

Supporting information to the paper: Dovrat, G. et al. 2021, "Can grazing moderate climatic effects on herbage nutritional quality?"

Supplementary Materials.

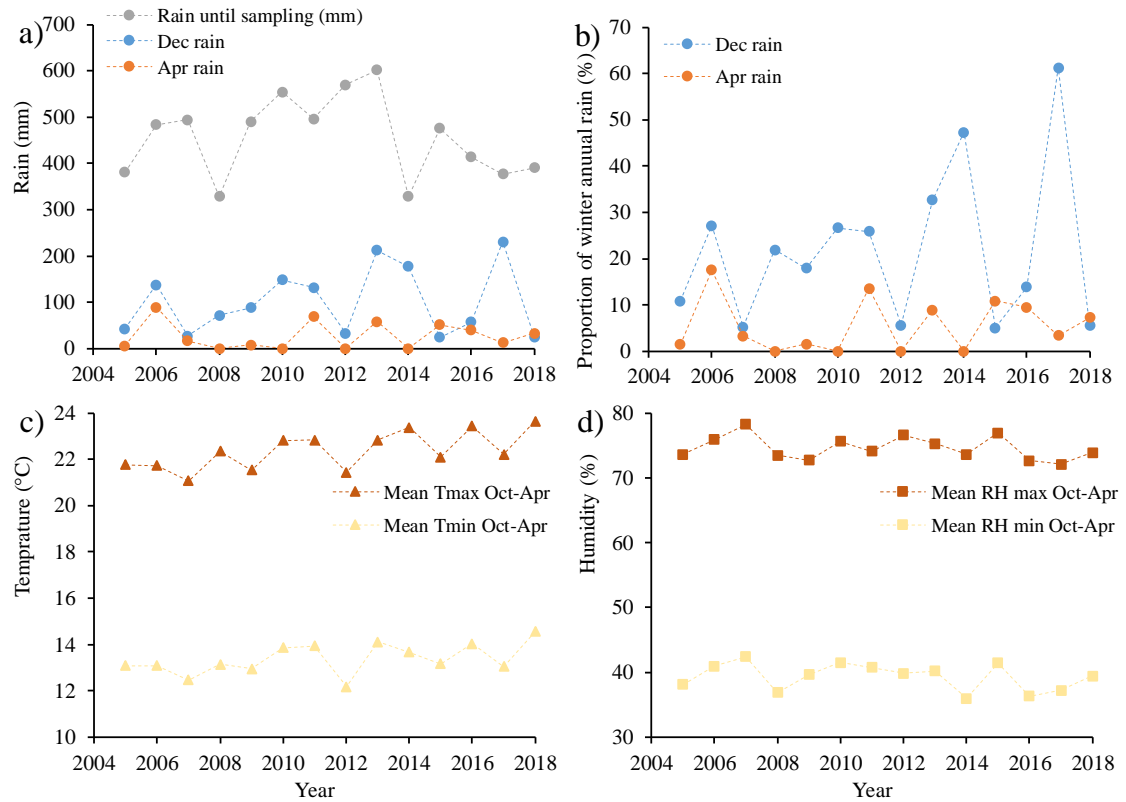


Figure S1. Climate data measured at the Karei Deshe Experimental Range Station during the research period, 2005–2018. Nine average climate variables included: accumulated seasonal rainfall amount (until the date of vegetation sampling, mm) presented alongside the amount of accumulated rain until December and until April (a), and the proportions of these rainfall amounts (i.e., percentages of total seasonal rainfall) (b), maximum and minimum temperatures (°C) (c), and maximum and minimum relative air humidity (%) measured daily between October and April (d).

Table S1. Calibration performance of the NIRS equations for herbage nutritional composition. SD is the standard deviation of nutritional parameters; SEC and SECV are the standard errors of calibration and cross-validation; R^2_{cal} and R^2_{cv} represent linearities of calibration and cross-validation, respectively; RPD (ratio per deviation) is an estimate of calibration quality. Calibrations use the first derivative of NIR spectra.

	N	Mean	SD	SEC	R^2_{cal}	SE _{cv}	R^2_{CV}	RPD
ash (g/kg DM)	302	11.10	3.22	0.72	0.95	1.50	0.83	3.88
CP (g/kg DM)	329	9.89	6.41	0.51	0.99	0.69	0.99	6.48
NDF (g/kg DM)	328	59.20	10.76	1.71	0.97	2.23	0.96	11.22
ADF (g/kg DM)	331	35.13	8.00	1.14	0.98	1.37	0.97	8.24
IVDMD (% of DM)	188	63.22	15.26	2.61	0.97	3.69	0.94	16.15

Tables S2. Results of the most parsimonious models for each of the five nutritional parameters.

The general structure of the models is:

$$Y_i(t) = a_0 + g_i + b \cdot X(t) + c_i \cdot X(t)$$

where $Y_i(t)$ is the value of the nutritional parameter in plot i at year t , a_0 is a general intercept, g_i is a treatment-specific intercept for the grazing intensity treatment in plot i , b is the slope of the effect of $X(t)$, a climate variable in year t , and c_i is a treatment specific slope for the interactive effect of grazing intensity in plot i and the climate variable in year t .

Parameter	Meaning	MLE (Lower – Upper S.I.)				
		NDF as affected by treatment and Maximum daily temperature. Additive model.	Protein as affected by treatment and Maximum daily temperature. Additive with interaction model.	Digestibility as affected by treatment and Maximum daily temperature. Additive with interaction model.	ADF as affected by treatment and Proportion of rain in December. Additive with interaction model.	Ash as affected by treatment and minimum humidity. Additive with interaction model.
a_0	General intercept	-63.671 (-64.918 -62.467)	21.528 (21.312 21.528)	59.432 (58.837 60.026)	1.809 (1.483 2.123)	-36.291 (-36.874 -35.692)
g_1	No grazing intercept	39.251 (38.073 40.036)	1.007 (0.574 1.443)	96.68 (95.713 97.647)	34.771 (34.424 35.119)	39.07 (38.679 39.461)
g_2	Heavy grazing intercept	33.187 (32.192 34.183)	32.429 (32.104 32.753)	100 (99 100)	31.602 (31.286 32.234)	14.213 (13.787 14.557)
g_3	Moderate grazing intercept	38.1 (36.957 39.243)	3.578 (3.113 3.964)	98.541 (97.555 99.526)	34.282 (33.939 34.624)	32.724 (32.396 33.051)
g_4	Very heavy grazing intercept	31.965 (31.006 32.924)	32.808 (32.479 33.136)	103.411 (102.377 104.445)	31.11 (30.488 31.421)	23.698 (23.461 23.935)
b	linear slope of climate variable	3.995 (33.995 33.995)	-100 (-100 -98.121)	-4.594 (-4.671 -4.518)	-83.974 (-85.983 -81.939)	1.877 (1.877 1.877)
c_1	Linear slope of the Interaction climate variable × Control treatment	-	29.162 (27.412 30.87)	-	91.344 (89.517 93.171)	-1.689 (-1.716 -1.659)
c_2	Interaction climate factor × Heavy grazing	-	-100 (-100 -97.156)	-	100 (98 100)	-1.042 (-1.064 -1.02)
c_3	Interaction Climate variable × Moderate grazing	-	19.647 (17.733 21.254)	-	92.79 (90.934 94.645)	-1.527 (-1.554 -1.501)
c_4	Interaction Climate variable × Very heavy grazing	-	-100 (-100 -97.212)	-	94.757 (92.862 96.652)	-1.271 (-1.295 -1.247)
sd	Normal error model parameter	5.378 (5.002 5.775)	1.988 (1.850 2.148)	6.26 (5.822 6.72)	2.941 (2.765 3.199)	2.081 (1.936 2.226)

Tables S3-S7. Comparison of models that test the effects of grazing intensity treatments and climate variables on herbage nutritional quality parameters. We used additive and multiplicative linear models with one of nine climate variables (as a continuous factor), four grazing treatments, their interaction and the intercept. All models were compared for each nutritional parameter, based on the Akaike information criterion corrected for a small sample size (AICc).

Table S3. Comparison of alternative models for NDF (%) of herbage. The models appear according to the order of AICc, with the most parsimonious model first in bold.

Model type	Climate variable	Maximum likelihood	No. Parameters	AICc	R ²
Linear	Maximum daily temperature between October and April	-1034.302	7	2082.947	0.402
Linear	Maximum daily temperature between October and April	-1041.368	6	2094.994	0.376
linear + interaction	Maximum daily temperature between October and April	-1048.031	11	2118.883	0.350
Intercept	Minimum daily relative humidity between October and April	-1053.002	7	2120.348	0.331
linear + interaction	Minimum daily relative humidity between October and April	-1049.021	11	2120.863	0.347
linear + interaction	Minimum daily relative humidity between October and April	-1053.283	7	2120.910	0.330
linear + interaction	Minimum daily relative humidity between October and April	-1053.289	7	2120.921	0.347
linear + interaction	Proportion of rain in December	-1050.062	11	2122.945	0.343
Linear	Minimum daily relative humidity between October and April	-1055.656	6	2123.569	0.320
linear + interaction	Maximum daily relative humidity between October and April	-1051.083	11	2124.986	0.338
linear + interaction	Maximum daily relative humidity between October and April	-1051.233	9	2125.286	0.338
linear + interaction	Rain in December	-1058.217	11	2139.254	0.310
linear + interaction	Minimum daily temperature between October and April	-1063.531	11	2149.881	0.287
Linear	Maximum daily temperature between October and April	-1082.331	3	2170.661	0.202
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-1079.109	8	2174.661	0.218
ANOVA	-	-1083.234	5	2176.651	0.198
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-1077.099	11	2177.018	0.227
Intercept	-	-1083.231	6	2178.719	0.198
linear + interaction	Rain in April	-1081.299	11	2185.418	0.207
linear + interaction	Proportion of rain in April	-1081.434	11	2185.688	0.207
Linear	Minimum daily relative humidity between October and April	-1096.441	3	2198.954	0.132

Table S4. Comparison of alternative models for protein (%) of herbage. The models appear according to the order of AICc, with the most parsimonious model first in bold.

Model type	Climate variable	Maximum likelihood	No. Parameters	AICc	R ²
linear + interaction	Maximum daily temperature between October and April	-703.676	11	1430.171	0.440
Linear	Maximum daily temperature between October and April	-715.686	6	1443.630	0.398
Linear	Maximum daily temperature between October and April	-715.698	7	1445.740	0.398
linear + interaction	Minimum daily relative humidity between October and April	-724.541	11	1471.903	0.365
linear + interaction	Minimum daily relative humidity between October and April	-728.848	7	1472.040	0.365
linear + interaction	Minimum daily relative humidity between October and April	-728.860	7	1472.064	0.349
Intercept	Minimum daily relative humidity between October and April	-730.462	7	1475.268	0.342
linear + interaction	Proportion of rain in December	-729.188	11	1481.196	0.347
linear + interaction	Maximum daily relative humidity between October and April	-729.766	11	1482.353	0.345
linear + interaction	Maximum daily relative humidity between October and April	-729.874	9	1482.567	0.345
linear + interaction	Minimum daily temperature between October and April	-730.627	11	1484.073	0.342
linear + interaction	Rain in December	-733.551	11	1489.923	0.330
Linear	Minimum daily relative humidity between October and April	-741.529	6	1495.315	0.297
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-754.471	8	1525.385	0.241
ANOVA	-	-757.900	5	1525.983	0.225
Intercept	-	-757.899	6	1528.054	0.225
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-753.834	11	1530.488	0.244
linear + interaction	Rain in April	-754.149	11	1531.117	0.242
linear + interaction	Proportion of rain in April	-754.359	11	1531.539	0.241
Multiplicative	Maximum daily temperature between October and April	-762.641	6	1537.540	0.203
Linear	Maximum daily temperature between October and April	-768.954	3	1543.98	0.172

Table S5. Comparison of alternative models for digestibility (%) of herbage. The models appear according to the order of AICc, with the most parsimonious model first in bold.

Model type	Climate variable	Maximum likelihood	No. Parameters	AICc	R ²
Linear	Maximum daily temperature between October and April	-1085.036	7	2184.415	0.329
linear + interaction	Maximum daily relative humidity between October and April	-1091.585	9	2205.990	0.302
linear + interaction	Maximum daily relative humidity between October and April	-1092.070	11	2206.961	0.300
linear + interaction	Maximum daily relative humidity between October and April	-1097.326	7	2208.996	0.302
Intercept	Maximum daily relative humidity between October and April	-1097.609	7	2209.562	0.276
Linear	Maximum daily temperature between October and April	-1102.542	6	2217.341	0.255
linear + interaction	Minimum daily relative humidity between October and April	-1098.857	11	2220.535	0.271
linear + interaction	Maximum daily temperature between October and April	-1101.854	11	2226.528	0.258

linear + interaction	Proportion of rain in December	-1103.282	11	2229.385	0.252
Linear	Maximum daily relative humidity between October and April	-1110.901	6	2234.059	0.217
Linear	Maximum daily relative humidity between October and April	-1120.433	3	2246.938	0.170
linear + interaction	Minimum daily temperature between October and April	-1112.581	11	2247.981	0.209
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-1116.824	8	2250.092	0.188
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-1114.830	11	2252.480	0.198
linear + interaction	Rain in December	-1115.676	11	2254.172	0.194
Linear	Maximum daily temperature between October and April	-1124.893	3	2255.858	0.148
ANOVA	-	-1132.801	5	2275.785	0.107
Intercept	-	-1132.794	6	2277.846	0.107
linear + interaction	Proportion of rain in April	-1129.250	11	2281.321	0.126
linear + interaction	Rain in April	-1130.076	11	2282.971	0.121
Multiplicative	Maximum daily temperature between October and April	-1135.404	6	2283.065	0.093

Table S6. Comparison of alternative models for ADF (%) of herbage. The models appear according to the order of AICc, with the most parsimonious model first in bold.

Model type	Climate variable	Maximum likelihood	No. Parameters	AICc	R ²
linear + interaction	Proportion of rain in December	-836.255	11	1695.330	0.351
Linear	Proportion of rain in December	-841.562	6	1695.381	0.330
Linear	Proportion of rain in December	-841.562	7	1697.467	0.330
Linear	Maximum daily temperature between October and April	-846.749	7	1707.842	0.308
Linear	Maximum daily temperature between October and April	-850.242	6	1712.742	0.294
linear + interaction	Maximum daily temperature between October and April	-847.508	11	1717.837	0.305
linear + interaction	Rain in December	-851.726	11	1726.272	0.288
linear + interaction	Minimum daily relative humidity between October and April	-854.348	11	1731.515	0.276
Linear	Proportion of rain in December	-865.0783	3	1736.229	0.228
Linear	Maximum daily temperature between October and April	-869.6673	3	1745.407	0.206
linear + interaction	Maximum daily relative humidity between October and April	-862.099	9	1747.018	0.242
linear + interaction	Maximum daily relative humidity between October and April	-862.114	11	1747.049	0.242
linear + interaction	Minimum daily temperature between October and April	-871.948	11	1766.715	0.196
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-884.164	8	1784.771	0.135
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-881.867	11	1786.554	0.147
ANOVA	-	-890.579	5	1791.341	0.101
Intercept	-	-890.577	6	1793.411	0.101
linear + interaction	Rain in April	-887.439	11	1797.697	0.118
linear + interaction	Proportion of rain in April	-888.112	11	1799.043	0.114

Table S7. Comparison of alternative models for ash (%) of herbage. The models appear according to the order of AICc, with the most parsimonious model first in bold.

Model type	Climate variable	Maximum likelihood	No. Parameters	AIC corr	R ²
linear + interaction	Minimum daily relative humidity between October and April	-717.140	11	1457.099	0.256
linear + interaction	Minimum daily relative humidity between October and April	-725.573	7	1465.489	0.217
linear + interaction	Maximum daily relative humidity between October and April	-725.577	7	1465.498	0.256
Intercept	Minimum daily relative humidity between October and April	-726.125	7	1466.594	0.214
Linear	Minimum daily relative humidity between October and April	-733.188	3	1472.449	0.181
linear + interaction	Maximum daily relative humidity between October and April	-725.207	9	1473.234	0.219
linear + interaction	Maximum daily relative humidity between October and April	-731.970	7	1478.283	0.219
Intercept	Maximum daily relative humidity between October and April	-732.208	7	1478.760	0.185
Linear	Minimum daily relative humidity between October and April	-735.001	6	1482.259	0.172
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	730.341	11	1483.501	0.194
linear + interaction	Seasonal rainfall amount, until the date of vegetation sampling	-733.585	8	1483.613	0.179
Linear	Maximum daily relative humidity between October and April	-738.911	3	1483.894	0.152
linear + interaction	Maximum daily relative humidity between October and April	-732.206	11	1487.231	0.185
linear + interaction	Maximum daily temperature between October and April	-741.529	11	1505.877	0.139
linear + interaction	Proportion of rain in December	-742.457	11	1507.733	0.134
Linear	Maximum daily relative humidity between October and April	-748.436	6	1509.130	0.102
ANOVA	-	-760.721	5	1531.625	0.034
linear + interaction	Rain in December	-755.251	11	1533.322	0.065
linear + interaction	Minimum daily temperature between October and April	-755.400	11	1533.620	0.064
Intercept	-	-760.717	6	1533.691	0.034
linear + interaction	Rain in April	-756.946	11	1536.713	0.055

Table S8. Data from the experiment.

Year	Treatment	Ash	ADF	Digestibility	NDF	Protein	Proportion of rain in Dec.	Minimum daily relative humidity between Oct.-April	Maximum daily temperature between Oct.-April
2005	Cont.	10.43	37.14	54.64	64.45	7.32	10.89	38.13	21.76
2006	Cont.	10.36	35.79	57.81	60.91	7.31	27.17	40.97	21.72
2007	Cont.	10.97	35.75	57.55	59.91	8.74	5.20	42.42	21.08
2008	Cont.	10.39	36.76	56.81	60.06	7.59	21.88	36.88	22.34
2009	Cont.	10.10	35.58	57.34	60.11	7.11	17.94	39.66	21.53
2010	Cont.	11.00	40.92	51.44	67.57	5.63	26.64	41.53	22.81
2011	Cont.	10.57	38.85	48.06	64.70	6.72	25.86	40.76	22.83
2012	Cont.	10.26	37.34	61.28	63.16	6.08	5.68	39.85	21.43
2013	Cont.	11.41	37.50	59.12	63.34	6.67	32.71	40.21	22.82
2014	Cont.	9.13	40.29	51.49	69.08	5.05	47.33	35.94	23.36

2015	Cont.	10.36	37.44	52.58	64.12	7.93	5.04	41.42	22.09
2016	Cont.	9.79	41.50	46.12	70.66	5.26	13.91	36.30	23.42
2017	Cont.	9.19	42.28	46.55	72.44	4.95	61.27	37.22	22.22
2018	Cont.	8.86	37.95	46.34	67.92	7.52	5.53	39.40	23.65
2005	Heavy	11.91	33.59	61.87	52.82	10.37	10.89	38.13	21.76
2006	Heavy	13.83	33.51	63.87	49.94	11.15	27.17	40.97	21.72
2007	Heavy	13.95	32.01	66.13	49.78	13.77	5.20	42.42	21.08
2008	Heavy	11.42	37.53	55.89	58.09	8.74	21.88	36.88	22.34
2009	Heavy	10.20	35.91	57.35	58.04	11.03	17.94	39.66	21.53
2010	Heavy	13.66	37.93	57.93	58.76	8.03	26.64	41.53	22.81
2011	Heavy	12.59	34.73	57.26	56.20	10.88	25.86	40.76	22.83
2012	Heavy	11.97	34.36	64.24	56.68	9.92	5.68	39.85	21.43
2013	Heavy	11.08	38.89	56.08	64.98	6.90	32.71	40.21	22.82
2014	Heavy	6.09	42.27	49.51	66.09	6.77	47.33	35.94	23.36
2015	Heavy	9.74	35.28	57.79	56.71	10.75	5.04	41.42	22.09
2016	Heavy	9.60	39.66	46.12	61.62	7.72	13.91	36.30	23.42
2017	Heavy	5.99	44.36	41.61	70.54	5.75	61.27	37.22	22.22
2018	Heavy	8.69	37.33	57.63	63.00	7.23	5.53	39.40	23.65
2005	Moderate	9.98	35.32	58.63	63.27	7.05	10.89	38.13	21.76
2006	Moderate	10.38	35.74	57.97	60.36	6.32	27.17	40.97	21.72
2007	Moderate	11.78	35.61	57.93	59.13	8.55	5.20	42.42	21.08
2008	Moderate	10.03	37.99	54.27	63.95	8.30	21.88	36.88	22.34
2009	Moderate	10.07	34.89	59.79	59.20	8.87	17.94	39.66	21.53
2010	Moderate	11.77	40.27	56.05	62.81	5.97	26.64	41.53	22.81
2011	Moderate	10.76	39.90	44.76	66.71	6.55	25.86	40.76	22.83
2012	Moderate	11.04	36.63	61.56	62.07	7.49	5.68	39.85	21.43
2013	Moderate	11.34	39.18	55.81	66.26	6.75	32.71	40.21	22.82
2014	Moderate	7.98	40.35	54.17	66.18	6.44	47.33	35.94	23.36
2015	Moderate	9.28	38.16	52.88	63.23	9.24	5.04	41.42	22.09
2016	Moderate	10.42	39.04	54.17	64.15	6.05	13.91	36.30	23.42
2017	Moderate	8.44	41.43	51.36	68.58	5.03	61.27	37.22	22.22
2018	Moderate	9.12	37.40	53.44	66.47	6.88	5.53	39.40	23.65
2005	Very Hea.	11.97	31.35	66.65	53.67	11.06	10.89	38.13	21.76
2006	Very Hea.	15.64	29.93	70.46	46.40	15.89	27.17	40.97	21.72
2007	Very Hea.	15.53	29.74	70.55	42.73	13.99	5.20	42.42	21.08
2008	Very Hea.	11.58	36.53	57.77	56.99	10.03	21.88	36.88	22.34
2009	Very Hea.	11.24	31.40	66.75	51.86	11.21	17.94	39.66	21.53
2010	Very Hea.	13.89	36.28	60.45	57.12	9.08	26.64	41.53	22.81
2011	Very Hea.	10.21	37.74	52.35	63.67	7.58	25.86	40.76	22.83
2012	Very Hea.	10.69	35.75	65.70	59.91	8.56	5.68	39.85	21.43
2013	Very Hea.	11.32	36.89	58.99	62.71	7.73	32.71	40.21	22.82
2014	Very Hea.	9.10	38.85	57.22	63.55	6.78	47.33	35.94	23.36
2015	Very Hea.	8.31	36.83	56.84	62.25	8.48	5.04	41.42	22.09
2016	Very Hea.	10.32	38.40	49.43	64.99	6.88	13.91	36.30	23.42
2017	Very Hea.	7.82	40.20	49.72	64.95	7.76	61.27	37.22	22.22
2018	Very Hea.	9.87	33.61	59.59	56.40	9.14	5.53	39.40	23.65