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Impacts of Rangeland Degradation on Soil Physical, Chemical and Seed Bank Properties along a Gradient in Three Rangeland Vegetation Types in Somali Region, Eastern Ethiopia

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Abstract

The Somali region of Ethiopia is a typical pastoral area, that occupy >50% of the 0.7 million km² rangeland in the country. However, all forms of rangeland degradations have become major threats to enhance a sustainable pastoral-livestock production in Ethiopia. But except for very few studies on rangeland condition assessments, no or too little research has been conducted to understand the different impacts of soil degradation on the range bio-physical ecology. As a result, there exists a gap in knowledge to plan present and future rangeland improvement interventions in the country. The purpose of this study is therefore, to understand the impacts of different rangeland degradation conditions on the soil physical, chemical and seed bank properties along a gradient. Three rangeland vegetation types were selected in Erere wereda, Shinille zone in north eastern Somali region of Ethiopia, classified as arid (60%) and arid and semi-arid (40%). The experimental sites included: the Asbuli grassland (9–11.8⁰N and 40–41.8⁰E), the Aydora open savanna (8–10.8⁰N and 40–418⁰E) and the Hurso closed savanna (4–6.8⁰N and 40–42.8⁰E), with an altitude ranging between 300 and 1200 m.a.s.l,. Each site was laid out in to four sites of degradation condition classes, namely: excellent (benchmark), good, moderate, and poor along the gradients. Accordingly, some important soil physical, chemical and soil seed bank parameters were analyzed using scientific procedures. Based on the results, soil texture showed a shift from clay type to silt clay, while soil erosion and compactions intensities were increased as rangeland conditions declined from excellent in to poor classes along the gradient. Further, increases in conditions of degradation simultaneously increased bulk density while vegetation covers showed a significant ($p < 0.05$) *reduction. This was explained in terms of increased bare ground with inverse proportion of basal cover. On the other hand, soil moisture, organic matter and organic carbon made a significant* ($p < 0.05$) *reduction as degradation condition increased from excellent into poor classes. Patterns in soil Nitrogen, available Phosphorus and Potassium also reduced significantly* ($p < 0.05$) *as rangeland degradation increased, may be due to higher leaching induced by higher runoff. Nevertheless, Cation exchange capacity, electrical conductivity, pH and percent base saturation (i.e. Ca, mg and Na) highly decreased as degradation was increased. To this end, deteriorations in rangeland condition has an overall negative impact on the soil physical and chemical characteristics, demanding for more efforts to improve the health of range vegetations. Likewise, number and density of regenerated plants declined in the soil seed banks from excellent to poor condition classes. Nevertheless, the soil seed banks still give an opportunity for rangeland improvement using appropriate rehabilitation, conservation and utilization techniques.*

Key words: Rangeland ecology, condition classes, soil texture, exchangeable ions, pH, soil nutrients.

Introduction

The Somali region, occupy >50% of the 0.7 million km^2 rangeland area in Ethiopia (SoRPARI, 2004) with a proportion of bush lands (35%), bush grasslands (30%), grasslands (25%) and bare lands (5%) (Amaha *et al*., 2008). The major soils include: i) Vertisols and Cambisols of limited agricultural potentials, ii) Fluvosols, relatively young soils developed from alluvial deposits, and iii) Chromic and Pellic Vertisols that are heavy clay soils in flat areas (EMA, 1988). Soils are stores of soil nutrients and moisture for plant growth (Kidane and Pieterse, 2008) whose type, amount and release is determined by the soil physical and chemical properties (Schlesinger *et al.,* 1990), that influence the nature of plant communities, interactions between plants (Greig-Smith, 1983) and soils, vegetative growth, and speed of succession (Snyman, 1998). Despite, soil heterogeneity can be altered by fertilization (Brandy, 1990), application patterns (Kidane and Pieterse, 2008) and distribution of animal excreta (Schlesinger et al., 1990) which influence range-forage production and productivity (McNaughton et al., 1985).

Clay soils have negatively charged large surface areas (Brandy, 1990) with higher soil-water and plant nutrient holding capacity (Thompson and Troeh, 1978). Exchangeable cations associated with cation exchange capacity (CEC) also activate the soil physico-chemical processes (Greig-Smith, 1983) by neutralizing excess negative charges (Brady, 1984) and enhance soil fertility (Mathew *et al*., 1994). Sandy soils have smaller surface areas (Turner, 1998), high air and water permeability (Vetter *et al*., 2006) lower soil-water and nutrient holding capacity (Brandy, 1990) and hence poor forage production (Greig-Smith, 1983) Soil organic matter (OM) binds soil particles and cations (Brady, 1984), prevent soil nutrients from leaching and supply N, S and P (Page and Beeton, 2000), increase moisture holding capacity (Brandy, 1990) and support optimum fodder production (Kidane and Pieterse, 2008). Soil pH determines solubility and storage of soil minerals (Thompson and Troeh, 1978), up take by plants, vegetation types and fodder production in rangelands (Greig-Smith, 1983; Vetter *et al*., 2006).

Rangeland degradation is explained in terms of a decline in the health of range bio-physical resources (Abdoulaye *et al*., 2006) caused by livestock over grazing or over stocking (Solomon et al., 2007) soil erosion, compaction and run-off (Panda, 2007), over use of woody trees and drought (Amaha *et al*., 2008) negatively affecting the vegetation ecosystems (Folliot *et al*., 1995), soil physical and chemical status (Brandy, 1990) and soil quality (Mathew *et al*., 1994). In Ethiopia, five levels of rangeland degradation conditions are noted ranging from excellent to poor or very poor (Gemedo *et al*., 2006) negatively affecting forage and livestock production (Page and Beeton, 2000), traditional management systems (Vetter *et al*., 2006), pastoral livelihood (Amaha *et al*., 2008) and becoming a major threat in all pastoral areas of Ethiopia (Solomon *et al*., 2007).

Nevertheless, and except for some soil textural surveys (Kidane and Pieterse, 2008), however, there are too little studies conducted on how the overall rangeland degradation in the country (Solomon *et al*., 2007) has impacted the soil physical and chemical properties (Gemedo *et al*., 2006) as well as the rangeland biological resources mainly the soil seed bank potentials (Amaha *et al*., 2008). To this end, the purpose of this study was to understand the impact of different rangeland degradation conditions on the soil physical, chemical and seed bank properties along a gradient in three rangeland vegetation types in eastern Ethiopia.

Materials and methods

Description of the study area

The investigation was carried out in Erer district of the Shinile zone, a part of the Great Rift Valley, in north-eastern Somali region of Ethiopia (Fig.1). The zone covers about 91,000 km^2, inhabited by nearly half a million pastoralists and over 2 million livestock (CSAE, 2000). Altitudes range from 300 to 1200 m.a.s.l having arid (60%) and arid and semi-arid (40%) agro-ecologies (SERP, 1990). Annual minimum to maximum temperatures and rainfalls are between 28 and 35 8 ^{0}C and 200 and 300 mm, respectively. Rainfall is bimodal with short rains from March to April and main rains from June to August. Main soil types include: vertisols (heavy dark clays), alluvial deposits and sandy loams (IPS, 2000). Mobile pastoralism is the dominant land-use system characterized by goat, cattle, camel and sheep production in their order of importance (SZAB, 2003) (Fig. 1).

The range vegetation types

Grassland: The herbaceous layers include the family Poaceaea, *Cyperaceae* and *Arecaceae* dominated. Perennial grasses include: *Panicum, Dactyloctenium, Eleucine, Cenchrus, Leptochloa, Sporobolus, Brachiaria, Cynodon, Cyperus,(Sedge), Phalaris* and *Polypogon*. The annual grasses include *Eragrostis, Echinochloa, Sorghum, Eriochloa, Frymbristylis, Hirta, Snowdonia, Setaria* and *Thebaica*. The forbs include: *Zygophylaceae, Caesalpiniaceae, Labiataceae, Euphorbaceae, Amaranthaceae* and *Malvaceae*. The weeds include: *Xanthium, Amaranthus and Parthenium*.

Open savanna/bush grassland: The vegetation is composed of grass, forbs, weeds and woody trees). The perennial grasses include *Chrysopogon, Dactyloctenium, Sporobolus, Panicum, Phalaris, Tetrapogon, Polypogon* and *Echinochloa.* The annual grasses include *Eragrostis*, *Tragus* and *Setaria*. The forbs include *Euphorbiaceae* and *Zygophylaceae*. The weeds consist of *Malvaceae, Rosaceae, Hebenareae, Parthenium, Amaranthaceae* and *Xanthaceae*. The families of the woody plants include *Mimosaceae, Capparaceae, Tiliaceae* and *Caesalpinaceae*

Closed savanna/bush land: The vegetation is composed of woody plant species mainly: *Acanthaceae, Agavaceae, Balanitaceae, Boraginaceae, Burseraceae, Caesalpinaceae, Capparaceae, Cupreussaceae, Euphorbiaceae, Labiataceae, Liliaceae, Mimosaceae, Papilionaceae, Rhamnaceae, Rosaceae, Salvadoraceae, Solananceae, Sterculiaceae, Tamarisaceae, Tiliaceae, Viscaceae and Vitaceae.* Accordingly, the family *Mimosaceae* was dominant in its frequency of occurrence, while *Papilionaceae, Burseraceae, Liliaceae* and *Tiliaceae* were observed to be common in occurrence.

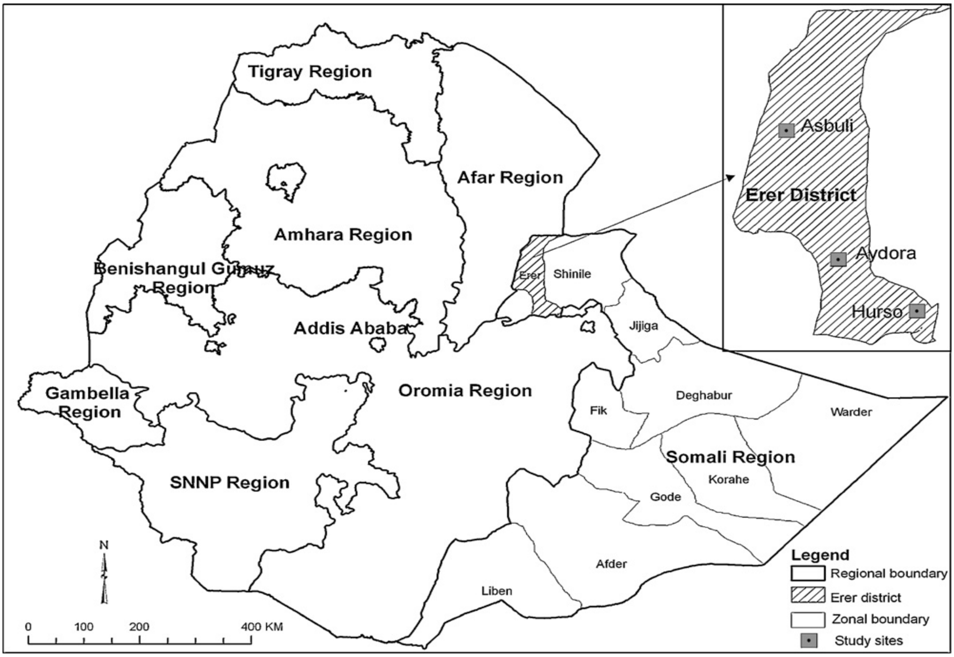

Fig.1. Location of experimental sites in Erere district, in Shinille zone of Somali region, eastern Ethiopia.

Experimental procedures

Site selection and field layout

The experimental sites were assessed, identified and selected through team participation approach (Walters-Bayer and Bayer, 2000) consisting local elders, rangeland managers and botanists in the Somali region. The sites included: the Asbuli grassland (9–11.8^{0}N and 40–41.8^{0}E), the Aydora open savanna (8–10.8^{0}N and 40–418^{0}E) and the Hurso closed savanna (between 4–6.8^{0}N and 40–42.8^{0}E). Each vegetation type was farther laid out in to o four relevant degradation condition classes based on vegetation cover (Van der Westhuizen *et al*., 2005), feed mass production levels (Vorster, 1982) indigenous knowledge of local pastoralists (Tainton, 1999) and similarities in soils and topography (Gabriel and Talbot, 1984). The condition classes include: i) excellent condition (EC) or enclosure as bench mark, ii) good condition (GC) or lightly grazed/browsed, iii) moderate condition (MC) or intermediately grazed/browsed and iv) poor condition (PC) or over grazed/browsed.

Soil sample collection for soil and seed bank analysis

Each condition classes in a specific range-vegetation type was taken as treatments, and replicated in to five plots, with a 1km x 0.5 km (0.5 km^2) belt transect each, and two soil sampling units per plot (300 cm width x 300 cm length x 60 cm depth each) were randomly assigned at every 50m interval (Kidanee Peiterse, 2008). Then the 2-10cm top plant debris removed with a sharp knife when necessary, whereby from each sampling unit, five soil samples (0-60 cm depth) for soil analysis, and other five samples (0-10 cm deep) for seed bank test were collected using an augur and categorically bulked (Amaha *et al*., 2008). Accordingly, from each condition class, five composite samples for soil analysis (500g each) and other twenty samples (1000g each) for seed bank test were prepared The soil physic-chemical analysis and seed bank test were conducted in a soil laboratory and in a green house at the Haremaya University, respectively.

Analysis of physical soil properties

Bulk density was determined from undisturbed (core) samples, dried at 105^{o}C for 24 hours (Baruah and Barthaku, 1997). Disturbed soil samples were air dried ground and sieved through a 2 mm sieve for analyzing selected attributes. Hydrometer method (Gee and Bauder, 1979) was applied to determine soil textures (clay, silt and sand). A penetrometer method (Vorester 1982) was used with values 0-5 kg/cm^2, to measure soil compaction. Thirty points at every 1 m interval were taken from each of a permanent cattle route (control) and from two parallel lines placed 2 m apart. Pedestal method was used to determine soil erosion (Baars *et al*., 1997) using 5, 4, 3, 2, 1, and 0 values representing soil erosion status of: with no soil movement, slight sand mulch, slope sided, steep sided and pavements with gullies, respectively. Field observations and open discussions with pastoral elders were also conducted on related bio-physical changes.

Analysis of soil chemical properties

Soil moisture was assessed using gravimetric method (Baruah and Barthakur, 1997), while percent organic carbon (OC) was determined by wet oxidation method (Walkley and Black, 1934) and organic matter calculated as %OC x 1.724. Total N was analyzed using Kjeldahl method (Jackson, 1970), whereas a pH meter in a 1:1 (v/v) soil to water suspension (Mclean, 1973) was used to measure soil pH. Available Phosphorus (P) and available potassium (K) were analyzed according to Olsen *et.al.*, (1954) and Schollenberger & Simon (1945), respectively. Cation exchange capacity (CEC) was determined by ammonium acetate method at pH 7 according to Schollenberger and Simon, (1945).

Analysis of soil seed bank properties

The greenhouse day and night temperatures were adjusted at 35.8 ^{0}C and 28 ^{0}C, respectively, in simulation to the field realities. The soil samples were randomly spread in 60 seedling plastic containers (30 cm diameter x10 cm deep each) and observed for one year. To enhance seed germination, 50 g of dried, ground and sieved fine dung granules were sprayed on soils in every container (Thompson and Grime, 1979). Other ten containers, filled only with fine dung granules, were used as control, to make sure that no seeds were present in the dung. The bottoms of all containers were drilled with 2-mm holes at five places each, to allow soil aeration and drainage, and were hand-watered with 20 mm water every evening. Seedlings emerging from soil samples in each condition class were identified, uprooted, counted and related parameters such as life forms (annuals and perennials), plant forms (woody plant, grass, forbs, weeds), abundance and plant density determined. Forbs were defined as unproblematic or desirable non-grass, while a weed was defined as a problematic or undesirable non-grass plant.

Data analysis

Descriptive statistics and one-way ANOVA (SPSS, 1996) were used to investigate the relationship between grazing response variables against the different condition classes and vegetation types (Steel and Torrie, 1980). Number Cruncher Statistical System (6.0) package (Hintze, 1998) was used to verify the significance in differences among rang vegetation types and between condition classes. Similarities in types between range vegetation types, was calculated using Sorensen's index (Greig- Smith, 1983).

Results and Discussions

Impacts of rangeland degradation on soil physical properties

Soil texture

The soil types were different in each rangeland vegetation type, whereby dark pellic vertisol was the typical soil type in the Asbuli open grassland, chromic vertisol and nitosol in the Aydora open savanna and regosol in the Hurso closed savanna. In terms of soil texture, with clay content of >50% was higher with lower silt and sand in the EC and GC classes, but the level in clay sharply declined, while with increased in silt and sand contents the MC and PC classes, shifting the texture from clay in to sandy clay loam with increased in degradation. In the Aydora open savanna, clay content (>50%) was significantly higher with moderate silt and lower sand level in the EC and GC classes, while sharply reduced in the MC and PC classes. However sand content highly increased along the gradient from EC to PC classes, altering the texture from clay to sandy clay along the gradient. Similarly in the Hurso closed savanna, clay, silt and sand contents in the EC were lower, but moderate in the GC to PC classes, whereas the clay content increased significantly along the gradient from EC to PC classes, with no difference in silt and sand contents, changing the texture from sandy loam sand to clay loam (Fig. 2).

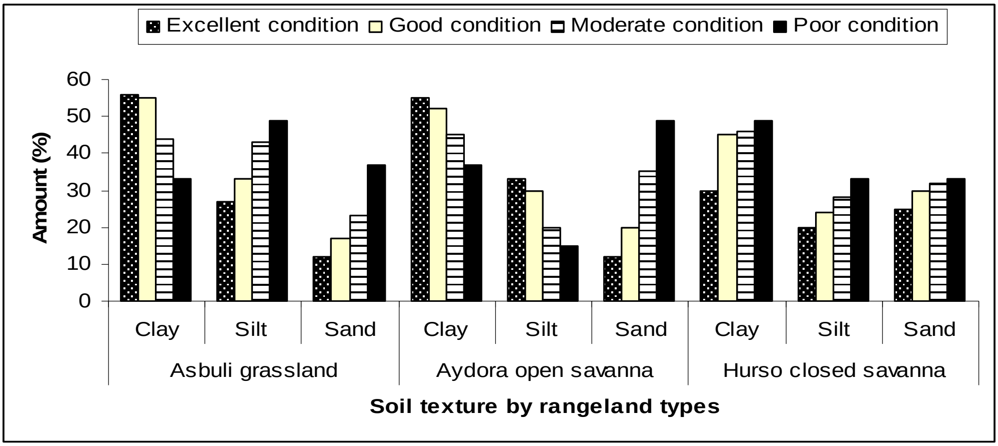

Fig. 2. Patterns in soil textures in three range types and four degradation condition classes

In conclusion, the result implicated that decline in rangeland condition from excellent to poor condition classes, negatively affected the top soils, soil particle sizes and porosity that are associated with water and air permeability and rangeland productivity. Moreover, the inherent soil parent material differences and bio-physical range conditions might affect the soil l textures, which may have negative impacts on water and soil nutrient holding capacities, and the ability to produce forage, as explained by Brady, (1990). Similar results were also reported by Kidane and Pieterse, (2008) regarding north-eastern rangelands in the Afar region of Ethiopia. Based on field observations, the shifts in soil textures farther enhanced gully formations and undesirable successions in vegetation types. For example, silt > 10% in the Great Rift valley of Ethiopia was adequate to form crusts, gullies and run-offs as discussed by Eylachew, (1999). Finally the pastoralists perceived that changes in soil textures have also altered composition of the animal species and the type of livestock production in place.

Soil compaction

Compared to the Point of reference of cattle routes, soil compaction levels Was significantly different among the four degradation condition classes. In context to average compaction levels in all the vegetation types, the highest soil compaction (4.5 to 5.0 kg cm^{-2}) occurred in the cattle routes, while the lowest compaction (< 2.5 kg cm^{-2}) was observed in the EC classes. Next to the cattle routes, the second higher compaction of ≥ 4 kg cm^{-2} was observed in the PC classes compared to the GC and MC classes having soil compaction levels of 3.0 and 3.5 kg cm^{-2}, respectively. In terms of each vegetation types, there was a linear but significantly different ($p < 0.05$) increase in soil compaction levels following increases in degradation from EC to PC conditions in the Asbuli open grassland and Hurso closed savanna. Despite increased levels of soil compaction from the EC to PC classes in the Aydora open savanna, however, no significant difference existed between MC and PC classes (Fig. 3). In conclusion, declines in rangeland conditions, increases soil compaction patterns, but induce positive correlation between degradation in rangeland conditions and soil compaction levels due to overgrazing and trampling.

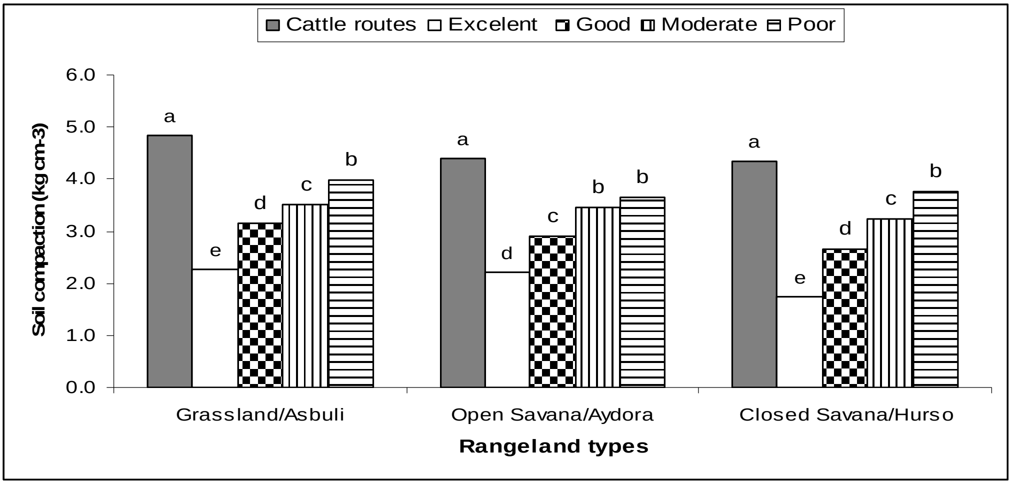

Fig. 3. Soil compaction patterns, along a degradation gradients in three rangeland vegetation types. (Different letters in the bar within the same rangeland types are significantly different at $p<0.05$)

In terms of impacts from soil compaction, Abdel-Megid *et al*, (1987) reported reduced water infiltration and aeration, while Van der westhuizen *et al.*, (1999) found poor plant respiration and soil seed germination unless the soil crust is broken. Soil compaction also enhanced encroachment in eastern rangelands of Ethiopia (Amaha *et al*., 2008), which is a typical indicator of rangeland degradation (Getachew *et al*., 2007). The local pastoralists also reported that, patterns in increasing compaction levels reduced the herbaceous layers and favored encroachment of undesirable woody trees and bushes in the area (Personal communication).

Soil erosion

The analysis showed that increased level in rangeland degradation conditions was highly associated with increased in the soil erosion forms and intensity. Accordingly, the least and most soil movement was observed in the EC and PC classes, respectively of all vegetation types, but relatively lower soil movement in Asbuli open grassland and Aydora open savanna than Hurso closed savanna. On the other hand, soil erosion and sand mulching in the MC classes was similar for Aydora open savanna and Hurso closed savanna with a slight increase for Asbuli open grassland. (Fig. 4).

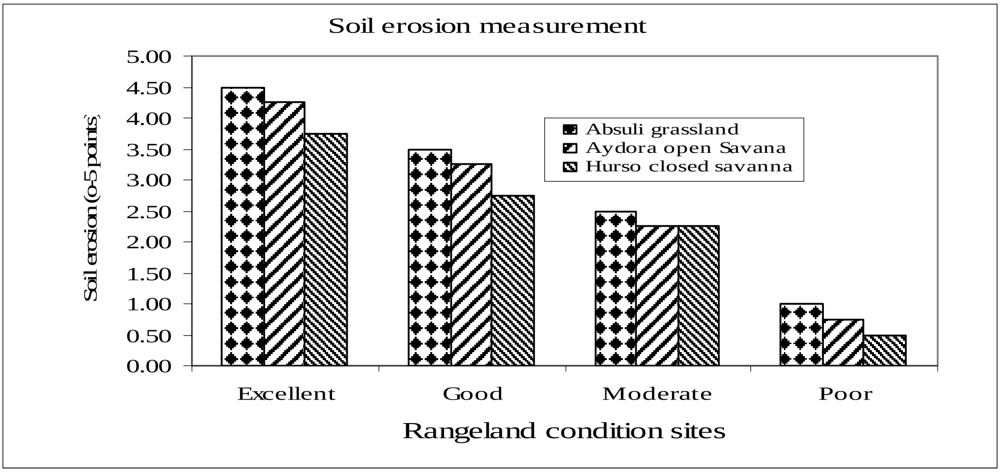

Fig. 4. Soil erosion intensities in relation to rangeland degradation condition classes
NB. The lower the reading is the higher the erosion in the respective condition class.

In conclusion, the herbaceous layers (grasses and forbs) showed better efficiency in arresting water run-offs and control of soil erosion than the woody tree canopies. In terms of cause and effect, the local pastoral communities reported that, increases in human, livestock population and poverty in the area induced over stocking, over grazing and excessive tree cutting and hence brought about greater erosion problems. Besides absence of effective grazing management systems and sufficient conservation efforts to recover from degradation farther enhanced run-off and increased soil erosion intensities.

Soil bulk density and vegetation cover

Values in bulk density at the different range vegetation types and degradation conditions showed a remarkable difference. Bulk density showed an increasing trend with degradation from EC to PC classes in all vegetation types. However, soil bulk density values for EC and GC classes in the Hurso closed savanna were lower compared to values of EC and GC classes in Aydora open savanna and Asbuli open grassland, respectively (Fig. 5). Farther, bulk density in the Aydora open savanna exceeded both values in the Asbuli grassland and Hurso closed savanna for all condition classes. This agrees with values of 1.0 to 1.6 gm cm^{-3}, bulk density ranges for clay, clay loam and silt loam surface soils reported by Brady (1984). The difference appears to be because of high content in organic carbon attributed o high humus accumulations from defoliations by *Accacia* spp dominated woody plants in Hurso than defoliation by the herbaceous layers at Asbuli and Aydora rangelands. Similarly, bulk density values of 2 gm cm^{-3} around watering points in middle Afar rangelands (Kidane and Pieterse, 2008) and 1.9 gm cm^{-3} in poorly managed south-eastern rangelands (Getachew *et al*., 2007) were also reported in Ethiopia.

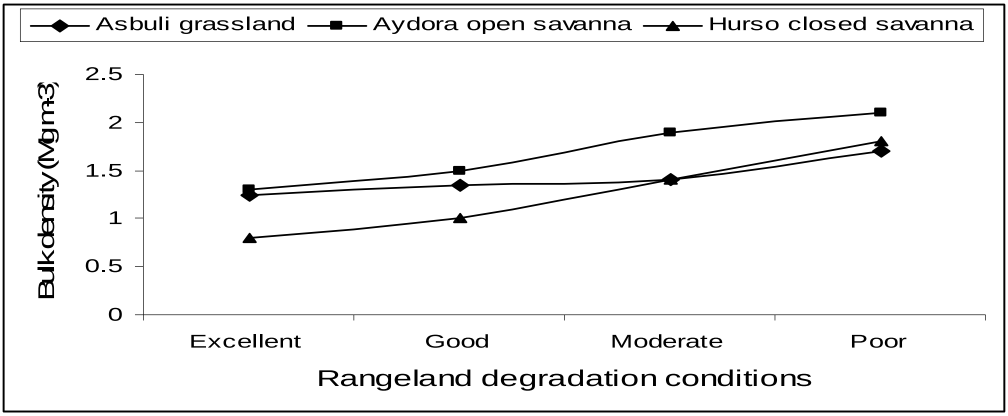

Figure 5. Soil bulk density patterns in relation to rangeland degradation condition classes

On the other hand, higher values in soil bulk densities were highly correlated with severity levels in basal cover reductions and increases in bare ground levels in the three rangeland vegetation types. For example, a higher degree of degradation and increased bulk density was observed in association with increased percent bare ground and under severe reductions in percent basal/canopy cover by all forms of vegetation degradation. Hence the higher bare ground in rangelands may subsequently, enhance negative effect in terms of the movement, distribution and mulch of soil particles, mainly sand (Fig. 2), soil compaction (Fig. 3) and soil erosion (Fig. 4) leading to higher bulk density due to very compacted top soils (Fig. 5).

In conclusion, declines in rangeland condition classes due to various forms of degradation increased soil bulk density or decreases porosity of the soils along the gradient. This may be associated with reduced humus accumulation and hence low organic matter content in one hand, and shift from high clay or silt in to high sandy clay or loamy sand(sandy loam) or sand on the other. Soil erosion and compaction also enhanced the process. The local pastoral communities, over stocking, continuous and more severe grazing intensities and over cutting of woody trees not only increased bare ground but negatively affected the soil bulk density.

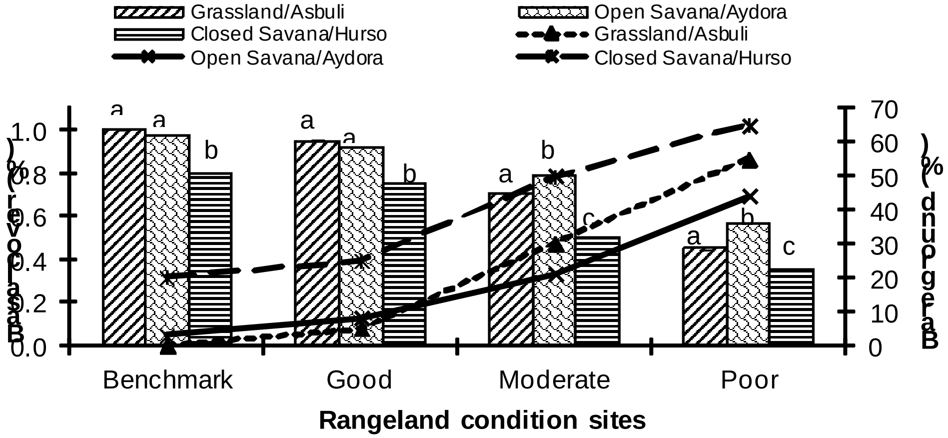

Figure 6. The proportion relationships between basal cover and bare ground in relation to rangeland condition sites ((Different letters in the bar within the same rangeland codition classes are significantly different at p<0.05)

According to the local pastoralists, the over all impact from increased soil bulk density is perceived in terms of high run-off, less water infiltration, moisture stress for plant growth, short to long term feed shortage and increased drought frequency. Observations under field conditions also implied that encroachment of woody undesirable species were favored, while palatable and perennial grasses severely reduced with increased in bulk density due to decline in rangeland condition classes.

Impacts of rangeland degradation on soil chemical properties

Soil organic matter, soil carbon and moisture contents

The analysis on the soil moisture content (H_2O) and organic carbon (OC) showed significant differences ($p < 0.05$) in the three rangeland vegetation types and their condition classes along the degradation gradient (Table 1). Accordingly, OC and H_2O contents in the Asbuli open grassland and Aydora open savanna were significantly higher in the EC, GC and MC classes than the PC class, but there was no significant difference between the EC, GC and MC classes.

In regard to the, OC and H_2O contents, in the Hurso closed savanna, the levels were generally higher and significant ($p<0.05$) in the EC and GC than the MC and PC classes but there was no significant difference ($p < 0.05$) between the EC and GC classes. Comparatively, the levels in OC and H_2O contents in the MC and PC classes were observed to be lower, nonetheless, the levels were not significantly different at $p < 0.05$.

Table 1. Soil nutrient analysis results (Mean±SD) of SOM, OC and H_2O contents in relation to conditions classes of the rangeland vegetation eco-systems (Means within a column with different superscriptsin the same rangeland types are significantly different at p<0.05)

The rangeland vegetation types and their condition classes	H_2O (%)	SOM (%)	OC (%)
Asbuli grassland			
Excellent	12.93 ± 1.1^{a}	2.58 ± 0.10^{a}	1.70 ± 0.04^{a}
Good	12.81 ± 1.1^{a}	2.52 ± 0.21^{a}	1.50 ± 0.06^{a}
Moderate	11.15 ± 1.08^{a}	2.32 ± 0.18^{a}	1.44 ± 0.07^{a}
Poor	5.11 ± 1.1^{c}	1.15 ± 0.10^{b}	0.67 ± 0.01^{b}
Aydora open savanna			
Excellent	11.15 ± 1.13^{a}	2.00 ± 0.42^{a}	1.36 ± 0.03^{a}
Good	10.74 ± 1.06^{ab}	1.90 ± 0.14^{a}	1.30 ± 0.20^{a}
Moderate	9.80 ± 1.12^{ab}	1.70 ± 0.10^{ab}	1.17 ± 0.04^{ab}
Poor	5.43 ± 0.25^{c}	1.55 ± 0.10^{b}	0.96 ± 0.02^{c}
Hurso closed savanna			
Excellent	11.85 ± 0.50^{a}	2.56 ± 0.10^{a}	1.49 ± 0.05^{a}
Good	11.21 ± 1.05^{a}	2.43 ± 0.12^{a}	1.41 ± 0.20^{a}
Moderate	9.74 ± 1.08^{b}	2.26 ± 0.14^{b}	1.24 ± 0.06^{b}
Poor	8.18 ± 1.12^{b}	2.13 ± 0.10^{b}	1.23 ± 0.05^{b}

Soil organic matter (SOM) is important in that, it determines soil organic carbon (OC) and soil moisture, (H_2O), while OC is useful to measure the degree of ecological degradation in rangelands (Brandy, 1990). Based on these general facts, therefore, SOM contents in the EC and GC classes in all the range vegetation types were significantly higher ($p < 0.05$), but declined there of. Hence rangelands with higher vegetation covers maintain higher SOM and hence sustain higher OC and H_2O contents in the soils.

This implies, well managed and protected rangelands have minimum ecological disturbances and less leaching from soil erosions. As a result, do accumulate adequate nutrients that favour a healthy growth of plants and hence enhance good forage production from the rangelands. In contrary, SOM showed a significant reduction ($p<0.05$) and hence lower OC and H_2O levels in the PC class ($p < 0.05$). This strongly suggested that, rangelands with higher degradation levels and related eco system disturbances become deficient in similar nutrient contents resulting in poor plant growth and hence lower forage production from the rangelands.

Soil total nitrogen, available phosphorus and potassium contents

Nitrogen (N), phosphorus (P) and Potassium (K) are being major nutrients that can control primary production, while under conditions of deficiency or excessive P, productivity may be limited (Reddy *et al*., 2000). In relation, the amount of N and available P in the soils of the Asbuli open grassland, Aydora open savanna and Hurso closed savanna were significantly lower ($p < 0.05$) and insufficient to support normal plant growth and optimal Biomass production under the degrading arid rangelands, suggesting the need for NP fertilization. On the other hand, K was not deficient in all the rangelands, but showed to be deficient as rangeland conditions decline from MC to PC classes (Table 2).

Despite this, the abundance in N was relatively higher in Asbuli open grassland and Hurso closed savanna compared to the Aydora open savanna. This may be due to a better leguminous composition of the herbaceous layers at Asbuli and Aaccia dominated woody plants species at Hurso, with potential to fix N respectively, while at Aydora, the bush cover was dominated by *Cadaba glandulosa*, which is a none N fixing ever green woody species (Table 2).

Table 2. Soil nutrient analysis results (Mean±SD) of total N and available P and K contents in relation to rangeland degradation condition classes (Means within a column with different superscriptsin the same rangeland types are significantly different at p<0.05)

The rangeland vegetation types and their condition classes	N (%)	Available P (mg kg^{-1})	Available K (mg kg^{-1})
Asbuli grassland			
Excellent	0.18±0.01 ^{a}	17.72±0.35 ^{a}	23.16±4.4 ^{a}
Good	0.11±0.01 ^{b}	14.26±0.63 ^{b}	21.13±4.0 ^{ab}
Moderate	0.10±0.00 ^{b}	12.03±0.54 ^{b}	20.01±2.95 ^{ab}
Poor	0.06±0.01 ^{C}	6.62±0.32 ^{C}	16.50±3.85 ^{c}
Aydora open savanna			
Excellent	0.08±0.03 ^{a}	9.51±0.43 ^{a}	24.23±4.10 ^{a}
Good	0.08±0.02 ^{a}	5.70±0.26 ^{b}	22.14±3.80 ^{a}
Moderate	0.08±0.03 ^{a}	2.63±0.12 ^{C}	17.90±3.60 ^{b}
Poor	0.06±0.01 ^{b}	2.49±0.12 ^{C}	15.03±3.15 ^{b}
Hurso closed savanna			
Excellent	0.10±0,02 ^{a}	6.621±0.10 ^{a}	24.69±2.60 ^{a}
Good	0.10±0,03 ^{a}	5.25±0.19 ^{a}	14.06±4.50 ^{b}
Moderate	0.08±0.03 ^{b}	3.81±0.18 ^{b}	11.68±2.10 ^{b}
Poor	0.06±0.01 ^{b}	1.75±0.32 ^{C}	8.87±1.60 ^{c}

Moreover, depletion of the nutrients was of a sever type under the moderate and poor degradation conditions. For example, compared to the EC in the Asbuli open grassland, the content in N, P and K in the MC and PC classes was reduced by 44 and 67%, 32 and 63% and 14 and 29%, respectively. The same findings were also reported by Kidane and Pietrse (2008) for the Afar grass lands in northern Ethiopia, as heavy grazing increased up to watering points.

In the Aydora open savanna, the reduction in N, P and K was 0 and 25%, 72 and 74% and 50 and 38% in the MC and PC classes, respectively. The same finding was confirmed at Yabello rangelands in southern Ethiopia, under low management conditions (Getachew *et al*., 2007).

Farther, reductions of 20 and 40% for N, 42and 74% for P and 53 and 64% for K was observed in the MC and PC classes of the Hurso closed savanna, respectively. In relation, Landon, (1991), explained that lower levels in SOM contents as a result of degradation reduce the N and P contents in soils, while all forms of erosion also leach K contents in soils in eastern Ethiopia (Eylachew, 1999). In conclusion, the study revealed that increased levels in rangeland degradation subsequently reduced the SOM contents and there by negatively affected the levels in N and P and K mainly along the degradation gradient from EC to PC classes. This farther suggested that there is a need for NPK fertilization to promote forage production as rangeland conditions decline to a moderate and / or poor condition, but the rate and frequency of application need to be studied carefully.

Cation exchangeable capacity (CEC), soil reaction (pH) and percent base saturation

The analysis revealed that, the cation exchange capacity and electrical conductivity generally showed an increasing trend with increase in the decline of rangeland condition class along the gradient except EC in Asbuli open grassland. Similar patterns were also observed regarding pH. This may be may be due to nutrient leaching and accumulation of the nutrients as degradation of various forms has increased (Table 3).

In relation to the rangeland vegetation types, CEC, EC, pH and percent base saturation in the Asbuli open grassland, Aydora open savanna and Hurso closed savanna showed no significant difference ($p > 0.05$) between the EC and GC, but were significantly lower ($p < 0.05$) than the MC and PC. However, the soil alkalinity increased as degradation condition increased from EC to PC in the three rangelands, which may have been influenced by increased accumulation of the cations mainly Ca and Na, opposed to the levels in Mg which made a significant reduction ($p < 0.05$) with declined in condition classes along the degradation gradient.

Table 3. Cation exchange capacity, pH and base saturation percentage of soils in four condition classes of three rangeland vegetation types in eastern Ethiopia (Means within a column with different superscriptsin the same rangeland types are significantly different at p<0.05)

The rangeland vegetation types and their condition classes	CEC (mEq 100 g^{-1})	EC (ds m^{-1}l)	pH	Base saturation (%)		
				Ca	Mg	Na
Asbuli grass land						
Excellent	13.0^{bc}	0.70^{a}	7.5^{a}	20.20^{a}	6.0^{a}	3.5^{c}
Good	14.0^{bc}	0.60^{a}	7.8^{a}	19.24^{a}	5.6^{ab}	3.5^{c}
Moderate	20.0^{b}	0.50^{ab}	8.0^{a}	17.04^{b}	5.1^{ab}	5.0^{b}
Poor	24.0^{a}	0.37^{c}	8.8^{b}	15.55^{c}	4.5^{c}	10.2^{a}
Aydora open savanna						
Excellent	8.0^{c}	0.30^{c}	7.2^{c}	12.36^{c}	10.0^{a}	2.2^{c}
Good	9.8^{c}	0.35^{c}	8.0^{b}	13.74^{c}	7.0^{b}	2.5^{c}
Moderate	33.0^{b}	1.10^{b}	8.5^{b}	39.51^{b}	3.7^{c}	8.2^{b}
Poor	42.0^{a}	1.55^{a}	9.2^{a}	48.96^{a}	3.5^{c}	10.2^{a}
Hurso closed savanna						
Excellent	11.3^{c}	0.54^{d}	8.0^{a}	15.45^{b}	15.0^{a}	3.0^{c}
Good	11.6^{c}	0.63^{c}	8.5^{b}	17.94^{b}	10.0^{b}	3.0^{c}
Moderate	23.0^{b}	0.89^{b}	8.6^{b}	27.54^{a}	5.1^{c}	12.0^{b}
Poor	46.0^{a}	2.2^{a}	9.0^{c}	30.31^{a}	4.5^{c}	15.0^{a}

Soil colors and associated implications in the rangeland eco-systems

The soil scientists at Alemaya University of Ethiopia broadly classified the soil colors of the different rangeland and related it to their chemical, physical and biological characteristics. Accordingly the soil colors for the Asbuli grassland, Aydora open savanna and Hurso closed savanna are black to dark brown, light black and red to yellow brown, respectively. The Asbuli and Aydora soils have higher water content and nutrients with moderate organic matter due to decomposition of plant and animal residues, having a substantial influence on the vegetation production associated with the soils. The Hurso closed savanna rangeland soil color is also an indication of the presence of adequate iron oxides and hydroxides supplying iron needed for plant growth. The same color in the sub-soil was also taken as soil well supplied with oxygen for the growth of plants and microbes. Almost all the soils for all rangeland vegetation types were found to be of the sodic type, explained as high in Na^{++} cations, but with an acceptable range of salt accumulation

Impacts of rangeland degradation on soil seed bank regeneration characteristics

The plant density was highest ($P < 0.05$) in the Asbuli grassland soil seed bank under EC class, but did not differ ($P > 0.05$) between the GC and MC classes. Although the Aydora open savanna, seedling densities in the EC and GC classes did not show a significant difference from each other ($P > 0.05$), but was significantly different ($P < 0.01$) from that of MC and PC classes. In the Hurso closed savanna soil seed bank, seedling density did not differ ($P > 0.05$) with rangeland degradation, except for the PC class, which was significantly lower ($P < 0.01$) than that of all the other three condition classes (Table 4).

Table 4. Seedling density m^{-2} and number of regenerated species (Mean±S.D.) from soil samples collected along a degradation gradient in three rangeland ecosystems, which germinated in the greenhouse (Means within a row with different superscripts in the same rangeland types are significantly different at $p<0.05$)

Parameters for rangeland ecosystem	Rangeland condition classes			
	Excellent	Good	Moderate	Poor
Asbuli grassland				
Plant density	$648±18^{a}$	$626±16^{b}$	$329±10.5^{bc}$	$176±13^{d}$
Number of species	$22±2.11^{b}$	$26±1.23^{a}$	$21±2.00^{b}$	$16±0.96^{c}$
Aydora open savanna				
Plant density	$640±27^{a}$	$580±22^{a}$	$470±43^{b}$	$320±54^{c}$
Number of species	$24±2.14^{a}$	$23±2.14^{a}$	$23±2.01^{a}$	$23±0.76^{a}$
Hurso closed savanna				
Plant density	$600±26^{a}$	$550±28^{a}$	$500±27^{a}$	$475±45^{c}$
Number of species	$25±2.01^{a}$	$23±1.96^{a}$	$20±0.46^{b}$	$21±0.47^{b}$

In the Asbuli grassland, the number of species in the soil seed bank was the highest in the GC class and lowest in the PC class at $p < 0.05$, while in the Aydora open savanna seed bank, the species richness did not differ significantly ($p > 0.05$), between the different condition classes. Likewise, the number of species for the Hurso closed

savanna only differed significantly ($p < 0.01$) between the poor and excellent rangeland condition classes, where it was highest for the excellent condition class.
On the other hand, there was no correlation between seedling density and species richness in the soil seed bank of the Asbuli grassland and the Aydora open savanna. This may imply that the rangeland ecosystem type had little influence on the relationship between seedling density and species richness. However, there was a positive correlation, between seedling density and species richness in the Hurso closed savanna.

Conclusion and Recommendation

Despite variations in levels of degradation, the degraded rangeland eco-systems in eastern Ethiopia, have the opportunity to regenerate and reproduce through promotion of *insitu* rangeland fodder production. Of course, this will require the use of appropriate restoration and conservation techniques and a stronger awareness creation among the stake holders at all levels.

Reference

Abdel-Magid A. H., M. J. Trlica and R. H. Hart 1987. Soil and vegetation responses to simulated trampling. *Journal of Range Management. 40: 303-306.*

Abdoulaye S. M, L.V. Rensburg, K.Kellner and A.Bationo, 2006. Soil Indicators of Rangeland Degradation in a Semi-arid Communal District in South Africa. International Scientific Conference on Desesrtification and Drylands Research. Tunizia.

Amaha Kassahun, H.A. Snyman and G.N. Smit, 2008. Soil seed bank evaluation along a

degradation gradient in arid rangelands of the Somali region, eastern Ethiopia. Journal *of Ecosystems and Environment. 12: 428–436*.

Baars R M T, E.C.Chileshe, D.M., KaloKoni 1997. Technical note: range condition in cattle densily areas in the western province of Zambia. *Tropical grasslands 31: 569-573*.

Baruah, T. C. and H. P. Barthaku, 1997. A Text book of Soil Analysis. Vikas Publishing House Pvt. Ltd., Delhi.

Brady, N.C. 1990 The Nature and Properties of Soils, 10th edn Macmillan Publishing Co., Inc., New York.

Central Statistics Authority of Ethiopia (CSAE), 2000. Livestock population estimates of Ethiopia, sample survey report, vol. II. Addis Ababa, Ethiopia.

Ethiopian Mapping Authority (EMA), 1988. National Atlas of Ethiopia. Birhanena Selam Printing Press, Addis Ababa

Eylachew Zewdie, 1999. Selected physical, chemical and mineralogical characteristics of major soils occurring in Chercher highlands, eastern Ethiopia. Ethiopian Society of Soil Sciences.

Folliot F.P., N.K. Brooks, M.H. Gregersen, L.A. Lundgren, 1995. Dryland Forestry Planning and Management. Mc Graw-Hill, New York USA

Gabriel, H.W., S.S. Talbot, 1984. Glossary of landscape and vegetation ecology for Alaska B.L.M. Alaska Teck. Report 10, US Department of Interior, Anchorage, Alaska.

Gee G.W. and J.W. Bauder, 1979. Particle size analysis by hydrometer. A simplified method for routine textural analysis and a sensitivity test of measurement parameters. *Soil Scieince Society of America Journal. 43: 1004–1007*.

Gemedo-Dalle T., B.L. Maass, J. Isselstein, 2006. Rangeland condition and trend in the semi-arid Borana lowlands, southern Oromia, Ethiopia. *African Journal of Range and forage Science. 23, 49–58.*

Getachew Haile, Mohammed Assen and Abule Ebro, 2007. Effects of rangeland management systems on soil characteristics of Yabello rangelands, southern Ethiopia. *Ethiopian Journal of Natural Resources: 9 (1): 19-35*.

Greig-Smith, P., 1983. Quantitative Plant Ecology. Butterworths, Washington.

Hintze, J.L., 1998. NCSS 6.0 Statistical System for Windows: Number Cruncher Statistical Systems. User's Guide. Kaysville, UT.

Industrial Project Service (IPS), 2000. Resource Potential Assessment and Project Identification Study of the Somali Region. Investment Office of the Somali Regional State, pp. 162–175.

Jackson M.L., 1970. Soil chemical analysis. Prenstic Hall, Inc., Engle Wood Cliffs. New Jersey.

Kidane Gebremeskel and P.J. Pieterse, 2006. Impact of grazing around a watering point on soil status of a semi-arid rangeland in Ethiopia. *Journal of Arid Environment. 6:2-8*

Reddy K.R , E.M. D'Angelo and W.G. Harris, 2000. Biogeochemistry of Wetlands. Hand Book of Soil Science. Ed. Malcolme E.Sumner.CRC Press, Washington DC, USA. Pp 103.

Mathews, B.W., L.E. Sollenberger, V.D. Nair, and C.R. Staples, 1994. Impact of grazing management on soil nitrogen, phosphorus,potassium and sulfur distribution. *J. Environmental Quailty. 23, 1006–1013.*

Mac Landon, J.R., 1991. Booker Tropical Soil Manual. A hand book for soil survey and agricultural land evaluation in the tropics and sub tropics. Longman, London.

Mclean, E.C., 1973. Testing soils for pH and lime requirements In: Soil Testing and Plant Analysis (Eds L. M. Walsh and J. D. Beaton). Soil Science Society of America, Madison, WI.

McNaughton, S.J., 1985. Ecology of a grazed system: the Serengeti. Ecol. Monogr. 55, 259–294.

Brady, N. C.1984. The nature and properties of soils. Macmillan Publishers, USA, pp 41, 50.

Olsen SR, C.V. Cole, F.C. Wantanable and L.A. Dean, 1954. Estimation of available in soil by extraction with sodium bicarbonate. USDA, Circ 939.

Page, M.J., R.J.S. Beeton, 2000. Is the removal of domestic stock sufficient to restore semi-arid conservation areas? Pac. Con. *Biol. 245–253.*

Schollenberger, C.J. and R.H. Simon, 1945. Determination of exchange capacity and exchangeable cations in soil with ammonium acetate. *Soil Science. 59: 13–24.*

Panda S.C. 2007. Soil water conservation and dry farming. Agrobios, India. Pp 36-40.

Schlesinger, W.H., J.F. Reynolds, G.L. Cunningham, L.F. Huenneke, W.F. Jarrell, R.A. Virginia, and W.G.Whitford, 1990. Biological feedbacks in global desertification. *Science 247: 1043–1048.*

Solomon, T.B., H.A. Snyman, G.N. Smit, 2007. Cattle management practices and perceptions of pastoralists towards rangeland degradation in Borana zone of Southern *Ethiopia Journal of Environmental Management 82, 481–494.*

Somali Region Pastoral and Agro-pastoral Research Institute (SoRPARI), 2004. Somali region rangeland and natural resources strategic research planning. Jigjiga, Ethiopia.

South-Eastern Rangelands Development Project (SERP), 1990. Assessment of Some Soil Characteristics for Selected Rangeland Sites in Harerighe Province, Eastern Ethiopia. Jigjiga, Ethiopia.

Snyman, H.A., 1998. Dynamics and sustainable utilization of the rangeland ecosystem in arid and semi-arid climates of southern *Africa. Journal of Arid Environment. 39: 645–666*.

Statistical Package for Social Sciences (SPSS), 1996. USA.

Steel, R.G.D., J.H.Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach, 2nd ed. McGraw-Hill, New York, USA, 633 pp.

Shinile Zone Administrative Bureau (SZAB), 2003. A Survey on Drought Impacts on the Pastoral Households' Socio-economic Setting in the Administrative Zone. Dire Dawa, Ethiopia.

Tainton, N.M., 1999. The ecology of the main grazing lands of South Africa. In:Tainton, N.M. (Ed.), Veld Management in South Africa. University of Natal Press, Petermarttizburg, 472 pp., pp. 23–50.

Thompson, I. M. and F. R. Troeh, 1978. Soils and soil fertility. 4th Edn. MacGraw-Hill Inc., London.

Thompson, K., J.P. Grime, 1979. Seasonal variation in the seed banks of herbaceous species in 10 contrasting habitats. J. Ecol. 67, 893–921.

Turner, M.D. (1998) Long-term effects of daily grazing orbits on nutrient availability in Sahelian West Africa. I. Gradients in thechemical composition of rangeland soils and vegetation. J. Biogeogr. 5, 669–682. Walkley,

Van der Westhuizen, H.C., H.A. Snyman, and H.J. Fouche´ , 2005. A degradation gradient for the assessment of rangeland condition of a semi-arid sourveld in Southern Africa. *African Journal of Range and forage Science* 22, 47–59.

Van der Westhuizen, H.C., W.J. Van der Rensburg and Snyman, 1999. The quantification of ranglnad condition in semi arid rangelands pf south Africa. *African Journl of range and forage science. 16: 9-21*

Vetter, S., W.N. Goqwana, W.J. Bond, W.S.W. Trollope, 2006. Effects of land tenure, geology and topography on vegetation and soils of two grassland types in South Africa. *African Journal of Range and forage Science* 23, 13–27.

Vorster, M., 1982. The development of the ecological index method for assessing veld condition in the Karoo. Proc. Grassld. *Society of South Africa* 17, 84–89

Walkley A and Black CA, 1934. An examination of wet digestion method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science*. 37:29-38.

Walters-Bayer, A., Bayer, W., 2000. Development-oriented socio-economic methods in grassland and annual production research. In: Field and Laboratory Methods for

Grassland and Animal Production Research, Wageningen, The Netherlands, 437 pp.