# Rangeland dynamics in South Omo Zone of Southern Ethiopia: Assessment of rangeland condition in relation to altitude and Grazing types

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## Abstract

A study was undertaken in Hamer and Benna-Tsemay districts of the Southern Ethiopia with the objective to determine the condition of the rangelands for grazing animals as influenced by altitude and grazing types. The rangelands in each of the study districts were stratified based on altitude and grazing types.

In the study districts, a total of 32, 3, 2, 7 and 29 species of grasses, legumes, sedges, other herbaceous plants and woody species were identified, respectively. The common and/or dominant grass species in the enclosures was *Cenchrus ciliaris* while in the communal grazing areas they were *Cynodon dactylon* and *Tetrapogon tennulis*. In riverside grazing areas, the common and/or dominant grass species was *Cynodon dactylon*. The total grass biomass of communal, riverside and enclosure areas found in the different altitude categories of the study districts ranged from 398-503; 98-626, and 1,132 – 1,209 kg/ha, respectively. The common and/or dominant woody species in the communal grazing areas were highly palatable species of *Acacia tortilis* and *Grewia bicolor* and less palatable *Solanum* species. In riverside grazing areas, the common and/or dominant woody plants were species of *Acacia tortilis, Grewia bicolor*, and *Solanum* species while in the enclosures; *Acacia brevispica* and *Acacia tortilis* were found. The woody vegetation density per hectare of communal, riverside and enclosure areas in the different altitude categories of the study districts ranged from 2,501-3,021; 2251-3,021, and 201-700,wd/ha respectively which showed that the communal and riverside grazing areas were bush encroached. The range condition scores ranged from 17.87-20.38 (communal), 22-27 (riverside), 31.05-31.2 (enclosures) which were poor, fair and good condition classes, respectively. Similarly, with regard to the same variable the scored varied from 22-32.87, 19.73-31.43, 17.97-31.44 and 17.87-31.28% in altitudes >1550m, 1250-1550m, 900-1250m, and 550-900m, respectively. The result indicated the need for rangeland improvement measures in communal and riverside grazing areas, in order to attain sustainable livestock production from these areas. Establishment of community based enclosures was found to be one of the ways to improve the condition of the rangelands.

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**Key words:** basal cover, grass species composition, rangeland rehabilitation, total range condition score, woody vegetation density

## Introduction

Rangelands are defined as those areas of the world, which by reasons of physical limitation, low and erratic precipitation, rough topography, poor drainage, or cold temperatures are unsuited for cultivation and which are a source of forage for free ranging native and domestic animals, as well as a source of wood products, water and wildlife (Herlocker 1999). Of these, extensive livestock production is the major land use on rangelands with large areas of land required per head of livestock (Zhou et al 1998). Accordingly, the condition of the rangelands which Trollope et al. (1990) defined; the state of health of the rangeland in terms of its ecological status, resistance to soil erosion and potential for producing forage for sustained optimum livestock production must be investigated. Furthermore, rangeland condition is a function of all plant forms (trees, grasses and shrubs) that occur in it (Friedel 1991). Rangeland condition cannot, therefore, be simply indexed according to its usefulness for a single priority land use. As with grassland, the composition and structure of each of the other components vary, which adds an extra and complicating dimension to rangeland assessment. In addition, the rangeland is frequently used by pastoralists who own different animal types (browsers and grazers). Assessment techniques need to consider the different vegetation components for the proper utilization of the available rangeland resources. Until recent times, research on rangeland dynamics has historically focused on the effects of various management practices on forage production and animal response, with little attention given to the impact of grazing on the condition of the soil. Since animal production is directly related to rangeland condition, rangeland degradation will result in a lower income (Danckwerts and Tainton 1996).

In the South Omo zone, pastoralists of different ethnic groups are found predominately in Hamer, Benna-Tsemay and kuraze districts which are primarily dependent on range based livestock production. More than 48% of the total land area of the study districts, Hamer and Benna-Tsemay, is used for grazing and/or browsing by cattle, sheep and goats. Even though the study areas have a vast area of rangeland, there was no research study undertaken to assess the condition of the rangelands and take appropriate management interventions in relation to livestock production. Accordingly, the objective of this study was to assess the condition of the grazing lands in the mentioned study districts as influenced by altitude and grazing types.

## Materials and methods

### Description of the study area

The assessment of the condition of the grazing lands was undertaken in Hamer and Benna-Tsemay districts of the South Omo zone of the Southern Nations, Nationalities, and People's Regional State in Ethiopia. The study area has been described in detail (Admasu et al 2010).

## Study procedures

### *Site selection and sampling procedures*

In the identification of rangeland sites for rangeland condition assessment study, the grazing areas in each of the study district were stratified into three (Benna-Tsemay district) and four (Hamer district) based on altitude, i.e., 550-900, > 900-1250, >1250-1550, and > 1550 m.a.s.l. (Table 1) (Holechek et al 1998).

**Table 1.** Number of sites selected for herbaceous and woody vegetations cover study in the study districts

| Districts | Altitude | Grazing types | | |
|---|---|---|---|---|
| | | Riverside | Communal | Enclosures |
| Benna-Tsemay | 550-900m | 3 | 5 | 2 |
| | 901-1250m | - | 3 | 2 |
| | 1251-1550m | 3 | 3 | 2 |
| | >1550m | - | - | - |
| Hamer | 550-900m | 3 | 5 | 2 |
| | 901-1250m | - | 4 | 2 |
| | 1251-1550m | - | 3 | 2 |
| | >1550 | 2 | - | 2 |
| Total | | 11 | 23 | 14 |

Within each altitude group, the grazing areas were further stratified into enclosures, riverside areas and other communal grazing areas. Enclosures are small areas of land (0.25 to 1 ha) protected by the different pastoral groups for use during the dry season, either by harvesting or allowing the animals to graze, and they are mainly found around their homestead and crop lands. They are established by the pastoralists to have reserve forage for sick and lactating animals, oxen, lambs, kids and calves. The riverside areas are those grazing lands that are near the rivers, where the rivers serve as a permanent source of water for the grazing animals. They are mostly grazed throughout the dry and wet seasons. The communal grazing areas are those grazing sites without a permanent water sources and are mainly grazed during the wet season. In years of good rainfall and early starting of the short rain, they can also be grazed during the dry season.

In each of the study district, the number of rangeland sites of the communal grazing areas and those grazing areas near the riverside were determined based on the proportional area of each of the grazing types in each altitude zone. Furthermore, two enclosure areas were included in each altitude zone for comparison purpose (Table 1). At each of the site, two transects of three to five km length were laid out randomly after thoroughly observing the nature of the vegetation and using information obtained from the pastoralists about the sites. The transects represent the rangeland site under study. In each transect, three sample sites were identified randomly after sub-dividing each transect into three parts for stratification purpose. At each of the sample site, a belt transects of 50 x 4 m was laid out randomly for the purpose of accommodating both the herbaceous and woody vegetation layers. Samples from the riverside areas were taken within 400-500 m from the river. Sampling was done from mid May- July, 2005 at time when most pasture plants grow and flower fully, which made the identification of plants very easy.

At each of the sample site, the herbaceous species composition and biomass was assessed by harvesting four quadrants of 1 m x 1 m randomly by throwing the quadrant each time towards the back and the herbaceous vegetation within the quadrant cut at ground level using hand shears. The cut samples were weighed using a simple balance immediately and were transferred into properly labeled paper bags and fasten at the top. The samples were kept in cool area until sampling for the day was completed and each of the sample in the paper bag was hand separated into the different species and were weighed. Then, they were sun-dried until the field work was completed.

#### ***Laboratory analytical analysis***

Each species was dried in an oven for 60ºC for 72 hours at Alege Agricultural technical college and the percent dry matter composition of each species was determined on weight basis (ILCA 1990).

Identification of the species was undertaken at two levels. Plants were identified in the field using guidebooks (CADU 1974; Reinhard and Admasu 1994; Bekele 1993) and with the assistance of experienced field technicians from Adami Tulu research centre Ethiopia. For those plants that were not identified in the field, a herbarium sample of each species was pressed using plant press, labeled, and sent to the National herbarium of Addis Ababa University for identification. The identified herbaceous species were classified into highly desirable, desirable and less desirable based on the information obtained from the herdsmen and researchers. Highly desirable species included species that are decreasers and perennials with a high palatability based upon the pastoralists' perceptions, while the desirable species are those that increase in abundance with moderate over-utilization, perennials and are average or high in terms of their palatability. The less desirable species include those species that increase in abundance with severe or extremely severe over utilization. This group includes both perennial and annual species that are less palatable as perceived by the pastoralists (Tainton 1999).

**Woody layer assessment**

All rooted live woody plants in each of the 50 x 4 m belt transect, regardless of being single or multi-stemmed were counted by species and were used for an estimation of the woody vegetation density per hectare. Each of the woody species was classified into highly palatable, intermediate and unpalatable according to the opinion of the pastoral communities. When the percentage density of woody plants per hectare (was) is less than 10% it (was) is considered as P (Present); greater than 10% but less than 20% (was) considered as common (C) and when it was greater than 20% it was considered as dominant (D).

**Assessment of rangeland condition**

The condition of the rangelands in the study districts was assessed by considering three layers (grass, woody and soil) according to Friedel (1991). Assessment of a rangeland ecosystem composed of different vegetation components; the determination of the range condition must incorporate three layers of assessments, i.e., the soil, grass layer and the tree-shrub layer. For the grass and the soil layers, the factors and criteria considered were based on criteria developed in South Africa (Tainton 1981) and adapted to fit semi arid, and sub-humid environments by Baars et al (1997). The woody vegetation layer was assessed using density data based on the suggestion given by Pratt and Gwynne (1977) for East African rangelands. The assessment factors were based on the composition of the grass layer, basal cover, litter cover, soil erosion, soil compaction and woody vegetation density summing up to a total of 50 points. The over all rating of vegetation and soil was interpreted as excellent when the score was 41-50 points, good (31-40 points), fair (21-30 points), poor (11-20 points) and very poor when the rating was less or equal to 10 points (Baars et al 1997).

**Herbaceous species composition**

For herbaceous species composition (1 to 10) points were considered based on the contribution of grasses only. The maximum score of 10 points was given if the contribution of decreaser grasses was 91-100%, 9 points if the decreaser grasses contributed 91-90% etc. Score of 3 and 4 points were given if deceaser grasses made up 10-40%, as well as <30% and equal or > 30% increasers, respectively. Score of 1 and 2 points were given if decreaser were least than 10%, respectively (Baars et al 1997).

**Basal and litter covers**

At each sample site, a representative sample area of 1m x 1m was selected for detailed assessment and three measurements were taken. The surface of basal cover of tufted grasses and their distribution was assessed as follows. The square meter was divided into eighth equal parts and all basal covers of plants in the quadrat were transferred (drawn) to one of the eighths in order to facilitate visual estimations. Only basal covers of live plants were considered. The highest score (10 points) was given for the basal cover of tufted species if the eighth was completely filled (corresponding to 12% basal cover of the original square meter). Accordingly, classes of < 3%, 3-6%, 6-9%, 9-12% were distinguished. Lower scores (0, 1 and 2 points) were given for basal cover with < 3%. The rating for litter cover within the same square meter was given the maximum score (10 points) when it exceeds 40% and a minimum score when the litter cover was less (least) than 3% (Baars et al 1997).

**Soil erosion and compaction**

Soil erosion assessment was made by visual observation and a scale of 0-5 points was considered. Soil erosion was rated based on the amount of pedestals (high parts of soil held together by plant roots with eroded soil around tuft), and in severe cases pavements (terraces of flat soil, normally without basal cover with a line of tufts between pavement). Three measurements were recorded at each of the sample site by identifying representative area. The highest score 5 point was given for no sign of erosion, (4 points = slight sand mulch; 3 points = weak pedestals; 2 points = steep sided pedestal; 1= pavement, 0= gullies). Soil compaction (1 to 5 points) was evaluated based on the level of capping or crust formation of the surface soil. The scores given to soil compaction ranged from 1-5 points. The highest score (5 points) was given for a soil surface with no capping; 4 points = isolated capping; 3 = greater than 50% capping; 2 = greater than 75% capping and 1 = almost 100% capping (Baars et al 1997).

**Woody vegetation density score**

The woody vegetation density score was undertaken as indicated below (table 2) where 10 points was given for areas with low density of woody vegetation while the lowest value was given for sites with a high density of woody vegetation (Table 2)..

**Table 2.** Woody vegetation density score

| Score | Woody density |
|---|---|
| 10 | <200 |
| 9 | 200-300 |
| 8 | 301-400 |
| 7 | 401-550 |
| 6 | 551-800 |
| 5 | 801-1000 |
| 4 | 1001-1600 |
| 3 | 1601-2600 |
| 2 | 2601-3700 |
| 1 | >3700 |

**Statistical analysis**

The data was analysed using the GLM procedure of Statistical Analytical System SAS computer software, i.e., the two-way analysis of variance with an interaction was used for all range condition parameters to study the effect of altitude and grazing (SAS 1987). Least significant difference was used for mean comparison. Furthermore, the relationship between the different variables was analysed by linear correlation using SAS computer software.

## Results and discussion

### Herbaceous and woody vegetation composition

A total of 32 species of grasses, three species of legumes, two species of sedges, and seven species of other herbaceous plants were identified in the study districts (annex tables 1 and 2).

Of the total herbaceous species recorded; on dry matter basis 38.2% were grasses of different species. Of the grass species, 24, 51 and 25% were highly desirable, desirable and less desirable for livestock, respectively. The less desirable grass species increased in the vegetation due to severe overgrazing and they are generally indicators of declining range condition (Van Oudtshoom 1999; Yvan and Tesema 2005).

In both districts, some species of herbaceous plants fell within a specific altitude category while others appeared in all altitude categories (annex tables 1 and 2). As it is widely argued, altitude has an important influence on the distribution, growth, and diversity of rangeland plants (Gemedo 2004; Getachew et al 2008). The variation observed in botanical composition in relation to altitude in the present study could be associated with the better precipitation received in higher altitude zones. *Tetrapogon tenellus, Digitaria abyssinica, Cynodon dactylon* and *Eragrostis cilianensis* were some of the dominant and/or common grass species found in communal grazing areas while *Eragrostis teniufolia, Eragrostis cylinderifolia*, Cynodon dactylon and Heteropogon contortus were among the dominant/or common grass species found in riverside grazing areas. The enclosure areas were dominated by *Cenchrus ciliari*s, *Cynodon dactylon*, and *Tetrapogon tenellus*. Most of the grass species found in the 550-900m altitude category such as Cynodon dactylon, are drought and heavy grazing tolerant which is in line with the reports of Amsalu and Baars (2002) and Adane (2003) and *C. ciliaris* is highly palatable and indicators of good rangeland condition (Van Oudtshoom 1999).

A total of 29 woody species were identified in the study districts and the percentage abundance of each species is given in annex tables 3 and 4.

Of the identified woody species, 27.6, 65.5, and 6.9% were highly palatable, intermediate and unpalatable for livestock, respectively. Of the highly palatable species, the largest was contributed by different species of *Acacia* and *Grewia* (Table 3).
The dominant and/or common woody species in the communal grazing areas and along riversides of the study districts were different species of *Acacia*, *Solanum*, and *Grewia villosa*, *Cucumis prophetarum*, *Rhus natelensis,. Cordia gharaf,* and *Commiphora africana.* Species of *Grewia*, *Acacia*, *Rhus natelensis, Olea africana,* and *Solanum* were the dominant and/or common woody species found in the enclosure areas of both districts (annex tables 3 and 4**).**

Many of the woody species identified in the study districts are important for livestock production. Although the height of the woody vegetation was not recorded in the study, it was observed during the fieldwork that some of the leaf biomass was beyond the reach of goats. Accordingly, the inclusion of animals like camel into the system will help in efficient utilization of the feed resource and for ecological balance. Studies have shown that integration of grazers and browsers having different feeding habits make more efficient use of the vegetation and are often more profitable. Furthermore, animal species like camels and goats can be used as a biological control of bush encroachment (Bothama 2002). *Solanum* species are indicators of a change in the condition of the rangeland towards deterioration and are also considered as poisonous plants species in Ethiopia (Coppock 1994).

### Woody vegetation density and bush encroachment

In the communal grazing areas of Benna-Tsemay district, the woody vegetation density per hectare (Wpd/ha) were 2,501-2,761, 2,501-3,414, and 2,501- 2,941 in the 550-900m, 900-1250m and 1250-1550m altitude zones, respectively while the values were 2,501-3,101, 2,501-2,941 and 2,501-3,021, in the 550-900m, 900-1250m and 1250-1550m altitude zones of Hamer district, respectively. The Wpd/ha was about 2,251-2,669 in sites along riverside in the 550-900m and 2,501-2,666 in sites along the riverside in the 1250-1550m altitude zone of Benna-Tsemay district, and 2,225-2,610 in the 550-900m and 2,501-3,021 in sites along the riverside in the >1550m altitude categories of Hamer district. The density of woody plants, (Wpd/ha) in enclosure areas found in the different altitude categories was 301-700, 301-338 and 201-300, in the 550-900m, 900-1250m, and 1250-1550m altitude areas of Benna-Tsemay district, respectively while the density in Hamer district was 301-339, 301-340, and 201-300 in 550-900m, 900-1250m and 1250-1550m altitudes, respectively and the low density of woody vegetation is attributed to the management influence of the communities (thinning of unwanted woody plants. In general, the communal and riverside grazing areas are bush encroached which suppresses grass production for grazing animals like cattle and sheep. The causal factors for bush encroachment are not absolutely clear (Prins and Van der Jeugd 1992), rather they are diverse and complex (Smit 2002). Nevertheless, Coppock (1994) reports on the Borana rangeland and the pastoralists accumulated indigenous knowledge suggested that drought favors woody vegetation than herbaceous species; the absence of fire, overgrazing and others have been found to initiate bush encroachment.

### The effect of altitude and grazing types on herbaceous biomass production

In the communal grazing areas of the study districts, there was no significant (P>0.05) difference in total biomass among the different altitude categories, indicating that they had similar total biomass (Table 3).

**Table 3.** Biomass production of the different grazing types located in different altitude categories of the study districts

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Communal grazing areas** | | | | | | |
| **Parameters** | **Benna-tsemay district** | | | **Hamer district** | | | |
| | **550-900m** | **900-1250m** | **1250-1550m** | **550-900m** | **900-1250m** | **1250-1550m** | **>1550m** |
| | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** |
| | 1231 ± 23.4$^{a}$ | 1232 ± 12$^{a}$ | 1235 ± 17.2$^{a}$ | 1279 ± 45.2$^{a}$ | 1256 ± 35.6$^{a}$ | 1253 ± 69.5$^{a}$ | - |
| | 413 ± 117.5$^{a}$ | 446 ± 28$^{a}$ | 503 ± 29.1$^{b}$ | 398 ± 17.6$^{a}$ | 403 ± 8.4$^{a}$ | 494 ± 13.6$^{b}$ | - |
| | 248 ± 14$^{a}$ | 232 ± 30.28$^{a}$ | 225 ± 20.3$^{b}$ | 221 ± 15.4$^{a}$ | 228 ± 9.5$^{a}$ | 241 ± 7.8$^{b}$ | - |
| | 105 ± 11.8$^{a}$ | 141 ± 27.3$^{b}$ | 186 ± 10.8$^{c}$ | 158 ± 28.3$^{a}$ | 166 ± 18.3$^{b}$ | 182 ± 6.8$^{c}$ | - |
| | 160 ± 8.2$^{a}$ | 173 ± 9.2$^{a}$ | 190 ± 21.5$^{a}$ | 119 ± 6.12$^{a}$ | 110 ± 6.3$^{a}$ | 171 ± 29.9$^{a}$ | - |
| | **Riverside grazing areas** | | | | | | |
| **Parameters** | **Benna-tsemay district** | | | **Hamer district** | | | |
| | **550-900m** | **900-1250m** | **1250-1550m** | **550-900m** | **900-1250m** | **1250-1550m** | **>1550m** |
| | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** |
| | 1207±65.2$^{a}$ | - | 1175±32.6$^{a}$ | 1179±44.2$^{a}$ | - | - | 144±38.9$^{b}$ |
| | 588±24.7$^{a}$ | - | 626±25.4$^{b}$ | 535±11.2$^{a}$ | - | - | 97.6±24.2$^{b}$ |
| | 193±24.7$^{a}$ | - | 276±25.6$^{b}$ | 213±11.2$^{a}$ | - | - | 0±00$^{b}$ |
| | 253.±10.2$^{a}$ | - | 223±36.2$^{a}$ | 159.5±4.6$^{a}$ | - | - | 59±24.2$^{b}$ |
| | 147±71$^{a}$ | - | 127±26.6$^{a}$ | 141±42.6$^{a}$ | - | - | 38.6±15.8$^{b}$ |
| | **Enclosure grazing areas** | | | | | | |
| **Parameters** | **Benna-tsemay district** | | | **Hamer district** | | | |
| | **550-900m** | **900-1250m** | **1250-1550m** | **550-900m** | **900-1250m** | **1250-1550m** | **>1550m** |
| | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** |
| Tb | 1372 ± 40.4$^{a}$ | 1436 ± 0 36.4$^{a}$ | 1570 ± 51$^{a}$ | 1257 ± 45$^{a}$ | 1358± 86.4$^{a}$ | 1486 ± 75$^{a}$ | 1572 ± 23$^{a}$ |
| Tg | 1132 ± 40.6$^{a}$ | 1146 ± 102$^{a}$ | 1209 ± 113.6$^{a}$ | 1132 ± 40.6$^{a}$ | 1146 ± 102$^{a}$ | 1209 ± 114$^{a}$ | 1197.± 67$^{a}$ |
| Hdg | 522 ± 40.36$^{a}$ | 535 ± 85.3$^{a}$ | 542 ± 65$^{a}$ | 504 ± 49.36$^{a}$ | 516 ± 5.3$^{a}$ | 534 ± 25$^{a}$ | 556 ± 48$^{a}$ |
| Dg | 517 ± 65.9$^{a}$ | 514 ± 96.2$^{a}$ | 526 ± 98.3$^{a}$ | 528 ± 35.9$^{a}$ | 524 ± 32$^{a}$ | 554 ± 48.3$^{a}$ | 578 ± 41.2$^{a}$ |
| Ld | 194.± 62.3$^{a}$ | 223 ± 87$^{a}$ | 214 ± 84..2$^{a}$ | 102 ± 12.3$^{a}$ | 107 ± 27$^{a}$ | 119 ± 24.6$^{a}$ | 63.2 ± 56.4$^{a}$ |

*Tb =Total Biomass, Tg = Total Grass Biomass, Hdg = Highly Desirable Grass Biomass, Dg = Desirable Grass Biomass, Ld = Less Desirable Grass Biomass ; Means with the same letter in a row for each district are not significantly different P<0.05)*

Even though the sites had different proportions of each, there was no difference among the different altitude in total biomass. In the districts, total grass and highly desirable grass biomass followed a similar pattern in that the communal grazing areas in the 1250-1550m altitude had a significantly (P<0.05) higher biomass than those in the other two altitude zones. There was no significant (P>0.05) difference in the indicated parameters in the communal grazing areas found in the 550-900m and 900-1250m altitude zones. The better biomass in communal grazing areas located in the 1250-1550m altitude categories could be associated with the better rainfall the area receives.

The riverside grazing areas found in the 550-900m altitude category (Tb = 1,179 kg/ha) of Hamer district had a significantly (P<0.001) higher total biomass than those located in >1550m altitude zone (144.2 kg/ha). On the other hand, in Benna-Tsemay district, the total biomass of riverside grazing sites located in the 550-900m (Tb = 1,206 kg/ha) altitude category was similar (P>0.05) to the total biomass of riverside grazing sites situated in the 1250-1550m (Tb = 1,174 kg/ha) altitude categories and this could be due to the variation in the grazing pressure in the different altitude categories.

The total grass biomass in riverside grazing areas of the 1250-1550m altitude categories (626.1 ± 25.4 kg/ha) of Benna-Tsemay district was significantly (P<0.05) higher than the value for a similar grazing type in the 550-900m altitude categories (588 ± 24.7 kg/ha) and such difference might be attributed to the variations in grazing pressure and altitude. On the other hand, riverside grazing areas in the 550-900m altitude categories of Hamer district had a significantly (P<0.05) higher (535 kg/ha) total grass biomass than those located in >1550m altitude zone (97 kg/ha). The possible reason for such difference was the variation in the grazing pressure between the sites. The heavy and continuous grazing pressure in the >1550m altitude category resulted in decreased biomass production. In grazing areas along the riverside of Benna-Tsemay district, the highly desirable (decreaser) grass biomass was significantly higher (P<0.05) in 1250-1550m altitude (276 kg/ha) than in the 550-900m (193 kg/ha) altitude categories and this might be attributed to the less number of livestock population (less grazing pressure) and human settlement in the 1250-1550m altitude than in the 550-900m altitude zone. Highly desirable grass species were not found in the >1550m altitude zone of Hamer district and this could be due to heavy grazing pressure by the animals of the pastoralists near by riversides and those migrating from other areas during the dry season. In riverside grazing areas of Hamer district, desirable (increasers) grass biomass production was significantly (P<0.05) higher in the 550-900m (159 kg/ha) than the >1550m (59 kg/ha) altitude zones and the possible reason is that, although almost all of the grasses in the area were of the desirable group, the biomass was low due to the increased grazing pressure. In the grazing areas along the riverside, the less desirable (invaders) grass biomass production was significantly higher (p<0.05) in the 550-900m altitude (141 kg/ha) than in >1550m altitude zone of Hamer district and this was due to the increased grazing pressure in the 1250-1550m altitude zone.

There was no significance (P>0.05) differences in any of the parameters (Total biomass, total grass biomass, highly desirable grass biomass, desirable and less desirable grass biomass) among the enclosure areas located in different altitude categories. The similarity in the measured parameters despite the difference in altitude could be due to the influence of management undertaken by the pastoralists. Because these sites are well managed by the pastoralists, the influence of other factors like rainfall that could have brought difference in yield was not observed and this requires further investigation. This finding conforms to the reports of Amsalu and Baars (2002); Gemedo et al (2006); Teshome et al (2009).

### Determination of range condition

*Effect of altitude on rangeland condition at different levels of grazing*

In both districts, the basal cover was significantly (P<0.05) higher in the communal grazing areas found in the 1250-1550m altitude category than in the 900-1250m and 550-900 m altitude categories, respectively. A similar pattern was observed in the riverside and enclosure grazing areas where the basal cover was higher in the mentioned grazing types at the higher altitude categories than those found in the lower altitude categories (Table 2). The possible reason for the higher basal cover in the different grazing types located in the higher altitude zones could be associated with the better precipitation in the higher altitude than in the lower altitude. Furthermore, it might be due to the replacement of most of the tufted decreaser grasses such as C. *ciliaris* by creeping grasses such as Cynodon dactylon species which cover the soil. A similar observation was made by Ayana **and Baars** (1999) and Amsalu and Baars (2002) from their studies in the Borana and mid rift valley areas of Ethiopia, respectively. If a basal cover value of ≥ 12.5% is for vegetation that has excellent cover; comparing this value with the mean values of the basal cover for the communal grazing areas in Benna-Tsemay (3.42) and Hamer districts (3.66), only demonstrate that the basal cover in these districts was low. Different factors can lead to a low basal cover and high soil loss from the surface. From this study, it would appear that overgrazing (O' Connor et al 2001); drought (Wilson and Tupper 1982); poor grazing practices (Snyman and Fouche 1993) and high density of woody vegetation (Smit 2002) are the most likely determinants. These factors are interrelated and it is difficult to separate the effect of one from the other without a long-term experiment.

**Table 4.** Range condition score in different grazing types of the different altitude zones in the study districts

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Communal grazing areas** | | | | | | | |
| | **Benna-Tsemay** | | | | **Hamer district** | | |
| **Parameters** | **>1250-1550 m** | **>900-1250 m** | **550-900m** | | **1250-1550m** | **900-1250m** | **550-900m** |
| | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** |
| Bc | 3.87 ± 0.97$^{a}$ | 3.14 ± 2.87$^{b}$ | 3.25 ± 0. 63$^{b}$ | | 3.96 ± 0.45$^{a}$ | 3.47 ± 0.61$^{b}$ | 3.54 ± 0.4$^{b}$ |
| Lc | 2.57 ± 1.02$^{a}$ | 2.32 ± 0. 32$^{b}$ | 2.23 ± 0.82$^{b}$ | | 2.23 ± 0.88$^{a}$ | 2.21± 0.22$^{b}$ | 2.34 ± 0.29$^{b}$ |
| Se | 3.03 ± 0.76$^{b}$ | 2.95 ± 0.43$^{b}$ | 2.83 ± 0.55$^{b}$ | | 3.16 ± 0.11$^{a}$ | 3.04 ± 0.06$^{b}$ | 3.07 ± 0.16$^{b}$ |
| Sc | 3.13 ± 0.73$^{a}$ | 2.89 ± 0.49$^{b}$ | 2.78 ± 0.5$^{b}$ | | 3.19 ± 0.11$^{a}$ | 2.89 ± 0.07$^{b}$ | 2.30 ± 0.14$^{b}$ |
| Gsc | 3.77 ± 0.33$^{a}$ | 3 ± 0.58b | 3.33 ± 0.33$^{b}$ | | 3.84 ± 0.23$^{a}$ | 2.95 ± 0.55$^{b}$ | 3.20 ± 0.1$^{b}$ |
| Wds | 3.68 ± 0.54 $^{a}$ | 3.25 ± 0.29$^{b}$ | 3.45 ± 0.4$^{b}$ | | 3.35 ± 0.25$^{a}$ | 3.14 ± 0.3$^{b}$ | 3.13 ± 0.24$^{b}$ |
| Ts | 20.4 ± 4.35 | 18.3 ± 2.11 | 17.9 ± 3.23 | | 19.7 ± 3.03 | 18.0 ± 1.59 | 17.6 ±1.33 |
| Rcd. | Poor | Poor | Poor | | Poor | Poor | Poor |
| **Riverside grazing areas** | | | | | | | |
| | **Benna-Tsemay** | | | | **Hamer district** | | |
| **Parameters** | **>1250-1550 m** | - | **550-900 m** | **>1550 m** | - | - | **550-900 m** |
| | **(LSM and SE)** | - | **(LSM and SE)** | **(LSM and SE)** | - | - | **(LSM and SE)** |
| Bc | 5.06 ± 0.44$^{a}$ | - | 4.71 ± 0.22$^{b}$ | 6.64 ± 0.29$^{a}$ | - | - | 4.81 ± 0.12$^{b}$ |
| Lc | 2.12 ± 1.87$^{a}$ | - | 2.38 ± 0.65$^{b}$ | 2.15 ± 0.17$^{a}$ | - | - | 2.36 ± 0.1$^{b}$ |
| Se | 3.32 ± 0.57$^{a}$ | - | 3.14 ± 0.34$^{b}$ | 3.69 ± 0.01$^{a}$ | - | - | 3.35 ± 0.3$^{b}$ |
| Sc | 3.48 ± 0.59$^{a}$ | - | 3.31 ± 0.45$^{b}$ | 3.49 ± 0.04$^{a}$ | - | - | 3.38 ± 0.13$^{b}$ |
| Gsc | 4.67 ± 0.44$^{a}$ | - | 4.53 ± 0. 09$^{b}$ | 1.36 ± 0.12$^{a}$ | - | - | 3.59 ± 0.21$^{b}$ |
| Wds | 3.83 ± 0.54$^{a}$ | - | 3.67 ± 0.12$^{b}$ | 3.67 ± 0.88$^{a}$ | - | - | 3.58 ± 0.58$^{b}$ |
| Ts | 21.8 ± 4.45 | - | 22.0 ± 1.85 | 22.0 ± 1.51 | - | - | 22.7 ± 1.41 |
| Rcd. | Fair | - | Fair | Fair | - | - | Fair |
| **Enclosure grazing areas** | | | | | | | |
| | **Benna-Tsemay** | | | | **Hamer district** | | |
| **Parameters** | **>1250-1550 m** | **>900-1250 m** | **550-900 m** | **>1550m** | **1251-1550m** | **901-1250m** | **550-900m** |
| | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** | **(LSM and SE)** |
| Bc | 7.29 ± 1.37$^{a}$ | 7.1 ± 0.6$^{b}$ | 6.94 ± 0.6$^{b}$ | 7.57 ± 0.19$^{a}$ | 7.58 ± 0.25$^{a}$ | 7.23 ± 0.24$^{b}$ | 7.1 ± 0.26$^{b}$ |
| Lc | 2.88 ± 0.33$^{a}$ | 2.85 ± 0.36$^{a}$ | 2.87 ± 0.18$^{a}$ | 3.22 ± 0.87b | 2.82 ± 0.33$^{b}$ | 2.85 ± 0.39$^{b}$ | 2.87 ± 0.17$^{b}$ |
| Se | 3.75 ± 0.07$^{a}$ | 3.52 ± 0.8$^{b}$ | 3.88 ± 0.11$^{b}$ | 3.99 ± 0.11$^{b}$ | 3.96 ± 0.01$^{b}$ | 3.87 ± 0.2$^{a}$ | 3.77 ± 0.82$^{a}$ |
| Sc | 3.83 ± 0.12$^{a}$ | 3.73 ± 0.18$^{b}$ | 3.68 ± 0.58$^{b}$ | 4.33 ± 0.06$^{a}$ | 3.63 ± 0.06$^{a}$ | 3.75 ± 0.18$^{b}$ | 3.54 ± 0.21$^{b}$ |
| Gsc | 5.67 ± 0.33$^{a}$ | 5.67 ±.33$^{a}$ | 5.71 ± 0.58$^{a}$ | 5.23 ± 0.33$^{a}$ | 5 ± 0.58$^{a}$ | 5.63 ± 0.33$^{a}$ | 5.67 ± 0.33$^{a}$ |
| Wds | 8.65 ± 0.01$^{a}$ | 8.33 ± 0.33$^{b}$ | 8.2 ± 0.33$^{b}$ | 8.53 ± 0.33$^{a}$ | 8.44 ± 0.58$^{a}$ | 8.13 ± 0.67$^{b}$ | 8.10 ± 0.33$^{b}$ |
| Ts | 31.1 ± 2.21 | 31.2 ± 2.6 | 31.3 ± 2.38 | 329 ± 1.89 | 31.4 ± 1.81 | 31.4 ± 2.01 | 31.1 ± 2.12 |
| Rcd. | Good | Good | Good | Good | Good | Good | Good |

*Bc = Basal cover; Lc = Litter cover; Se = Soil erosion; Sc = Soil compaction; Gsc = Grass species composition; Wds = Woody density score, Ts = Total score, and Rcd = Range condition, Means with the same letter in a row for each district are not significantly different (P<0.05)*

The results of litter cover and soil compaction in communal grazing areas of Benna-Tsemay district and soil erosion and compaction values in the communal grazing areas of Hamer district followed a similar pattern to that of basal cover. In both study districts, litter cover was significantly (p<0.01) higher in rangeland sites along the riverside in the 550-900m altitude category than those found in the 1250-1550m and >1550m altitude ranges; and this could be associated with grazing pressure. The intensity of grazing is higher in

1250-1550m and >1550m altitude zones than in the 550-900m altitude zone. The loss of soil was lower ($P<0.05$) and the soil was less compacted ($P<0.05$) in enclosures found in the 1250-1550m and >1550m altitude categories than those located in the 900-1250m and 550-900m altitude zones (Table 2).

The better litter cover, less soil compaction and loss of soil in the communal grazing areas found in the 1250-1550m altitude than in the 900-1250m and 550-900m altitude zones could be related to the relatively better rainfall in the 1250-1550 m altitude than in the other two altitude categories where some residual plants add to the litter cover. It could also be associated with the better basal cover values in the 1250-1550m altitude than in the 550-900m and 900-1250m altitude ranges.

Furthermore, the soil was less compacted in the 1250-1550m altitude which can be related with the nature of the soil. The soil in the 1250-1550m altitude is a black soil an indication that it has more organic matter than the soils in the 900-1250m and 550-900m altitude zones which could have prevented it from being compacted. The relatively higher loss of soil in Benna-Tsemay district than in Hamer was due to the uneven topography of the district and the less basal and litter covers that facilitated soil erosion.

In the study districts, the grass specie composition score was significantly higher ($P<0.05$) in the communal grazing areas found in the 1250-1550m altitude zone (Benna-Tsemay = 3.77 ± 0.33; Hamer = 3.84 ± 0.23) than those found in the 900-1250m (Benna-Tsemay = 3.00 ± 0.58; Hamer = 2.95 ± 0.55) and 550-900m (Benna-Tsemay = 3.33 ± 0.33; Hamer = 3.20 ± 0.1) altitude categories but there was no significant difference ($p>0.05$) in grass species composition rating between the latter two altitude categories. The possible reason for this could be the interaction effect of altitude and grazing, as elevation has an important influence on the distribution, growth, and density of rangeland plants (Herlocker 1999; Amsalu and Baars 2002).

In grazing areas along the riverside of Benna-Tsemay district, the rating for grass species composition was significantly ($p<0.05$) higher in the 1250-1550m (3.67 ± 0.44) than in the 550-900m (3.53 ± 0.09). On the other hand, in Hamer district, it was higher in riverside grazing areas found in the lower altitude (3.59 ± 0.21) than in the >1550m (1.36 ± 0.12) altitude category (Table 2). In general, the riverside grazing areas at the 550-900m altitude categories showed better species composition, because these areas are far from the residence of the pastoralists, therefore, most animals graze these areas only in time of feed shortage particularly in critical periods of rain shortage. The rating for grass species composition was similar ($P>0.05$) for the enclosure sites found in different altitude categories (Table 2), despite their difference in other parameters. This indicates that grass species composition score alone is not a good indicator of the condition of rangeland and this observation concurred with the findings of Ayana and Baars (1999); and Amsalu and Baars (2002) of their studies in Borana and mid rift valley of Ethiopia, respectively.

The score for woody vegetation density was lower ($P<0.05$) in communal grazing areas in the 900-1250m, and 550-900m altitude categories than those found in the 1250-1550m altitude zones, but it was similar ($P>0.05$) for communal grazing areas at 550-900m and 900-1250m altitude categories (Table 2). This implies from a grazer point of view that, the higher the density of the woody plants the less the suitability of the area for animals that are primarily dependent on grass. The higher the score for woody vegetation density the better the rangelands for grazing animals like cattle and sheep. Similarly, in both districts and in grazing lands along the riversides, the scores for woody plant density was higher in grazing lands located in the higher altitude than in those located in the lower altitude ($p<0.05$) and this revealed from a grazer point of view that, the riverside grazing areas in the former altitude zones are better than those found in the latter altitude categories. In the enclosure areas of both districts, the scores for woody vegetation density was higher ($P<0.05$) in the 1250-1550m and >1550m altitude categories than those found in the 900-1250m and 550-900m altitude zones. There was no significant ($P>0.05$) difference in the mentioned parameter in enclosures found in the 900-1250m and 550-900m altitude zones (Table 2). The possible reason for this similarity may not be attached to altitude or grazing type but it could be due to the influence of the bush management undertaken by the pastoralists (thinning of unwanted plants). In general, the communal and riverside grazing areas are bush encroached which require bush/shrub management interventions.

The communal grazing areas of the study districts were in poor rangeland condition for grazing animals like cattle and sheep, and this implies that there is a need to improve the condition of the rangeland. The total score and the condition class were similar in both districts; and the sites along riversides were in fair condition class (Table 2). Although, they were relatively better in their rangeland condition score and class than the communally grazed sites, the results clearly showed that these areas also require rangeland improvement practices. The enclosures in the different altitude zones had a similar ($P>0.05$) total score and range condition class in both study districts (Table 2). In general, the condition of the rangelands in the enclosure areas was good which implies that making enclosures is a plausible method of improving the rangeland. The results of this study further demonstrates that, given proper management like resting of the grazing land, the rangeland sites can bounce back remarkably well and this is in agreement with the reports of Gemedo et al 2006; Teshome et al (2009).

**The effect of grazing on rangeland condition at different altitudes**

In all altitude categories, the enclousres had a significantly higher ($p<0.05$) basal cover (except for the enclosures and riverside grazing areas in altitude > 1550 m), litter cover, better soil condition expressed in terms of soil erosion and compaction, higher scores of grass and woody vegetation density, a higher total range condition score and a better rangeland condition class than the other grazing types. The similarity in basal cover in the enclosures and riverside grazing areas located in > 1550 m is associated with the less grazing pressure in the enclosure areas compared to the riverside grazing areas and the high grazing pressure in grazing areas along riversides which caused the herbaceous cover to be dominated by *Cynodon dactylon* which contributed much to the basal cover of the grazing areas. In study districts, the loss and compactness of the soil was significantly ($P<0.01$) higher in the communal grazing areas than in the enclosures (Table 4) and this implies that the condition of the soil is better in the enclosures than in communal grazing areas.

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**Interaction effect of altitude and grazing on range condition**

There was a significant ($P \leq 0.05$) interaction between altitude and grazing types in both study districts in parameters measured for rangeland condition analysis, i.e., basal cover, litter cover, soil erosion, soil compaction and total biomass. The possible reason for the interaction between altitude and grazing could be partly due to the variation of grazing pressure between altitudes, but more importantly, it could be that the natural plant community of a site varies with altitude difference, as a result, they respond differently to similar grazing effect and this observation is in agreement with the reports of Ayana and Baars (1999) and Amsalu and Baars (2002). As plant communities are influenced by the living and non-living components of the ecosystem, it may not be easy from this study alone to fully explain the mechanisms behind such interactions. Accordingly, this part of the study requires further investigation.

**Correlation among variables**

In the study districts, total biomass production was negatively correlated ($P \leq 0.05$) with soil erosion, soil compaction, and woody vegetation density which implies that the total biomass production decreased with an increase in the mentioned variables (Snyman, 1999 and Smit, 2002). On the other hand, the total biomass was positively correlated ($P \leq 0.05$) with basal cover and litter cover in the communal and riverside grazing areas; and this indicates that there was an increase in total biomass due to increase in basal and litter covers; and this is in agreement with Barnes et al (1991).

In the enclosures, the total biomass was negatively correlated ($P \leq 0.05$) with soil erosion and soil compaction but it was positively correlated with basal and litter covers and woody vegetation density. The positive correlation of total biomass with woody vegetation density in enclosures was due to the thinning of the woody plants by the pastoralists (Less number of woody plants). In the study districts, basal cover was positively correlated ($P<0.01$) with litter cover and negatively correlated ($P<0.01$) with soil erosion and soil compaction in the communal, riverside grazing areas and enclosures. Increase in the loss of soil and compactness can be an indication of the loss of vegetation, which lowers the basal cover. Moreover, it was negatively correlated ($P<0.01$) with woody vegetation density in the communal and riverside grazing areas while it was positively correlated ($P<0.01$) with woody vegetation density in the enclosures. Litter cover in the study districts, was negatively correlated ($P<0.01$) with soil erosion, woody vegetation density and soil compaction in the communal and riverside grazing areas and it was negatively correlated ($P<0.01$) with soil erosion, and soil compaction but positively correlated ($P<0.01$) with woody density in the enclosures.

## Conclusions

- The solution to the poor condition of the existing rangelands requires the definite commitment and full participation from the pastoralists, government and non- governmental organizations that are directly or indirectly involved in rangeland resources utilization, management, conservation and other related activities**.** The pastoral communities must be advised and trained on proper rangeland management and improvement measures (e.g., proper grazing management, resting of grazing lands, different methods of bush management including their economic use) suitable to the area.

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**Annex table 1**. Herbaceous species identified in different altitude categories and grazing types of Benna-Tsemay district

| Grasses | Category | 550-900 m | | | >900-1250 m | | >1250-1550 m | | |
|---|---|---|---|---|---|---|---|---|---|
| | | CM | R | E | CM | E | CM | R | E |
| *Aristida adscensionsis* | LD | P | P | - | - | - | P | - | - |
| *Aristida somalensis* | LD | - | P | - | - | - | - | - | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Bothriochola insculpta* | HD | P | - | - | P | - | C | P | - |
| *Brachiara dictyonuera* | DS | P | P | - | - | - | - | - | - |
| *Brachiaria mutica* | HD | P | - | - | - | - | - | - | - |
| *Cenchrus ciliaris* | HD | P | C | D | - | C | P | P | C |
| *Chloris pycnothrix* | LD | P | - | C | - | - | - | - | - |
| *Chloris preuii* | DS | - | - | | - | - | - | - | - |
| *Chloris roxbarghiana* | DS | - | - | C | - | - | - | - | - |
| *Cynodon dactylon* | DS | P | P | | C | C | C | P | - |
| *Cynodon plectostchyum* | DS | P | P | | C | - | C | - | - |
| *Dactyloctenium aegypticum* | DS | P | - | | - | - | - | - | - |
| *Digitaria abyssinica* | HD | C | P | C | - | - | - | P | - |
| *Digitaria scalarum* | LD | P | - | P | - | - | - | - | - |
| *Digitaria ternata* | HD | P | P | | P | - | P | - | P |
| *Enneapogon cenchriodes* | HD | - | | | - | - | P | - | - |
| *Entropogon macrostachyus* | DS | - | P | | - | P | - | - | P |
| *Eragraostis teniufolia* | DS | P | | | P | - | P | P | P |
| *Eragrostis braun ii* | DS | C | | | - | - | - | - | - |
| *Eragrostis cilianensis* | DS | C | P | P | P | P | P | P | P |
| *Eragrostis cylindrifolia* | LD | P | | | - | - | P | P | - |
| *Eragrostis habrantha* | DS | - | P | C | - | - | - | P | P |
| *Eragrostis superba* | DS | - | - | | - | - | - | P | C |
| *Harpanchene schimpri* | LD | P | - | | - | - | C | C | C |
| *Hetropogon conturtus* | LD | - | - | | P | - | P | C | - |
| *Hyperrhenia filipindula* | HD | - | - | - | - | - | P | - | - |
| *Leptothrium senegalense* | DS | P | P | - | - | - | - | - | - |
| *Microchloa kunthii* | LD | - | - | - | - | - | - | - | - |
| *Panicum maximum* | HD | P | | - | - | - | - | C | P |
| *Perotis patns* | HD | - | - | - | - | - | - | P | - |
| *Sporobolus pyramidalis* | DS | P | - | - | - | - | - | P | P |
| *Tetrapogon teneullus* | HD | C | P | C | - | D | P | P | C |
| **Legumes** | | | | | | | | | |
| *Crotolaria rosenii* | HD | D | D | D | D | D | C | C | C |
| *Crotolaria spinosa* | DS | D | D | C | D | C | C | C | C |
| *Indigofera spicata spira* | DS | D | D | C | D | C | C | C | C |
| **Sedges** | | | | | | | | | |
| *Cyperus bulbosus* | LD | C | C | P | C | - | C | C | C |
| *Cyperus obtusifloris* | LD | C | C | P | | - | - | - | - |
| **Other plants** | | | | | | | | | |
| *Occimum species* | | C | C | C | C | P | P | P | P |
| *Achyranthes aspara* | | D | D | C | D | C | D | C | P |
| *Tephrosiaspecies* | | C | P | P | D | P | P | P | P |
| *Tribulus terrestris* | | D | D | P | C | P | P | P | P |
| *Commelina benghalensis* | | C | C | P | C | P | P | P | P |
| *Sida ovata* | | C | C | P | P | P | P | P | P |
| *Bidens pilosa* | | D | D | C | P | C | D | C | P |

*Cate = Categories, HD = Highly desirable; DS = Desirable; LD = Less desirable; P = Present (<5% of DM); C = Common (>5% and <20% of DM), D = Dominant (>20% of DM), (Amsalu and Baars 2002) CM = Communal grazing areas, R = Riverside grazing areas and E = Enclosure*

**Annex table 2.** Herbaceous species identified in different altitude categories and grazing types of Hamer district

| Grasses | Category | 550-900 m | | | 900-1250m | | >1250-1550 m | | >1550m | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CM | R | E | CM | E | CM | E | R | E |
| Aristida adscensionsis | LD | C | P | - | P | - | P | - | - | - |
| *Aristida somalensis* | LD | P | - | - | P | - | - | - | - | - |
| *Bothriochola insculpta* | HD | C | C | - | P | - | P | - | - | - |
| *Brachiara dictyonuera* | DS | P | C | - | P | - | - | - | - | - |
| *Brachiaria mutica* | HD | P | - | - | - | - | - | - | - | - |
| *Cenchrus ciliaris* | HD | P | - | D | P | C | P | C | - | C |
| *Chloris pycnohtrix* | LD | - | - | C | - | - | - | - | - | - |
| *Chloris preurii* | DS | - | - | | - | - | - | - | - | - |
| *Chloris roxbarghiana* | DS | - | - | C | - | - | - | - | - | - |
| *Cynodon dactylon* | DS | P | P | | P | C | C | - | D | D |
| *Cynodon plectostchyum* | DS | P | - | | C | - | P | - | P | P |
| *Dactyloctenium aegypticum* | DS | P | - | | - | - | - | - | - | - |
| *Digitaria abyssinica* | HD | P | - | C | - | - | - | - | - | - |
| *Digitaria scalarum* | LD | P | - | P | P | - | P | - | - | - |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Digitaria ternata* | HD | P | - | | P | - | - | P | - | - |
| *Enneapogon cenchriodes* | HD | P | - | | P | - | - | - | - | - |
| *Entropogon macrostachyus* | DS | - | - | | - | P | - | P | - | - |
| *Eragraostis teniufolia* | DS | P | P | | P | - | P | P | C | C |
| *Eragrostis braunii* | DS | P | - | | - | - | P | - | - | - |
| *Eragrostis cilianensis* | DS | P | P | P | P | P | P | P | P | P |
| *Eragrostis cylindrifolia* | LD | P | C | | - | - | - | - | - | - |
| *Eragrostis habrantha* | DD | P | - | P | C | - | P | P | P | P |
| *Eragrostis superba* | DD | P | P | - | P | - | - | C | - | - |
| *Harpanchene schimprii* | LD | P | - | - | P | - | - | C | - | - |
| *Hetropogon conturtus* | LD | P | - | - | - | - | - | - | - | - |
| *Hyperrhenia filipindula* | HD | P | - | - | - | - | - | - | - | - |
| *Leptothrium senegalense* | DS | P | - | - | P | - | - | - | - | - |
| *Microchloa kunttii* | LD | P | - | - | - | - | - | - | - | - |
| *Panicum maximum* | HD | C | - | - | - | - | - | P | - | - |
| *Perotis patns* | HD | P | - | - | - | - | - | - | - | - |
| *Sporobolus pyramidalis* | DS | P | - | - | P | - | P | P | - | - |
| *Tetrapogon teneullus* | HD | C | P | C | C | D | C | C | P | P |
| **Legumes** | | | | | | | | | | |
| *Crotolaria rosenii* | HD | C | C | D | C | D | C | C | P | P |
| *Crotolaria spinosa* | DS | C | C | C | D | C | C | C | - | |
| *Indigofera spicata spira* | DS | C | C | C | D | C | P | C | C | P |
| Sedges | | | | | | | | | | |
| *Cyperus bulbosus* | LD | P | P | P | C | - | C | C | P | P |
| *Cyperus obtusifloris* | LD | - | - | P | P | - | P | - | | |
| Other plants | | | | | | | | | | |
| *Occimum species* | | P | P | C | P | P | P | P | | |
| *Achyranthes aspara* | | D | D | C | D | C | D | P | P | P |
| *Tephrosia species* | | P | P | P | C | P | P | P | P | P |
| *Tribulus terrestris* | | C | C | P | C | P | C | P | | |
| *Commelina benghalensis* | | P | P | P | P | P | P | P | P | P |
| Sida ovata | | P | P | P | C | P | P | | P | P |
| Bidens pilosa | | C | C | C | D | C | C | | P | P |

*Cate = Categories, HD = Highly desirable; DS = Desirable; LD = Less desirable; P = Present (<5% of DM); C = Common (>5% and <20% of DM), D = Dominant (>20% of DM), (Amsalu and Baars, 2002) CM = Communal grazing areas, R= Riverside grazing areas and E = Enclosure*

**Annex table 3.** Woody species density in percentage per hectare in Benna-Tsemay district

| Woody species | Pala gr. | 550-900m | | | 900-1250m | | 1250-1550m | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **CM** | **R** | **E** | **CM** | **E** | **CM** | **R** | **E** |
| Acacia brevispica | Int | 3.12 | - | 32.3 | 3.55 | 9.83 | 2.72 | 2.5 | 28.3 |
| *Acacia Senegal* | Int | 3.93 | 2.92 | 35.1 | 3.86 | 23.62 | 5.96 | 3.96 | 35.65 |
| *Acacia mellifera* | Int | 0.25 | 0.65 | 2.3 | 1.25 | - | 5.58 | 3.65 | - |
| *Acacia nubica* | Hpl | 2.5 | 2.75 | 2 | 2.67 | 9.87 | 3.62 | 5.91 | - |
| *Acacia tortilis* | Hpl | 25.65 | 25.85 | 28.3 | 3.89 | 19.23 | 2.63 | 2.53 | 2.78 |
| *Acacia nilotica* | Hpl | 2.63 | 2.6 | - | 10.6 | 19.65 | 2.75 | 3.4 | - |
| *Azanga garcheana* | Int | | 1.92 | - | - | - | 1.52 | 1.69 | - |
| *Acacia terminalia* | Int | 2.23 | 2.65 | - | 2.35 | 9.2 | 2.58 | 2.3 | - |
| *Asparegus spps* | Int | 0.25 | - | - | - | - | - | - | - |
| *Boswellia boranensis* | Upl | 2.25 | 2.7 | - | 2.45 | 8.6 | - | - | - |
| *Calpurnia subdecandra* | Int | - | - | - | | - | - | - | - |
| *Celtis kraussiana* | Int | - | - | - | - | - | 0.3 | 0.65 | - |
| *Commiphora africana* | Int | 2.75 | 3.87 | - | 3.97 | - | 10.23 | 3.96 | - |
| *Commiphora erlangerana* | Int | - | - | - | - | - | 0.61 | 5.78 | - |
| *Cordia gharaf* | Int | - | - | - | - | - | - | - | - |
| *Cucumis prophetarum* | Int | 2.21 | - | - | 0.75 | - | 22.6 | 6.89 | - |
| *Galiniera coffeoides* | Hpl | 0.74 | 0.85 | - | - | - | - | - | - |
| *Grewia bicolor* | Hpl | 0.74 | 2.85 | - | 3.85 | - | 1.33 | 2.35 | 9.67 |
| *Grewia villosa* | Hpl | 0.25 | 1.5 | - | 10.65 | - | 1.25 | 2.45 | - |
| *Grewia tenax* | Hpl | 3.93 | 3.83 | - | - | - | 0.93 | 1.65 | - |
| *Olea africana* | Hpl | - | - | - | - | - | - | - | - |
| *Rhus natalensis* | Int | 1.25 | 1.12 | - | 1.2 | - | 0.93 | 0.65 | - |
| *Salvadora persica* | Int | 0.25 | 0.75 | - | 11.4 | - | - | - | - |
| *Securinega virosa* | Int | 0.25 | 0.35 | - | - | - | 1.93 | 0.43 | 23.6 |
| *Solanum* species | Unt | 44.82 | 42.84 | - | 37.56 | - | 30.67 | 46.3 | - |
| *Ximenia americana* | Int | - | - | - | | - | 0.47 | 1.3 | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Zizyphus mucronata* | Int | - | - | - | - | - | 0.65 | 0.8 | - |
| *Zizphus spina- spina Christi* | Int | - | - | - | - | - | 0.74 | 0.85 | - |

*Pala. Gr = Palatability groups; Hpl = Highly palatable; Int = Intermediate palatability; Upl = Unpalatable; P = Present <10% of density), C = Common (>10% and <20% of density), D = Dominant (>20% of density), CM = Communal grazing areas; R = Riverside grazing areas and E = Enclosure*

**Annex table 4.** Woody species density in percentage per hectare in Hamer district

| Woody species | Pala gr. | 550-900m | | | 900-1250m | | 1250-1550m | | | >1550m | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CM | R | E | CM | E | CM | R | E | R | E |
| Acacia brevispica | Int | 3.93 | - | 4.3 | 3.55 | 4.83 | 2.72 | 2.5 | 28.3 | 3.65 | 4.25 |
| *Acacia Senegal* | Int | 3.12 | 2.92 | 38.58 | 3.86 | 4.62 | 5.96 | 3.96 | 35.65 | - | - |
| *Acacia mellifera* | Int | 0.25 | 0.65 | 4.3 | 1.25 | - | 5.58 | 3.65 | - | - | - |
| *Acacia nubica* | Hpl | 2.5 | 2.75 | 4.52 | 2.67 | 4.87 | 3.62 | 5.91 | - | 4.96 | 4.98 |
| *Acacia tortilis* | Hpl | 28.65 | 21.85 | 48.3 | 3.89 | 39.23 | 2.63 | 2.53 | 2.78 | - | - |
| *Acacia nilotica* | Hpl | 2.63 | 2.6 | - | 10.6 | 28.65 | 2.75 | 3.4 | - | 9.67 | 45.6 |
| *Azanga garcheana* | Int | | 1.92 | - | - | - | 1.52 | 1.69 | - | 25.1 | - |
| *Acacia terminalia* | Int | 2.23 | 2.65 | - | 2.35 | 9.2 | 2.58 | 2.3 | - | 3.5 | 2.57 |
| *Asparegus spps* | Int | 0.25 | - | - | - | - | - | - | - | - | - |
| *Boswellia boranensis* | Upl | 4.25 | 2.7 | - | 2.45 | 8.6 | - | - | - | - | - |
| *Calpurnia subdecandra* | Int | - | - | - | | - | - | - | - | 4.33 | - |
| *Celtis kraussiana* | Int | - | - | - | - | - | 0.3 | 0.65 | - | - | - |
| *Commiphora africana* | Int | 4.75 | 3.87 | - | 3.97 | - | 10.23 | 3.96 | - | 27.1 | - |
| *Commiphora erlangerana* | Int | - | - | - | - | - | 0.61 | 5.78 | - | - | - |
| *Cordia gharaf* | Int | - | - | - | - | - | - | - | - | - | - |
| *Cucumis prophetarum* | Int | 2.21 | - | - | 0.75 | - | 22.6 | 6.89 | - | - | - |
| *Galiniera coffeoides* | Hpl | 0.74 | 0.85 | - | - | - | - | - | - | - | - |
| *Grewia bicolor* | Hpl | 0.74 | 2.85 | - | 3.85 | - | 1.33 | 2.35 | 9.67 | - | - |
| *Grewia villosa* | Hpl | 0.25 | 1.5 | - | 10.65 | - | 1.25 | 2.45 | - | - | - |
| *Grewia tenax* | Hpl | 3.93 | 3.83 | - | - | - | 0.93 | 1.65 | - | - | - |
| *Olea Africana* | Hpl | - | - | - | - | - | - | - | - | 4.94 | 43.6 |
| *Rhus natalensis* | Int | 1.25 | 1.12 | - | 1.2 | - | 0.93 | 0.65 | - | 8.62 | - |
| *Salvadora persica* | Int | 0.25 | 0.75 | - | 11.4 | - | - | - | - | - | - |
| *Securinega virosa* | Int | 0.25 | 0.35 | - | - | - | 1.93 | 0.43 | 23.6 | - | - |
| *Solanum* species | Unt | 37.82 | 46.84 | - | 37.56 | - | 30.67 | 46.3 | - | 9.67 | - |
| *Ximenia Americana* | Int | - | - | - | | - | 0.47 | 1.3 | - | - | - |
| *Zizyphus mucronata* | Int | - | - | - | - | - | 0.65 | 0.8 | - | - | - |
| *Zizphus spina- spina christi* | Int | - | - | - | - | - | 0.74 | 0.85 | - | - | - |

*Pala. Gr = Palatability groups; Hpl = Highly palatable; Int = Intermediate palatability; Upl = Unpalatable; P =Present (<10% of density), C = Common (>10% and <20% of density), D = Dominant (>20% of density), CM =Communal grazing areas; R = Riverside grazing areas and E = Enclosure.*

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