

Supplementary Materials: Analysis of Vegetation Phytosociological Characteristics and Soil Physico-Chemical Conditions in Harishin Rangelands of Eastern Ethiopia

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The Somali Regional State is a major pastoral habitat in Ethiopia. It has a total land area of about 327,000 km² of which, about 90% is classified as rangeland. Like other arid and semi-arid rangeland ecosystems in the country, the rangelands in the region have long been exposed to extensive livestock grazing pressures. For instance, the pastoralists in the Harshin District in the region have been using enclosures in response to declining rangeland resources. Various studies were conducted to assess the direction of vegetation change in the context of rangeland enclosures to estimate dry matter yields and to indirectly measure the species composition.

However, no study has been conducted using the phytosociological data analysis method for rangeland vegetation layers of the rangelands in Ethiopia in general and the Harishin rangelands in particular. Such an analysis is important to provide detailed information on vegetation social status and to offer insights on rangeland ecosystem function and its restoration.

Therefore, the supplementary materials of listed below tables are used to analyse the phytosociological characteristics of the Harishin rangelands vegetation and soil parameters.

Table S1. Attributes of herbaceous species in enclosure areas averaged for 12 plots used for analyzing frequency, density, abundance, and Importance Value Index (IVI) in the Harishin Rangelands of Ethiopia.

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Table S2. Attributes of herbaceous species in open grazing areas averaged for 12 plots used for analyzing frequency, density, abundance, and Importance Value Index (IVI) in Harishin Rangelands of Ethiopia.

Species Scientific Name	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Plot 12
<i>Abutilon fruticasum</i>	0	4.42	4.08	0	0	0	0	0	0	0	0	0
<i>Acanthospermum hispidum</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Achyranthus aspera</i>	3	0	0	0	0	0	0	0	0	2	0	0
<i>Aristida adoensis</i>	0	0	0	5.08	0	0	0	0	0	0	0	0
<i>Aristida adscensionis</i>	0	0	5.5	0	4.75	0	0	0	0	0	1.08	0
<i>Balenites aegyptiaca</i>	0	0	0	0	0	0	0	0	0	5.08	0	0
<i>Blepharis ciliaris</i>	3.25	1.17	0.58	0	0	0	0	0	0	0	0	0
<i>Cenchrus ciliaris</i>	3.08	6.5	5	0	0	0	8.08	6.67	0	0	5.17	1
<i>Chrysopogon aucheri</i>	4.08	0	0	0	0	0	5.08	0	5.25	0	0	0
<i>Crotalaria laburnifolia</i>	1.75	1.08	0	0	0	1.83	4.25	0	5.17	0	0	3.83
<i>Cynodon dactylon</i>	0.5	2.17	22.58	0	0	0	19.33	11.08	6.25	0	0	6.5
<i>Dactyloctenium aegyptium</i>	0	0	1.58	0	0	0	0	0	0	0	0	0
<i>Dactyloctenium scindicum</i>	0	0	0	0	0	0	3.75	5.17	0	0	2.83	0
<i>Eragrostis aspera</i>	7.83	247.5	0	0	124.42	2.58	45.08	0.25	46.25	0	0	0
<i>Eragrostis cilianensis</i>	0	0	17	88.75	0	41.92	25.58	0	0	0	0	0
<i>Eragrostis ciliaris</i>	5.58	0	0	0	0	0	0	0	0	7.33	13	0
<i>Eragrostis schludefurthii</i>	0	0	0	0	0	0	0	0	0	0	0	3.58
<i>Eragrostis sp</i>	0	0	0	0	0	0	0	0	0	0	3.75	0
<i>Eragrostis superba</i>	0	0	0	0	0	0	0	0	11.08	0	3.08	0
<i>Eriachloa colonum</i>	0	0	0	0	0	0	0	0	0	0	0.58	0
<i>Gomphocarpus fruticosus</i>	0	6.67	0	0	0	0	0	0	0	0	0	3.33
<i>Heliotropium somalense</i>	0	3.58	0	1.83	1.5	0	0	0	0	0	0	0.42
<i>Heliotropium zeylonicum</i>	0	0	0	0	0	0	6.58	0	0	0	0	0
<i>Hibiscus aponeurus</i>	2.58	0	0	2	2.42	0	8.25	0	9.58	0	0	0
<i>Indigofera articulate</i>	0	0	0	0	0	0	7.67	4.17	0	0	0	0
<i>Lactuca sativa</i>	0	0	1.83	0	0	0	0	0	0	0	0	0
<i>Leucas microphylla</i>	0	0.17	0	0	0	0	0	0	0	1.17	0	0
<i>Ocimum lamiiifolium</i>	0	0	0	0	2.17	2.08	0	0	4.58	0	2.58	3.33
<i>Ocimum urticifolium</i>	0	3.75	0	1.58	0	0	0	1.58	0	0	0	0
<i>Panicum atrosanguineum</i>	15	0	0	1.83	1.58	0	3.83	3.17	3.92	0	0	0
<i>Parthenium hysterophorus</i>	0	0	0	0	0	0	0	0	0	0	2.42	0
<i>Senna occidentalis</i>	0	0.33	0	0.33	0.67	0	0	0	0	0	0	0

Table S5. Attributes of vegetation parameters using principal component analysis ordination and statistically compared with the 12 plots of each enclosure and the open-access communal grazing areas of the Harishin rangelands, Ethiopia.

Management Practices	Plot Code	Herb Diversity Exp (H')	Herb Richness	Herb Biomass	Herb Basal Cover %	Woody Richness	Woody Diversity Exp (H')	Woody Canopy
Enclosure	E1	10.18	17.00	420.69	88.00	3.00	1.84	8.98
Enclosure	E2	5.58	16.00	367.72	81.87	7.00	4.62	18.02
Enclosure	E3	5.05	10.00	428.86	83.40	5.00	3.82	9.72
Enclosure	E4	8.17	15.00	400.00	78.53	3.00	1.99	54.46
Enclosure	E5	7.17	23.00	581.16	84.53	3.00	1.99	71.73
Enclosure	E6	8.41	12.00	375.05	88.13	3.00	1.99	24.11
Enclosure	E7	7.77	12.00	387.54	83.80	4.00	2.20	12.98
Enclosure	E8	4.44	8.00	232.25	86.67	4.00	1.77	13.18
Enclosure	E9	4.22	9.00	319.63	74.80	4.00	2.08	30.17
Enclosure	E10	7.10	14.00	313.00	95.40	4.00	1.90	6.64
Enclosure	E11	4.71	14.00	440.01	93.40	4.00	2.69	14.47
Enclosure	E12	5.81	12.00	337.33	89.87	3.00	1.84	16.66
Open grazing	O1	10.91	13.00	171.14	24.20	6.00	3.67	42.31
Open grazing	O2	1.75	10.00	133.27	39.67	8.00	3.10	19.85
Open grazing	O3	5.93	11.00	147.78	20.60	4.00	5.10	30.11
Open grazing	O4	2.59	10.00	83.40	15.07	3.00	2.64	46.63
Open grazing	O5	1.79	8.00	112.67	18.87	5.00	3.71	72.12
Open grazing	O6	1.82	5.00	157.02	39.87	3.00	2.86	38.69
Open grazing	O7	4.81	12.00	204.15	36.20	3.00	1.97	31.36
Open grazing	O8	5.10	8.00	207.11	39.13	3.00	1.99	51.29
Open grazing	O9	3.86	9.00	176.32	30.87	3.00	2.64	44.00
Open grazing	O10	4.48	7.00	218.56	38.40	5.00	3.97	51.04
Open grazing	O11	4.31	6.00	196.08	33.93	4.00	3.78	20.73
Open grazing	O12	6.75	7.00	208.48	41.07	4.00	2.64	46.72

Table S6. Attributes of soil physico-chemical parameters using principal component analysis ordination and statistically compared with pooled six plots of each enclosure and the open-access communal grazing areas of the Harishin rangelands, Ethiopia.

Management Practices	Plot Code	P	K	SOC	SOM	N	EC	PH	Bulk Density	Sand %	Clay %	Silt %
Enclosure	E1	5.24	1.96	1.01	2.59	0.09	0.16	7.45	1.22	43.64	20.36	36
Enclosure	E2	7.73	1.99	1.20	2.07	0.1	0.17	7.41	1.05	51.64	12.36	36

Enclosure	E3	2.49	2.17	1.52	2.62	0.13	0.14	7.45	1.19	41.64	21.36	37
Enclosure	E4	2.32	1.73	1.31	2.26	0.11	0.18	7.4	1.22	51.64	16.36	32
Enclosure	E5	4.24	2.54	1.45	2.5	0.08	0.15	7.4	1.31	50	13.45	33
Enclosure	E6	5.27	2.15	1.59	2.74	0.11	0.13	7.45	1.21	47.2	14.03	34
Open grazing	O1	5.58	1.61	0.97	1.67	0.08	0.18	7.78	1.23	49.64	12.36	38
Open grazing	O2	10.39	1.6	1.50	1.74	0.13	0.68	7.42	1.23	47.64	14.36	38
Open grazing	O3	4.03	1.76	1.22	2.1	0.1	0.24	7.72	1.17	45.64	16.36	38
Open grazing	O4	6.35	1.64	0.76	1.31	0.07	0.17	7.75	1.19	45.64	20.36	34
Open grazing	O5	8.3	1.85	0.83	1.43	0.32	0.23	7.5	1.16	46	18	37
Open grazing	O6	6.95	1.58	0.73	1.25	0.24	0.59	7.73	1.18	47	20	35

Table S7. Herbaceous species relative dominance, relative frequency and relative density and IVI Distribution analysis in open grazing areas of the Harishin rangelands, Ethiopia.

Species Scientific Name	Relative Abundance	Relative Density	Relative Frequency	IVI
<i>Eragrostis aspera</i>	26.99	42.52	5.79	75.29
<i>Eragrostis cilianensis</i>	17.27	15.54	3.31	36.11
<i>Cynodon dactylon</i>	3.90	6.14	5.79	15.82
<i>Tragus racemosus</i>	3.12	4.22	4.96	12.30
<i>Cenchrus ciliaris</i>	2.02	3.18	5.79	10.99
<i>Panicum atrosanguineum</i>	1.95	2.63	4.96	9.54
<i>Tragus berteronianus</i>	1.56	2.10	4.96	8.62
<i>Hibiscus aponeurus</i>	1.98	2.23	4.13	8.34
<i>Eragrostis ciliaris</i>	3.44	2.33	2.48	8.25
<i>Crotalaria laburnifolia</i>	1.19	1.61	4.96	7.76
<i>Solanum incanum</i>	0.80	1.08	4.96	6.85
<i>Ocimum lamiifolium</i>	1.18	1.32	4.13	6.63
<i>Eragrostis superba</i>	2.82	1.27	1.65	5.75
<i>Chrysopogon aucheri</i>	1.92	1.29	2.48	5.69
<i>Solanum somalense</i>	1.02	0.92	3.31	5.25
<i>Dactyloctenium scindicum</i>	1.56	1.05	2.48	5.09
<i>Indigofera articulata</i>	2.36	1.06	1.65	5.07
<i>Aristida adscencionis</i>	1.51	1.02	2.48	5.00

<i>Heliotropium somalense</i>	0.73	0.66	3.31	4.69
<i>Gomphocarpus fruticosus</i>	1.99	0.90	1.65	4.54
<i>Sida</i> sp.	1.18	0.80	2.48	4.46
<i>Abutilon fruticasum</i>	1.69	0.76	1.65	4.11
<i>Heliotropium zeylonicum</i>	2.62	0.59	0.83	4.04
<i>Ocimum urticifolium</i>	0.92	0.62	2.48	4.02
<i>Blepharis ciliaris</i>	0.66	0.45	2.48	3.59
<i>Sporobolus marginatus</i>	1.25	0.56	1.65	3.46
<i>Aristida adoensis</i>	2.03	0.46	0.83	3.31
<i>Balanites aegyptiaca</i>	2.03	0.46	0.83	3.31
<i>Achyranthus aspera</i>	1.00	0.45	1.65	3.10
<i>Senna occidentalis</i>	0.18	0.12	2.48	2.78
<i>Eragrostis</i> sp	1.49	0.34	0.83	2.66
<i>Eragrostis schluenifurthii</i>	1.43	0.32	0.83	2.58
<i>Setaria verticillata</i>	1.40	0.31	0.83	2.54
<i>Leucas microphylla</i>	0.27	0.12	1.65	2.04
<i>Parthenium hysterophorus</i>	0.96	0.22	0.83	2.01
<i>Lactuca sativa</i>	0.73	0.16	0.83	1.72
<i>Dactyloctenium aegyptium</i>	0.63	0.14	0.83	1.60
<i>Eriachloa colonum</i>	0.23	0.05	0.83	1.11

A/F = abundance to frequency ratio; IVI = Importance Value Index

Table S8. Herbaceous species relative dominance, relative frequency and relative density and IVI Distribution analysis in enclosure areas of the Harishin rangelands, Ethiopia.

Species Scientific Name	Relative Abundance	Relative Frequency	Relative Density	IVI
<i>Cynodon dactylon</i>	8.43	5.93	19.60	33.96
<i>Eragrostis cilianensis</i>	16.85	2.22	14.68	33.75
<i>Cenchrus ciliaris</i>	5.47	7.41	15.89	28.78
<i>Chrysopogon aucheri</i>	3.42	5.93	7.94	17.29
<i>Aristida adscensionis</i>	6.21	2.22	5.41	13.84
<i>Dactyloctenium scindicum</i>	2.35	4.44	4.09	10.89
<i>Aristida adoensis</i>	5.17	0.74	1.50	7.42

<i>Dactyloctenium aegyptium</i>	5.17	0.74	1.50	7.42
<i>Ocimum lamiifolium</i>	0.73	5.19	1.49	7.40
<i>Crotalaria laburnifolia</i>	1.78	2.96	2.06	6.80
<i>Panicum atrosanguineum</i>	1.25	3.70	1.81	6.76
<i>Eragrostis aspera</i>	2.35	2.22	2.05	6.62
<i>Crotalaria albicaulis</i>	1.60	2.96	1.86	6.42
<i>Heliotropium somalense</i>	2.16	2.22	1.88	6.27
<i>Ageratum conyzoides</i>	2.99	1.48	1.74	6.21
<i>Panicum sp</i>	3.82	0.74	1.11	5.67
<i>Lactuca sativa</i>	1.70	2.22	1.48	5.40
<i>Sporobolus marginatus</i>	0.65	3.70	0.95	5.30
<i>Sansevieria abyssinica</i>	3.42	0.74	0.99	5.15
<i>Chloris radiota</i>	1.01	2.96	1.17	5.14
<i>Tephrosia emeroides</i>	1.54	2.22	1.34	5.10
<i>Parthenium hysterophorus</i>	1.64	1.48	0.95	4.08
<i>Setaria verticillata</i>	0.95	2.22	0.83	4.00
<i>Hibiscus aponeurus</i>	1.39	1.48	0.81	3.68
<i>Asparagus asiaticus</i>	0.76	2.22	0.66	3.64
<i>Tephrosia interrupta</i>	1.11	1.48	0.64	3.24
<i>Crotalaria radiota</i>	1.89	0.74	0.55	3.18
<i>Ocimum urficifolium</i>	0.95	1.48	0.55	2.98
<i>Sida sp</i>	0.22	2.22	0.19	2.63
<i>Eragrostis sp</i>	1.33	0.74	0.39	2.46
<i>Oxygonum atriplicifolium</i>	1.27	0.74	0.37	2.39
<i>Achyranthus aspera</i>	0.32	1.48	0.19	1.99
<i>Bothriochlea insulpta</i>	0.32	1.48	0.19	1.99
<i>Setaria acromelaena</i>	0.31	1.48	0.18	1.97
<i>Commicarpus verticillatus</i>	0.95	0.74	0.27	1.96
<i>Hibiscus trionum</i>	0.95	0.74	0.27	1.96
<i>Senna occidentalis</i>	0.28	1.48	0.16	1.92
<i>Leucas microphylla</i>	0.25	1.48	0.15	1.88
<i>Abutilon frutica</i>	0.83	0.74	0.24	1.81

<i>Blepharis ciliaris</i>	0.20	1.48	0.12	1.80
<i>Indigofera articulate</i>	0.66	0.74	0.19	1.59
<i>Crotalaria natalitia</i>	0.62	0.74	0.18	1.54
<i>Hibiscus aspera</i>	0.60	0.74	0.17	1.51
<i>Sansevieria sp</i>	0.58	0.74	0.17	1.49
<i>Senna obtusifolia</i>	0.58	0.74	0.17	1.49
<i>Launea intyrbacea</i>	0.56	0.74	0.16	1.46
<i>Hypoestes forskafii</i>	0.54	0.74	0.16	1.44
<i>Tragus berteronionus</i>	0.54	0.74	0.16	1.44
<i>Sonchus oleraceus</i>	0.25	0.74	0.07	1.06
<i>Enteropogon elegans</i>	0.23	0.74	0.07	1.04
<i>Tragus racemosus</i>	0.23	0.74	0.07	1.04
<i>Cucumis ficifolius</i>	0.19	0.74	0.06	0.99
<i>Flaveria terinervia</i>	0.15	0.74	0.04	0.94
<i>Tagetes minuta</i>	0.15	0.74	0.04	0.94
<i>Verbesina encelioides</i>	0.12	0.74	0.03	0.89

A/F = abundance to frequency ratio; IVI = Importance Value Index

Table S9. Woody species relative dominance, relative frequency and relative density and IVI Distribution analysis species in open grazing areas of the Harishin rangelands, Ethiopia.

Spp	Relative Frequency	Relative Canopy	Relative Density	IVI
<i>Acacia busie</i>	19.57	9.16	29.40	58.13
<i>Acacia nilotica</i>	19.57	8.84	22.82	51.23
<i>Acacia etbica</i>	15.22	12.55	21.86	49.62
<i>Acacia toritilis</i>	6.52	30.51	2.51	39.55
<i>Acacia melifera</i>	15.22	4.17	15.09	34.48
<i>Acacia abyssinica</i>	6.52	25.35	2.32	34.20
<i>Acacia oerfota</i>	4.35	8.34	0.58	13.26
<i>Balenites aegyptiaca</i>	6.52	0.21	3.68	10.41
<i>Securinega virosa</i>	6.52	0.86	1.74	9.13

A/F = abundance to frequency ratio; IVI = Importance Value Index

Table S10. Woody species relative dominance, relative frequency and relative density and IVI Distribution analysis species in enclosure areas of the Harishin rangelands, Ethiopia.

Values	Relative Canopy Cover	Relative Density	Relative Frequency	IVI
<i>Acacia nilotica</i>	26.6500134	35.36231884	32.43246749	94.4448
<i>Acacia etbica</i>	22.09501567	44.34782609	21.621645	88.06449
<i>Acacia busie</i>	34.48212901	8.985507246	18.91893937	62.38658
<i>Acacia melifera</i>	9.351184518	4.057971014	10.8108225	24.21998
<i>Securinea virosa</i>	1.997781774	4.927536232	5.405411249	12.33073
<i>Acacia nubica</i>	3.426103881	1.15942029	5.405411249	9.990935
<i>Grewia ferruginea</i>	1.997781774	1.15942029	5.405411249	8.562613

A/F = abundance to frequency ratio; IVI = Importance Value Index