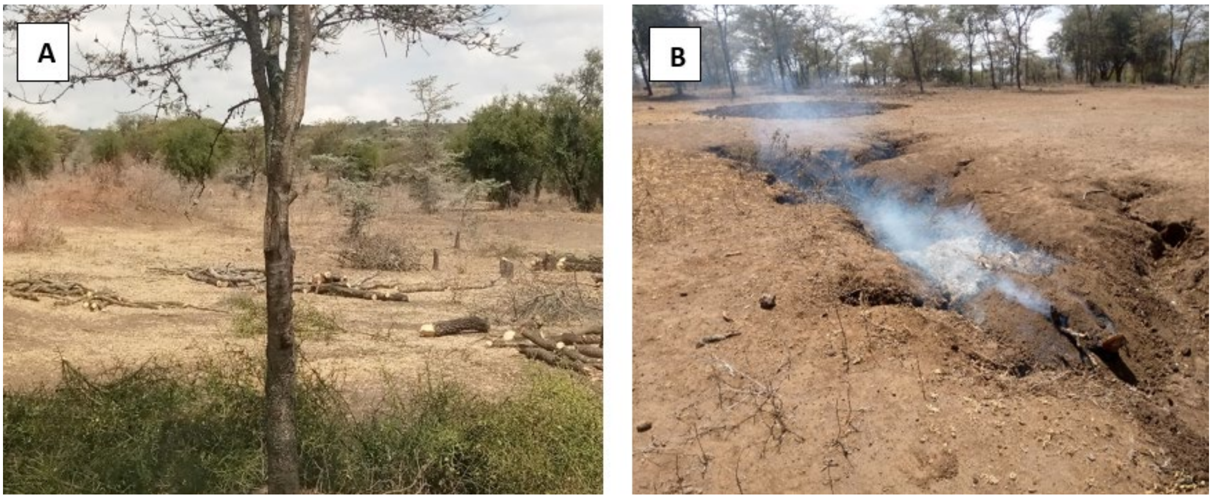

Figure 21: (A) Fuelwood harvesting in *Alalili* (B) Charcoal burning in the *Alalili*.

5. Conclusion and Recommendations

The findings from this piece of work have generally indicated that Maasai *Alalili* silvo-pastoral conservation systems are still performing better with reference made on their abundance and spatial distribution. However, their size and vegetation cover seemed to decline tremendously with time and space sending a message to the government and rangeland conservation authorities about their possible loss in the near future. The evolving effects of growing population, LULCC and environmental pressures such as climate change are communicated to biodiversity conservation societies for the purpose of counteracting against such threats. Moreover, this work suggests that an inclusion of *Alalili* practices into core pasture production and management areas, facilitating their reinforcement into policy and practices will boost their survival, suitability and sustainability.

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