INTL J TROP DRYLANDS
Volume 7, Number 1, June 2023
Pages: 46-54

E-ISSN: 2580-2828
DOI: 10.13057/tropdrylands/t070106

Assessment of soil health in uncontrolled grazing areas in the Administrative Post of Luro, Lautem, East Timor

DELFIM DA-COSTA[1,2,♥]
[1]Department of Agronomy, Universidade Nacional Timor Lorosae. Avenida Cidade de Lisboa Road, Dili, Timor-Leste.
Tel.: +67-033-21202, ♥email: delfimdacosta915@gmail.com
[2]Center for Climate Change and Biodiversity. Cidade de Lisboa, Dili, Timor-Leste

Manuscript received: 13 April 2023. Revision accepted: 10 June 2023.

Abstract. *Da-Costa D. 2023. Assessment of soil health in uncontrolled grazing areas in the Administrative Post of Luro, Lautem, East Timor. Intl J Trop Drylands 7: 46-54.* Uncontrolled grazing practices have been judged as the main cause of soil degradation in grassland areas. This study was conducted to provide baseline information on soil health in uncontrolled grazing areas in the administrative post of Luro, municipality of Lautem, East Timor (Timor Leste). Furthermore, 40 soil samples were collected from eight uncontrolled grazing areas using the core method; five points sampling per each site (four in corners and one in in the center) sampling points distances were 100 to 150 m apart, and each point represented three different soil layers (0-5 cm, 5-10 cm, and 10-20 cm). All soil samples were transported to the laboratory of the Faculty of Agriculture, Universidade Nacional Timor Lororsae, East Timor. Samples preparation and analysis followed the procedure and guidelines of McKenzie et al. (2002) and Liu et al. (2019) for physical properties, while Soil Organic Matter (SOM) analysis used Loss-On-Ignition (LOI) adopted from Nakhli et al. (2019). In addition, all soil chemical properties were analyzed using Kjeldhal and Bray-1 method following the soil analysis guidelines of JICA (2014). The study showed that soil physical properties in the uncontrolled grazing areas in Luro are characterized by high bulk density, poor porosity, and low organic matter content. Furthermore, soil pH remains neutral in areas where uncontrolled grazing is practiced but with very low nitrogen and potassium levels. In contrast, phosphorus is very high in the Cotamuto and Lakawa but very low in the Afabubo areas. Furthermore, low literacy levels and livelihoods are key socioeconomic factors that directly influence uncontrolled grazing practices. Hence, promoting sustainable grazing methods among communities towards raising livestock for their livelihood is recommended.

Keywords: Agriculture development, ecological risk, livestock

INTRODUCTION

Soil health is the fitness of the soil to sustain the growth, development, and yield of vegetation: crops, grasses, shrubs, and forests (Sopialena et al. 2017; Tahat et al. 2020). In contrast, soil degradation means adverse changes in soil properties and processes can be set in motion by disturbing the dynamic equilibrium of soil with its environment by natural or anthropogenic (human) perturbations over time (Lal et al. 2003).

The soil's physical properties are the components that greatly influence the texture, structure, porosity, and pore space fraction of soil (Gray et al. 2011; Fu et al. 2022). Chemical properties include soil pH, exchange capacity, salt-affected soil, and calcareous soil, while biological properties include soil biota, flora, and fauna (McCauley et al. 2005). The physical properties of soil include texture, bulk density, porosity, moisture, and erosion. Soil texture is the particle-size distribution that determines the soil's coarseness or fineness. The physical and chemical weathering process of rocks and minerals results in a wide range of sizes, such as stones, gravel, sand, silt, and very small clay particles, simultaneously (Ellis and Foth 1997; Mahilum 2004; Schoeneberger et al. 2012).

Aside from soil's physical and biological properties, soil pH range is important in soil productivity as it determines the availability of other nutrients for crop uptake. For example, nitrogen availability is maximum between pH 6 to 8 because this is the most favorable range for the soil microbes to mineralize the nitrogen in organic matter and organisms to fix nitrogen symbiotically. In addition, maximum phosphorus availability is within the range of 6.5 to 7.5, while potassium is widely available in alkaline soil (Ellis and Foth 1997). UNEP (1992) reported the degree of soil degradation by sub-continental regions, which indicates that 15% of the total area in the world has degraded, with Africa and Asia dominating the list. Even in Asia, soil degradation has increased to about 18%.

Land degradation was estimated to begin in East Timor when the general process of commencing mercantilism and economic reforms occurred due to sandalwood (*Santalum album* L.) exploration in 1718 (Sousa 2018). It resulted in massive deforestation and loss of biodiversity (McWilliam 2003). As a result, land cover changes have been observed, and the most critical changes are in woodland; from 1989 to 1999, woodland has been reduced from 7% to 22%, followed by forest from 6% to 7%, while agriculture land decreased from 26% to 24% of total area (Bouma and Kobryn 2004). In addition, 30% of forests were lost from 1972 to 1999, based on analysis of satellite images (MAF 2007). Most people are involved in shifting cultivation, uncontrolled grazing, uncontrolled forest fire, slash-and-burn and firewood collection. Moreover, the primary sources of livelihood are agriculture, livestock production, and forestry, which are directly associated with the land's quality and resources (NAP 2008).

Approximately 3,600 ha of the grassland areas are being utilized by the community under uncontrolled grazing practices for grazing cattle, buffalo, horses, goats, and sheep. In addition, burning practices are customarily done by herders in grassland during the dry season to give space for the next grass to grow when the wet season comes (IWMPR 2012). Environmental degradations in the country have been noticed and cited in several important documents on uncontrolled grazing practices that have initiated a sequence of environmental degradation. The general opinion is that soil degradation in uncontrolled grazing areas is associated with poor livestock raising management, lack of knowledge, weakness of policies, land ownership issues, and other socioeconomic problems (NBSAP 2011; MAF 2018; NDC 2022).

A series of studies on uncontrolled grazing and grazing management effects on soil health have been conducted in other places (Yong-Zhong et al. 2005; Savadogo et al. 2007; Maitima et al. 2009; Piñeiro et al. 2010; Matano et al. 2015). However, no study has been conducted on uncontrolled grazing influences on soil health in Luro administrative post. Therefore, this study was conducted with three main objectives, namely to: assess soil physical, chemical, and biological properties in uncontrolled grazing areas; assess the socioeconomic conditions of farmers who practice uncontrolled grazing; and find the association between socioeconomic characteristics and soil degradation to identify important parameters for policy-making that will ensure the soil for agriculture and livestock production sustainability.

MATERIALS AND METHODS

Study area

The study was conducted during the dry season in the Lautem municipality of Cotamuto, Lakawa, and Afabubo Villages, East Timor in 2022. These villages geographically are located between latitude 8°33'07.13"S and longitude 126°48'27.33"E with an elevation from 119 to 782 meters above the sea level (masl) (Figure 1). The wet season is between November and May, with a range of 92 mm to 237 mm, and the dry season is from June until early November, with an average rainfall of 30 mm to 108 mm (Figure 2). Three soil types are found in the study area: Entisols, Inceptisols, and vertisols (IWMPR 2012).

Methods

Soil health measurement

Moreover, 40 soil samples were collected randomly in 8 uncontrolled grazing areas; two in the village of Cotamuto, two in the village of Lakawa, and four in the village of Afabubo. The selections of uncontrolled grazing areas were based on the grazing intensities, sizes of grassland, and non-conflict areas. Soil samples were collected using the core method; five points sampling per each site (four in corners and one in in the center) sampling points distances were 100 to 150 m apart, and each point represented three different soil layers (0-5 cm, 5-10 cm, and 10-20 cm).

All samples were transported to the laboratory of the faculty of agriculture, Universidade Nacional Timor Lorosae, East Timor and continue with the analysis; soil physical properties analysis used the gravimetric method: soil moisture (Liu et al. 2019), soil porosity and bulk density (McKenzie et al. 2002). Furthermore, SOM was measured by the loss-on-ignition (LOI) method; determining organic matter involves the heated destruction of all organic matter in the soil or sediment (Nakhli et al. 2019). In addition, 45 households were interviewed for the socioeconomic factors, and data were analyzed using multiple regression.

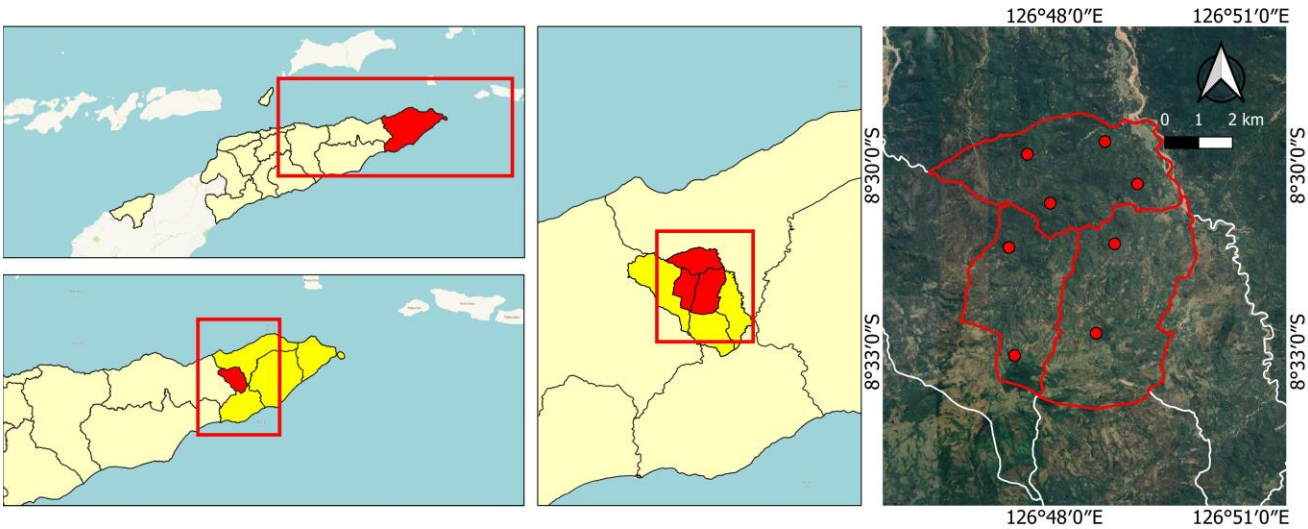

Figure 1. Map of the study area in in the Administrative Post of Luro, Lautem, East Timor

Determination of soil moisture content

The gravimetric method measured the moisture content by calculating the mass loss ratio after drying at 105°C (Liu et al. 2019).

$$\text{Soil Moisture} = \frac{(\text{wt of wet soil} + \text{ring}) - (\text{wt of dry soil} + \text{ring})}{(\text{wt of dry soil} + \text{ring}) - \text{ring}} \text{ x } 100$$

Determination of soil porosity

The percentage of pores was measured by specific gravity from then used to calculate porosity (McKenzie et al. 2002).

$$Porosity\ (\%) = 1 - \frac{\text{Bulk Density } g.cm^{-3}}{\text{Specific gravity } g.cm^{-3}}\ x\ 100\ \%$$

Determination of bulk density

The soil bulk density is the weight per unit volume of oven-dry soil, that is, the ratio of dry soil mass to total volume (McKenzie et al. 2002).

$$\text{Bulk density}(\frac{\text{g}}{\text{cm}^3}) = \frac{\text{weight of oven} - \text{dry soil (g)}}{\text{volume of soil (cm}^3)}$$

Soil Organic Matter (SOM): SOM was measured by the Loss-On-Ignition (LOI) method. Determining organic matter involves the heated destruction of all organic matter in the soil or sediment (Nakhli et al. 2019). Soil pH: Weigh about 10g of soil sample into the container. Add 50ml of distilled water to the soil and shake the container for about 2-3 minutes, then allow the soil to settle for 2 minutes. Next, measure the PH value of the water above the soil in the container. Finally, the soil nutrients (NPK): total soil nitrogen was measured by the nitrogen Kjeldhall method, and phosphorus and potassium (potassium the same as Kalium) were measured by the Bray-1 method (JICA 2014).

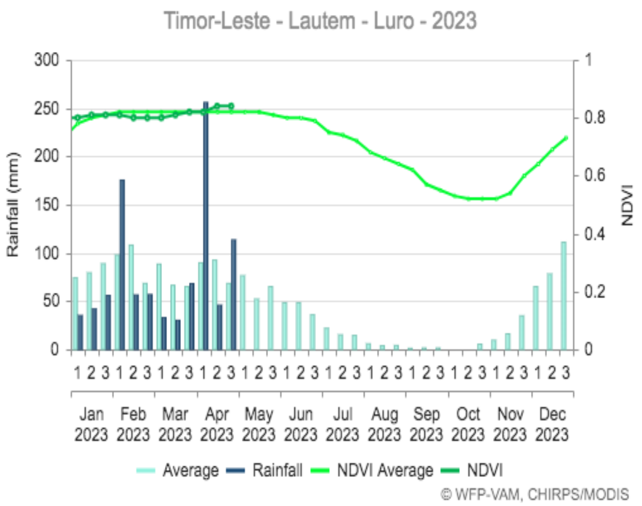

Figure 2. Rainfall and NDVI data of Luro Administrative Post, East Timor (Source: Online WFP-VAM)

Socioeconomic

Socioeconomic data were gathered through the survey and visits to farmers' houses that practice uncontrolled grazing in the study site. Purposive sampling was used to interview 45 household heads. Nexy, the descriptive analyses were used to analyze the socioeconomic status. (Education *(X_1)*, main livelihood*(X_2)*, main income *(X_3)*, and raising livestock *(X_4)*. Therefore, to determine the relationship between socioeconomic variables and soil degradation, multiple regression was used by function:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + e$$

Where:

Y : Value of the Dependent variable (soil degradation)
a : Constant or intercept
b : Beta coefficient
X : independent variable (socio-economic variables)
e : residual error

Data analysis

Descriptive analysis was used to analyze the socioeconomic factors in the study. At the same time, inferential statistics and multiple regressions were used to analyze the relationship between socioeconomic variables and soil degradation. Therefore, the soil degradation was analyzed using descriptive and inferential statistics (complete random design). Moreover, Duncan's Multiple Range Test (DMRT) at 5% was used to determine the significance at each degraded site. In addition, the SPSS program and Excel software were utilized to process the data.

RESULTS AND DISCUSSION

Biophysical characteristics

Soil biophysical characteristics in grazing areas are measured by bulk density, soil porosity, and soil organic matter. In Cotamuto, there was no significant difference (DMRT 5%) between sites; bulk density value ranged from 1.27 to 1.59, soil porosity ranged from 38.37 to 50.85%, and soil organic matter percentage ranged from 3.26 to 3.99. In Lakawa, bulk density and soil porosity have no significant difference between sites; bulk density value ranged from 1.29 to 1.66, while soil porosity ranged from 35.95 to 50.21%. Overall, SOM in Cotamuto, Lakawa, and Afabubo were low fall under benchmarck, although highest SOM found in Cotamuto and lowest in Afabubo (Figure 3).

The soil biophysical properties in uncontrolled grazing areas are shown in Figure 3. In Cotamuto, soil organic matter, soil porosity, and bulk density are not significantly different among sites. Bulk density is not statistically different (DMRT 5%) but is slightly different from one site to another. High bulk density was found in site Cotamuto C (1.57 g/cm^3) and lowest in site Lakawa B (1.27 g/cm^3). The grassland's Bulk density is affected by the grazing intensity and the number of livestock grazing; the soil becomes compact if the intensity of grazing activity is increased. In addition, livestock grazing on ground cover continuously in the same area could affect grass growth. Grass would disappear if the number of livestock increased, but grazing areas would remain limited. Livestock movement by free grazing in the area led to the soil being compacted due to intense livestock trampling. These data of bulk density considered as compacted status is in line with the previous study conducted by Ellis and Foth (1997) revealed that bulk density for organic soil should be less than 1 g.cm$^{-3,}$ and for the optimum topsoil range is 1.3 g.cm^{-3}. Soil bulk density of more than 1.3 g.cm^{-3} indicates that the soil is compacted.

Moreover, soil with high bulk density has fewer pores. As shown in Figure 3, an increase in bulk density means low pores. Low porosity in soil could lead to low water absorption capacity during the rainy season. As a result, there is the possibility of high run-off instead of high water infiltration, less moisture, and also affects soil organisms. Fewer pores affects air circulation and soil moisture content to sustain soil organisms and soil health. These porosities can be drawn from an organic matter, whether high or low organic matter in the soil. The soil status can be considered low productivity due to the low porosity indicated in fewer pores and low organic matter. Moreover, less organic matter in the Cotamuto site led soil to low productivity, negatively affecting grass growth and harming livestock and farmers' livelihood. The recent study in Kenya and Tanzania by Matano et al. (2015) revealed that the high intensity of free grazing activities has contributed to the increasing bulk density and decreasing organic matter in grazing areas. Piñeiro et al. (2010) stressed that overgrazing activities might directly or indirectly affect the amount of C available for SOC formation by changing the proportion of Net Primary Productivity (NPP) allocated to below or aboveground organisms.

In Lakawa, bulk density and soil porosity are not significantly different among sites. Soil bulk density was slightly higher in Afabubo D (1.66 g/cm^3) while low bulk density was found in Afabubo B (1.29 g/cm^3). Most bulk densities were above 1.3 g/cm^3, which generally harms growing grass and makes it fragile to catch up to a wilting point as these sites have very low soil moisture. The reasons for slight differences in bulk density among sites in Afabubo are the differences in large grazing areas and the number of grazing livestock. In areas where livestock grazing is less, less effect was observed in short grazing periods, but if free grazing is continuously kept, soil compaction will result. Soil compacted by cattle grazing is susceptible to superficial erosion after rains due to its reduced capacity for water infiltration and greater surface run-off (Gray et al. 2011).

The soil porosity observation results have the same case with bulk density. The soil is less porous in Afabubo D (35.95%), while in Afabubo B, the soil has good porosity (50.21%). High porosity in Afabubo B was affected not by free grazing but by soil texture. In this site, the soil texture was sandy, and even the porosity was high, but not by organic matter. Sandy soils can be easily leached and remove nutrients and organic matter. Slopes exacerbate this and make it susceptible to erosion or run-off. Grass growth is very limited due to less moisture and compaction except in Afabubo B, but still, not much grass has grown due to less moisture. According to Ellis and Foth (1997), desirable soil for plant growth has a total porosity of 50%, one-half macro pore porosity, and one-half micro pore porosity. Such soil has a good balance between water retention for plant use and oxygen supply for root respiration.

Soil organic matter in Afabubo B is significantly higher in all sites, but organic matter is lower in Afabubo D. However, the organic matter in Afabubo A and C are found in adjacent points (DMRT 5%). The ground littered down and decomposed by microorganisms determines the organic matter in the soil cover. These components are interlinked to execute roles and functions in providing organic matter. The physical characteristics of soil have important roles in allowing the presence of microorganisms; microorganisms need soil moisture to decompose litter. High grazing frequencies in the same area affect grass to be extinct, less ground cover to low moisture, high run-off, and soil to be compacted, resulting in poor organic matter.

Intense grazing on the same land alters soil density, resulting in soil compaction due to the weight of animal movements and the mechanical forces of livestock grazing. This negatively impacts soil erosion, reduced rainfall infiltration rate, and degradation of vegetation cover (Matano et al. 2015). In addition, Savadogo et al. (2007) emphasized that less pore space can limit gas exchange and reduce root growth. Both mechanisms suggest that soil compaction reduces plant production and, thus, SOC storage.

Free grazing practices have affected soil biophysical properties in Afabubo. Soil organic matter is not significantly different (DMRT 5%) among sites as well as soil bulk density and porosity. Very low organic matter, high bulk density, and less porosity were the characteristics of soil found in the whole Afabubo grazing sites. Wiesmeier et al. (2019) found through their research that the compaction and poor soil structure in cultivated fields was attributed to loss of SOC, which averaged 46% less in cultivated A horizon than uncultivated A horizons and 35% less in cultivated B horizons compared to uncultivated B horizons, respectively.

Moreover, when the bulk density of soil is high, the soil tends to be more compact and heavier. This kind of soil is not suitable for growing any vegetation since the pores space for roots and moisture contents are not available. Topsoil could suffer compaction from any pressure, disturbing its pattern to accommodate an environmental preference for grasses. As a result, shallow grass rooting occurs and is vulnerable to reaching a permanent wilting point. According to Yong-Zhong et al. (2005), soil compaction under grazing is attributed to trampling by herbivores. Soil compaction reduces water infiltration, increases run-off under grazing conditions, and decreases water available for plant growth.

Soil porosity in grazing areas and bulk density in Afabubo are affected. Free grazing activity seemed to trigger degradation. Most cattle and sheep were freely grazing in that area. The soil will likely lose its pores and might be transformed into a compacted one (Figure 3). There was no significant difference among sites, as shown at DMRT 5%, but soils are poor in porosity on average, which could lead to worst conditions such as erosion, run-off, and siltation in watershed areas. These align with Blanco and Lal (2008), who stated that excessive grazing could degrade soil structure, reducing aggregate stability, pore-size distribution, macro-porosity, total porosity, and water infiltration rate. Meanwhile, Johnson and Matchett (2001) revealed that grazing could also change C allocation patterns affecting the amount of C entering the soil. Belowground biomass directly enters the soil and contributes more to SOM formation than aboveground tissues.

Soil chemical characteristics in an uncontrolled grazing area

Soil chemical properties measured are soil pH and macro-nutrients represented by nitrogen, phosphorus, and potassium level to estimate how fertile the soil is within an uncontrolled grazing area. Soil pH significantly differs between sites, with the highest pH in Afabubo and significantly lowest in Lakawa, while the pH in Cotamuto at the adjacent point. On the other hand, total nitrogen, phosphorus, and potassium availabilities have no significant difference; total nitrogen ranged from 0.11 to 0.18, and phosphorus availability ranged from 10.25 to 83.07, while potassium availability ranged from 0.23 to 0.26 (Table 1).

Soil chemical properties have no significant differences with total nitrogen, phosphorus availability, or potassium availability except soil pH. Soil pH in the grazing area showed a significant difference (DMRT 5%). Soil pH in Daudere is significantly lower pH found in Afabubo. However, soil pH in Lakawa and Cotamuto fell at adjacent points. Soil pH in Afabubo is relatively neutral in the whole area, but as pH increases, it tends to be alkaline due to overgrazing activities. Consequently, livestock left to freely graze in the area without keeping in paddocks have been raised. Several previous studies have shown that soil pH could increase to alkalinity status by overgrazing, as per the study by Wang and Batkhisig (2014). In addition, Yong-Zhong et al. (2005) found that overgrazing practices made soil slightly alkaline, with pH values of up to 8.72.

Total nitrogen in grazing areas is not significantly different (DMRT 5%) among sites; however, the total nitrogen is higher in Afabubo than in other sites. The grazing site in Cotamuto has a very poor nitrogen content (Table 1). The loss of nitrogen may be due to run-off triggered by overgrazing and made in soil-less porous and increased leaching during the rainy season. These findings align with Yong-Zhong et al. (2005), who concluded through their study that continuous grazing resulted in a considerable decrease in ground cover, accelerated soil erosion, and loss of soil organic carbon and nitrogen.

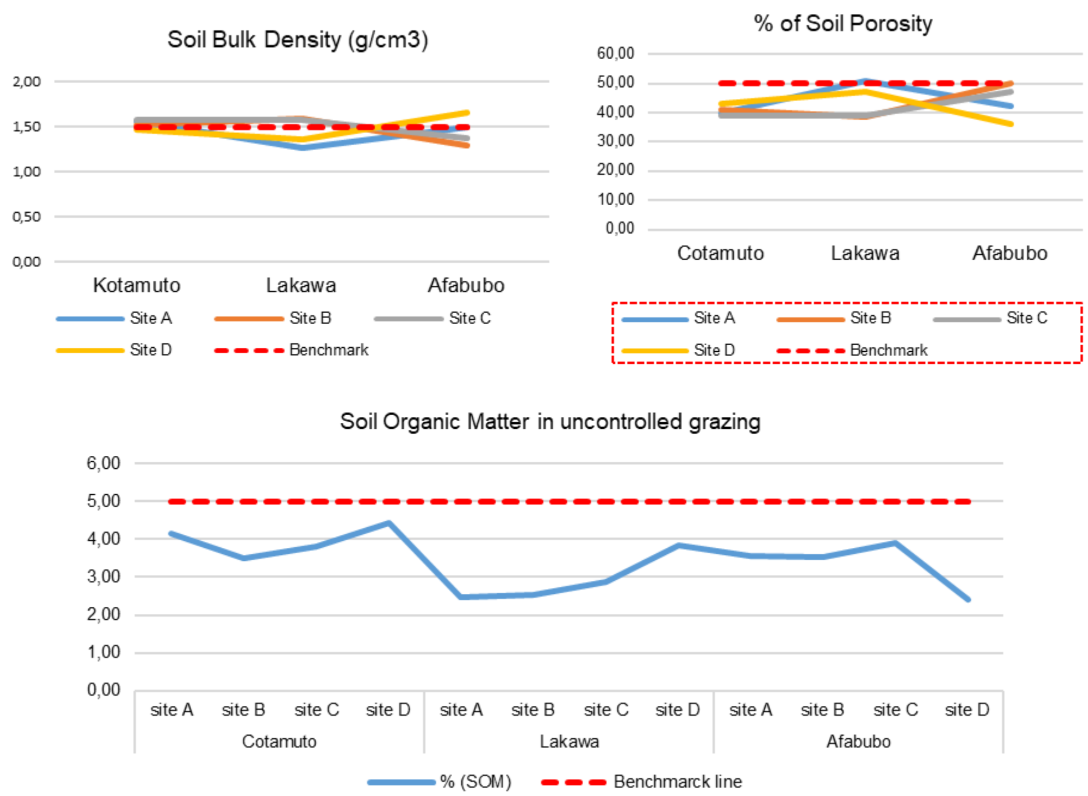

Figure 3. Soil bulk density, porosity, and organic matter

In grazing sites, phosphorous availability in Afabubo was less available (Table 1), but Cotamuto and Lakawa found abundance available. No significantly different (DMRT 5%) in terms of phosphorous availability among sites, but slightly different from one to another, with the highest in Cotamuto and lowest in Afabubo. Free grazing practices were found in the entire watershed, particularly during the dry season, because no garden crops are grown anywhere. Therefore, farmers felt free to leave their livestock to graze; however, these practices lead the soil in Luro Administrative Post to be in poor condition making it less productive. Maitima et al. (2009) reported that soil pH increased with overgrazing and organic matter, and essential macronutrients decreased.

Potassium availability was found at an optimum level in Cotamuto, while in two other sites of Lakawa and Afabubo, low level (Table 1). There were no significant differences (DMRT 5%) among sites. However, slight differences from one site to another, with the highest in Cotamuto and the lowest in Afabubo and Lakawa (0.23 Cmolc/kg). Chang et al. (2014) proved that overgrazing negatively impacted nutrient retention in the soil through a simulation model and concluded that overgrazing depletes soil organic carbon. In addition, they mentioned that more grassland degradation was caused by mismanagement of livestock keeping and free grazing methods.

Socioeconomic survey results

Socioeconomic variables consist of education level and main livelihood (Figure 4). Most farmers have big family sizes and are in their productive ages, but very few have attended school. Their sources of livelihood include farming, raising livestock, and a few firewood gatherings.

Education

In terms of education, more than half of the respondents had no formal education in the entire uncontrolled grazing area. That was aligned with the country's data (Census 2022) reported the education rate in the overall country was 70.1%; illiteracy of age ranged from 15 to 24. This study found that in Cotamuto and Lakawa, one-third of the respondents obtained their junior high school, while in Afabubo, 27% finished their primary education. Data suggests that most farmer-respondents in the study site did not have formal education, while for those who attended school, only a few obtained higher than junior high school.

Main livelihood

The households' main livelihoods were dominantly farming, while few engaged in livestock and hired labor (Figure 4). In Cotamuto, 73% of respondents were engaged in farming, while the remaining had hired labor and livestock raising as their main livelihood, with 13% each. In Lakawa, 71% of respondents engaged in farming and 29% engaged in livestock, but none of them had main livelihood from hired labour. In Afabubo, raising livestock was not their main livelihood, 80% of them had main livelihood from farming. These are inline with the national data in the 2010 census, Timorese are mainly agricultural people, with 63% of households engaged in agricultural production and 80% rearing many livestock. However, 20% are into hired labor but do farming during rest days. Moreover, farmers with limited and/or lack of knowledge are engaged in the worst land preparation practices and committed to destroying soil productivity, resulting in massive degradation, low yields, and household income. As suggested by Jha and Dang (2008), farmers head comprise 67% of the population of East Timor, of which 44% are poor, and nearly 42% are vulnerable to poverty.

Table 1. The chemical parameters in uncontrolled grazing areas

Site	pH (H_2O)	N Total (%)	P Ave. (ppm)	K Ave. (Cmolc/kg)
Cotamuto	6.93 ab	0.11 a	83.07 a	0.25 a
Lakawa	6.8 ab	0.17 a	59.29 a	0.23 a
Afabubo	6.71 b	0.18 a	10.25 a	0.23 a

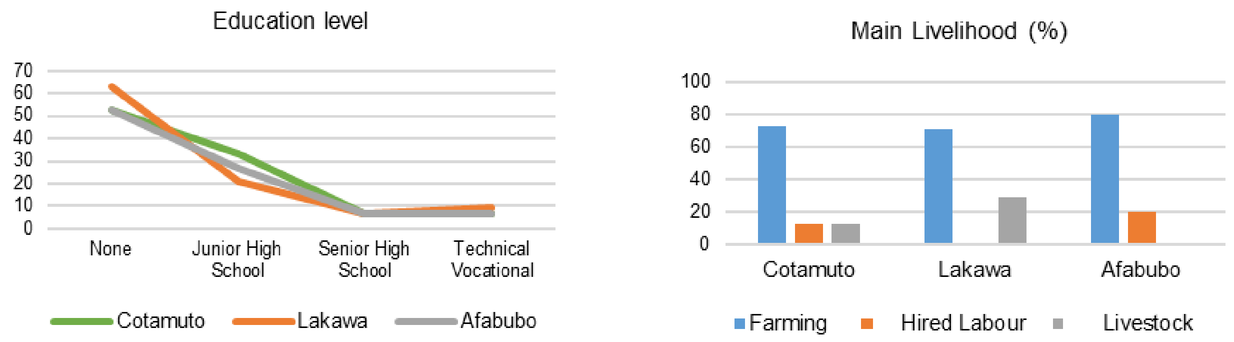

Figure 4. Education level and main livelihood

Raising livestock

Most farmers raise livestock, 93% in Cotamuto and 80% in Lakawa and Afabubo. Farmers in Cotamuto and Lakawa primarily own cattle, while sheep are mostly raised in Afabubo (Figure 5). In terms of the way they keep their livestock, all farmers in the Lakawa and Afabubo practiced uncontrolled grazing, while in Cotamuto mostly kept the animals fenced at night time and allowed them to graze in fallowed slash-and-burn areas (Table 2).

Livestock raising

A big proportion of the households in the study site are engaged in livestock production both as a main and alternative occupation. Raising livestock was highest in Cotamuto with 93.33% and slightly low in the Lakawa and Afabubo with 80% (Figure 5); these performances are common in Lautem municipality as have been reported by Ministry Economy and Development (MED) in 2011 that 84% of all household in Lautem municipality raise livestock; furthermore, Lautem municipality was the second biggest owner after Bobonaro municipality with 88.8% of households. All farmers mostly raised livestock because of the multipurpose reason they were raised. Livestock serves as household income, an asset for the future, and a social function for the wedding ceremony. Livestock also serves as cultural and ritual events, as an honored wealth to marry a woman, and for agricultural activities, particularly rice field tillage, instead of using modern agricultural machinery.

Besides the abovementioned value of livestock, it negatively impacts the soil if it grazes freely everywhere. Lack of grazing control and management leads livestock trumped on the ground with high intensity, and more frequently, could threaten soil productivity, grass sustainability, and other hydrological hazards. Through a field study in Mongolia, Wang and Batkhishig (2014) concluded that increasing the number of livestock in the same area would tend to overgraze affects soil water physical properties, top soil become more compact and decreasing soil moisture.

Livestock distribution

More than half (57.14%) of farmers in Cotamuto raised cattle and goats. A similar pattern was recorded in Lakawa but a slightly higher percentage (69.23%), while in Afabubo, the majority (92.31%) raised sheep (Table 2). Raising livestock is being opted as a traditional activity in East Timor as the report of MED 2011 and NSD 2011 mentioned that one of the most traditional activities of households in East Timor is raising livestock, for the overall country there are 80% raised livestock, and 23% are owned cattle in 2010, in addition in 2011 increased to 31% of household owned cattle mostly involved by rural/poor household.

Regarding keeping livestock, most (92.87%) of respondents living in Cotamuto kept their livestock in paddocks at night time and open grazing. However, more than half the place in them is in fallow burned areas. In Lakawa, all left their livestock in open grazing; a little less than half (41.67%) kept them in paddocks at night time. In Afabubo, all respondents placed their livestock in paddocks and grazing areas.

Data suggests that most farmers primarily utilize paddocks and grazing areas to keep their livestock. It was observed that free grazing without putting back in paddocks at night was practiced at the study site. Keeping in paddocks is usually practiced during wet or crop-growing seasons to avoid crop disturbance; these situations are practiced commonly by farmers. Waldron et al. (2015) described that way keeping cattle is commonly grazed for all or most of the year in open grassland and kept on the paddock at night, seasonally, or in some cases, not at all.

The relationship between socioeconomic factors and grazing area degradation

Multiple regression was used to determine the relationship between socioeconomic factors and soil degradation in watershed areas using socioeconomic data as independent variables and each soil properties data as dependent variables. This was done for three villages (Cotamuto, Lakawa, and Afabubo). First, the regression value in R^2 was used to interpret the relationship of both independent and dependent variables, followed by looking at coefficient values to determine either negative or positive effects in every single variable (Table 3).

The socioeconomic variables and soil degradation concerning free grazing in Cotamuto have a moderate relationship with physical properties and a strong relationship with biological and chemical properties with BD R^2 = 0.426, SP R^2 = 0.418, SOM R^2 = 0.496, N R^2 = 0.789, P R^2 = 0.375, and K R^2 = 0.716, respectively. In Lakwa, the relationship is low to moderate; the BD R^2 = 0.359, SP R^2 = 0.360, SOM 0.480, N R^2 = 0.385, P R^2 = 0.086, and K R^2 = 0.488. while in Afabubo, the relationship is moderate to a strong relationship. The BD R2 = 0.534, SP R^2 = 0.688, SOM R^2 = 0.903 N R^2 = 0.791 P R^2 = 0.559, and K R^2 = 0.529 (Table 3).

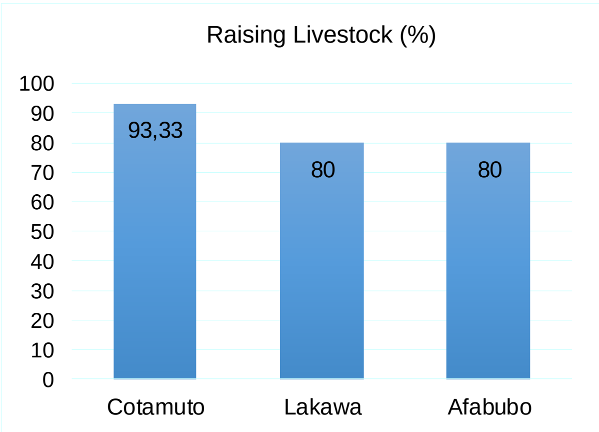

Figure 5. Percentage of raising livestock

Table 2. Livestock distribution and way of keeping

Area/village	Livestock distribution (%)			Way of keeping (%)		
	Cattle	Sheep	Goat	In paddock	Uncontrolled grazing	In fallowed/ burned area
Cotamuto	57.14	21.43	57.14	92.87	92.87	57.14
Lakawa	69.23	7.69	69.23	41.67	100.00	25.00
Afabubo	30.77	92.31	15.38	100.00	100.00	33.33

Table 3. The correlations between education and livelihood to physical soil quality

Site	Socioeconomic	BD	SP	SOM	N	P	K
Cotamuto	Education	0.068 ns	-2.711 ns	-1.238 ns	0.003 ns	-63.59 ns	0.002 ns
	Main Livelihood	0.425 ns	-16.218 ns	-1.174 ns	0.007 ns	-12.098 ns	-0.017 ns
	Livestock Raising	0.030 ns	-0.986 ns	3.211 ns	-0.048 ns	75.393 ns	0.009 ns
	Statistical	R^2 = 0.426	R^2 = 0.418	R^2 = 0.496	R^2 = 0.789	R^2 = 0.375	R^2 = 0.716
	Summary	F = 0.557	F = 0.539	F = 0.737	F = 2.957	F = 0.450	F = 1.894
Lakawa	Education	-0.022 ns	0.087	7.499 ns	-0.005 ns	-9.000 ns	0.107 ns
	Main Livelihood	0.315 ns	-11.45 ns	-1.540 ns	-0.005 ns	10.442 ns	-0.160 ns
	Livestock Raising	0.053 ns	-2.048 ns	-3.222 ns	-0.019 ns	-1.584 ns	0.061 ns
	Statistical	R2 = 0.359	R2 = 0.360	R2 = 0.480	R2 = 0.385	R2 = 0.086	R2 = 0.488
	Summary	F = 0.561	F = 0.562	F = 0.923	F = 0.627	F = 0.094	F = 0.952
Afabubo	Education	-0.001 ns	-1.946 ns	3.529 ***	-0.006 ns	108.940 ns	-0.049 ns
	Main Livelihood	0.226 ns	-11.022 ns	-0.943 ns	0.121 ns	-37.548 ns	-0.040 ns
	Livestock Raising	0.264 ns	-9.237 ns	-0.132 ns	-0.021 ns	9.120 ns	-0.022 ns
	Statistical	R^2 = 0.534	R^2 = 0.688	R^2 = 0.903	R^2 = 0.791	R^2 = 0.559	R^2 = 0.529
	Summary	F = 0.859	F = 1.656	F = 6.958	F = 2.844	F = 0.951	F = 0.843

Note: ns: Non-significant, * = 0.05, ** = 0.01, *** = 0.001, BD: Bulk Density, SP: Porosity, SOM: Soil Organic Matter, N: Nitrogen, P: Phosphorous, K: Potassium

Overall, the socioeconomic variables have no significant relationship with soil bulk density, porosity, and soil nutrients (Table 3), but grazing area degradation have widely reported in several studies has influenced by socioeconomic factors (Yong-Zhong et al. 2005; Chang et al. 2014). However, there is a moderate relationship instead. As a social relationship, soil degradation is widely recognized that no single factor is determining the quality and productivity of soil; anyhow, dynamic changes thru time and are affected by both socioeconomic and edaphology (agrology) factors. Agriculture practices ignoring agroecosystem stability have already posed more damage to nature than any other human activity (Balmford et al. 2012).

Unlike in Cotamuto and Lakawa, education level strongly relates to soil organic matter in Afabubo. This indicates farmers are not sensitive to the degradation because they lack awareness and do not value the grassland for their own life. Although knowledge of the importance of conservation is crucial, access to information, capacity building, and public awareness program would be equally important to improve farmers' awareness of managing grassland in sustainable ways (Wang and Batkhishig 2014).

Soil properties in uncontrolled grazing have a low to moderate relationship to the farmers' education level and livelihood; it may have been influenced by cultural or lack of information and policies (MAF 2018). Soil health problems can be caused by edaphic and climatic factors: soil type, structure, and soil formation process, including rainfalls, temperature, and land cover, contribute to soil property changes. The result mentioned a different view than other studies (Savadogo et al. 2007; Maitima et al. 2009; Piñeiro et al. 2010). Land ownership may influence soil degradation and uncontrolled grazing practices that this study does not assess. According to the National action program report for climate change, land tenure, and ownership trigger land degradation and low interest in conserving and protecting forests and grassland (NAP 2008).

Conclusions from the findings of the study, the following conclusions are drawn: (i) Uncontrolled grazing practices have directly affected soil productivity for livestock grazing and other purposes. Regarding soil biophysical properties, the soil became low in moisture content, very compacted, and less porous. The practice also removed the vegetation on the ground, which made the soil prone to a high evaporation rate, and increased soil moisture losses; it allowed for massive and continuous soil erosion. It also eliminated soil microorganisms that have important roles in decomposing organic matter. With continuous uncontrolled grazing practices, the balance in the ecosystem is affected. The soil health status in the study area is prone to high run-off, erosion, and loss of productivity. (ii) Across the study site, there are low levels of education and few alternative livelihoods; however, there is a moderate relationship between socioeconomic factors and soil degradation. Therefore, more studies on socioeconomic influences on uncontrolled grazing must be recommended to provide proper options for decision-makers and land users to promote conservative practices while utilizing land and other natural resources.

ACKNOWLEDGEMENTS

I would like to acknowledge the support of the Universidade Nacional Timor Lorosae, Dean of the Faculty of Agriculture and Head of the Department of Agronomy, East Timor, for this study.

REFERENCES

Balmford A, Green R, Phalan B. 2012. What conservationists need to know about farming. Proc R Soc B 279 (1739): 2714-2724. DOI: 10.1098/rspb.2012.0515.

Blanco-Canqui H, Lal R. 2008. Principle of soil conservation and management. Springer. USA. DOI: 10.1007/978-1-4020-8709-7.

Bouma GA, Kobryn HT. 2004. Vegetation cover change in East Timor, 1989-1999. Nat Resour Forum 28 (1): 1-12. DOI: 10.1111/j.0165-0203.2004.00067.x.

Census. 2022. Population and Housing Census, Preliminary Results. Government of Timor-Leste, Timor-Leste.

Chang XF, Zhu XX, Wang SP, Cui SJ, Luo CY, Zhang ZH, Wilkes A. 2014. Impacts of management practices on soil organic carbon in degraded alpine meadows on the Tibetan Plateau. Biogeosciences 11 (13): 3495-3503. DOI: 10.5194/bg-11-3495-2014.

Ellis B, Foth H. 1997. Soil Fertility (2nd ed.). CRC Press, Boca Raton. DOI: 10.1201/9780203739341.

Fu Y, de Jonge LW, Moldrup P, Paradelo M, Arthur E. 2022. Improvements in soil physical properties after long-term manure addition depend on soil and crop type. Geoderma 425. DOI: 10.1016/j.geoderma.2022.116062.

Gray J, Chapman G, Murphy B. 2011. Assessing Land Management Within Capability in NSW, Monitoring, Evaluation and Reporting Program. Technical Report Series. Office of Environment and Heritage, Sydney.

IWMPR. 2012. Integrated Watershed Management Plan for Raumoco Watershed, Timor-Leste the European Union's Food Security Programme for Timor-Teste. A Project Implemented by Hivos Timor-Leste. Dili, Timor-Leste.

Jha R, Dang T. 2008. Vulnerability and Poverty in Timor-Lesté. Departmental Working Papers 2008-11. The Australian National University, Arndt-Corden Department of Economics.

JICA. 2014. Soil analysis manual. Ministry of Agriculture, Forestry and Food Security (MAFFS), Sierra Leone Agricultural Research Institute (SLARI), Rokupr Agricultural Research Centre (RARC). RECS International Inc., NTC International Co., Ltd.

Johnson LC, Matchett JR. 2001. Fire and grazing regulate belowground processes in tallgrass prairie. Ecology 82 (12): 3377-3389. DOI: 10.1890/0012-9658(2001)082[3377:FAGRBP]2.0.CO;2.

Lal R, Iivari T, Kimble JM. 2003. Soil Degradation in the United States: Extent, Severity, and Trends. CRC Press, Boca Raton. DOI: 10.1201/9780203496381.

Liu Y, Cui Z, Huang Z, López-Vicente M, Wu G. 2019. Influence of soil moisture and plant roots on the soil infiltration capacity at different stages in arid grasslands of China. Catena 182: 104147. DOI: 10.1016/j.catena.2019.104147.

MAF. 2007. Ministry of Agriculture, Forestry and Fisheries. First National Report Land Degradation in Timor-Leste. Submitted to the Secretariat of UNCCD.

MAF. 2018. The Country Report of Land Degradation Neutrality Target Setting Program. Ministry of Agriculture and Fisheries, Timor-Leste.

Mahilum BC. 2004. Basic Soil Science and Concept in Tropical Soil. Trop Ag Hawaai, Inc., Hawaii County.

Maitima JM, Mugatha SM, Reid RS, Gachimbi LN, Majule A, Lyaruu H, Pomery D, Mathai S, Mugisha S. 2009. The linkages between land use change, land degradation and biodiversity across East Africa. Afr J Environ Sci Technol 3: 310-325. DOI: 10.5897/AJEST08.173.

Matano A, Kanangire CK, Anyona DN, Abuom PO, Gelder FB, Dida GO, Owuor PO, Ofulla AVO. 2015. Effects of land use change on land degradation reflected by soil properties along Mara River, Kenya and Tanzania. Open J Soil Sci 5 (1): 20-38. DOI: 10.4236/ojss.2015.51003.

McCauley A, Jones C, Jacobsen J. 2005. Basic soil properties. Soil Water Manag Module 1 (1): 1-12.

McKenzie N, Coughlan K, Cresswell H. 2002. Soil Physical Measurement and Interpretation for Land Evaluation 5. CSIRO Publishing, Clayton South. DOI: 10.1071/9780643069879.

McWilliam A. 2003. New beginnings in East Timorese forest management. J Southeast Asian Stud 34 (2): 307-327. DOI: 10.1017/S0022463403000274.

Nakhli SAA, Panta S, Brown JD, Tian J, Imhoff PT. 2019. Quantifying biochar content in a field soil with varying organic matter content using a two-temperature loss on ignition method. Sci Total Environ 658: 1106-1116. DOI: 10.1016/j.scitotenv.2018.12.174.

NAP. 2008. Timor-Leste National Action Programme to Combat Land Degradation. Dili, Timor-Leste.

NBSAP. 2011. The National Biodiversity Strategy and Action Plan of Timor-Leste (2011-2020). Government of Timor-Leste, East Timor.

NDC. 2022. Nationally Determined Contribution 2022-2030. Government of Timor-Leste, East Timor.

Piñeiro G, Paruelo JM, Oesterheld M, Jobbagy EG. 2010. Pathways of grazing effects on soil organic carbon and nitrogen. Rangel ecol manag 3 (1): 109-119. DOI: 10.2111/08-255.1.

Savadogo P, Sawadogo L, Tiveau D. 2007. Effects of grazing intensity and prescribed fire on soil physical and hydrological properties and pasture yield in the savanna woodlands of Burkina Faso. Agric Ecosyst Environ 118 (1-4): 80-92. DOI: 10.1016/j.agee.2006.05.002.

Schoeneberger PJ, Wysocki DA, Benham EC, Eds. 2012. Field Book for Describing and Sampling Soils. Government Printing Office, Washington, D.C.

Sopialena, Rosfiansyah, Sila S. 2017. The benefit of top soil and fertilizer mixture to improve the ex-coal mining land. Nusantara Biosci 9: 36-43. DOI: 10.13057/nusbiosci/n090107.

Sousa IC. 2018. History of East Timor between Myths, Memory Realms, Macau and the Challenges of Cultural Antrophology. East-West Institute for Advanced Studies, China.

Tahat MM, Alananbeh KM, Othman YA, Leskovar DI. 2020. Soil health and sustainable agriculture. Sustainability 12 (12): 4859. DOI: 10.3390/su12124859.

UNEP. 1992. World Atlas of Desertification. Edward Arnold Press, London.

Waldron A, Justicia R, Smith LE. 2015. Making biodiversity-friendly cocoa pay: Combining yield, certification, and REDD for shade management. Ecol Appl 25: 361-372. DOI: 10.1890/13-0313.1.

Wang Q, Batkhishig O. 2014. Impact of overgrazing on semiarid ecosystem soil properties: A case study of the eastern hovsgol lake area, Mongolia. J Ecosyst Ecograph 4: 140. DOI: 10.4172/2157-7625.1000140.

Wiesmeier M, Urbanski L, Hobley E, Lang B, Lützow Mv, Marin-Spiotta E, Wesemael Bv, Rabot E, Lie M, Garcia-Franco N, Wollschläger U, Vogel H, Kögel-Knabner I. 2019. Soil organic carbon storage as a key function of soils-A review of drivers and indicators at various scales. Geoderma 333: 149-162. DOI: 10.1016/j.geoderma.2018.07.026.

Yong-Zhong S, Yu-Lin L, Jian-Yuan C, Wen-Zhi Z. 2005. Influences of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China. Catena 59 (3): 267-278. DOI: 10.1016/j.catena.2004.09.001.