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Decision Support System (DSS) for Managing a Beef Herd and Its Grazing Habitat's Sustainability: Biological/Agricultural Basis of the Technology and Its Validation

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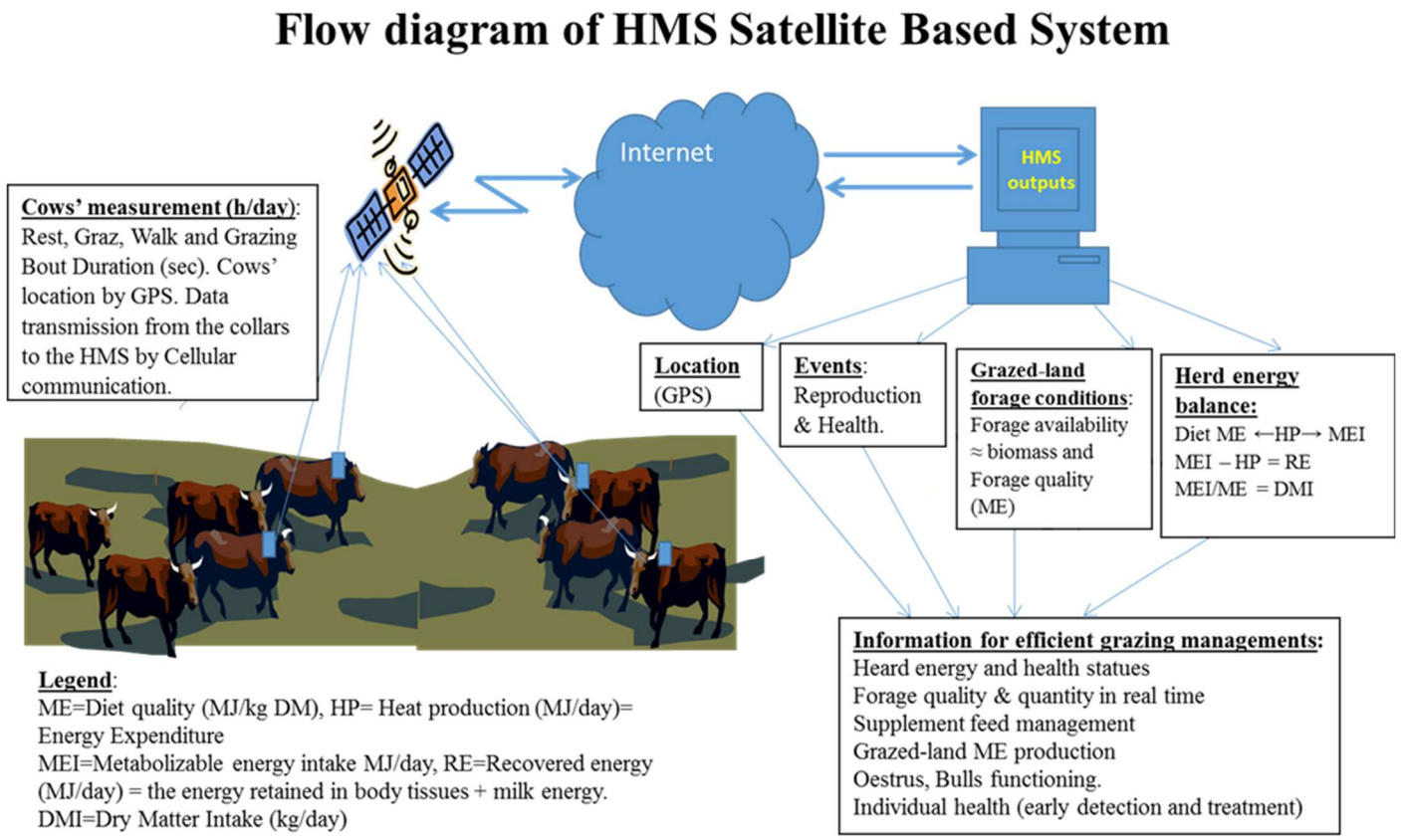

Decision Support System (DSS) for Managing a Beef Herd and Its Grazing Habitat's using the HMS information

A) In the first year of the study 2016-17 in the autumn the cows were grazed at very low biomass, GBD was high (forage availability is low) consequently cows PL intake (kg DM/day), was 62.8% of the DMI, that measured by the HMS, (Table 2. (the main manuscript file **MMS**)), a significantly above the recommended PL level [20]. In later

years we significantly paid attention (by using the GBD value) to not arrive at this level of PL consumption.

B) In the first year of the study, the forage biomass was very low in the study plot at the beginning of the rainy seasons, as was identified by the GBD. The cows were moved to the neighbor plot on 24/1/17. Before the cows' were transferred, the GBD in the study plot was high (52 s, low biomass) with a significant trend of GBD increases, i.e. biomass reduction (Figure 5 MMS). This herd transfer occurred during the calving seasons. Following the cow's movements to the new plot (first event 29/1/21) seven cows were alerted by the HMS as sick, and the total loss of cows in this year was 13 (four of them with collars). We concluded that transferring cows to another plot in the middle of the calving season is the wrong operation. We agreed with the farmers not to repeat it in the following years. Without the sensitive identification of the diseases in the first year, we would not have linked it to the severe stress of moving the herd to a new plot in this reproduction state.

C) In September 2018 the HMS sent alerts on five cows that were suspected to be sick in one week (epidemic alert). The farmer checked the cows (locations are sent automatically) and the veterinarians identified it as the Three-day fever (Bovine Ephemeral Fever). Consequently, all the sick cows of the herd were treated and returned to the study herd.

D) In the years 2017-18 to 2020-21, four fully reproductive cycle years, we managed the herd nutrition state. The management decisions were dictated by the level of biomass and its trend of changes as indicated by the GBD level and by cow's DMI and energy balance levels and trend of changes (Figures 5, 6, and 7 MMS). The herd management was done by giving a significant amount of wheat hay supplement in the summer and autumn of 2018 and supplemented for short time in the autumn of 2020 (figure 5 MMS). We moved the herd to an alternative plot at the end of spring to summer 2019 because the GBD showed a significant trend of forage reduction. We decided to leave enough biomass for the calving season (autumn and winter). This management prevented the situation of the significant reduction in the DMI (consequently reduction in the MEI and the RE), the BW, and the BCS decreased

(Figures 7, 2, and 3 respectively MMS). We assume that this decision improved the weaning ratio in the years 2020 and 2021.

Unlike the first year of the study, throughout the last four years of the study, the HMS' herd' health events alerts were treated immediately. The significant effect of the bovine-flies in the spring on the cow's behavior (greater walking and less grazing) was identified but was not treated.

In conclusion: The HMS information on herd' energy balance, forage availability and quality, and health events were significantly used for decisions on the timing for: 1) Feeding the herd with wheat hay supplement, 2) moving the herd to the alternative plot, 3) immediately respond to health events. The decisions and their timing improved the herd and grazed-land management. We suggest that the significant increases of study herd performance as weaning rate was the outcome of the management improvement.

Study Meteorological Data

The weather parameters of ambient temperature minimum and maximum (°C), relative humidity (RH, %), and calculated thermal humidity index (THI, °F) for heat load throughout the study (average of every 2 weeks) are presented in (**Figure S1**).

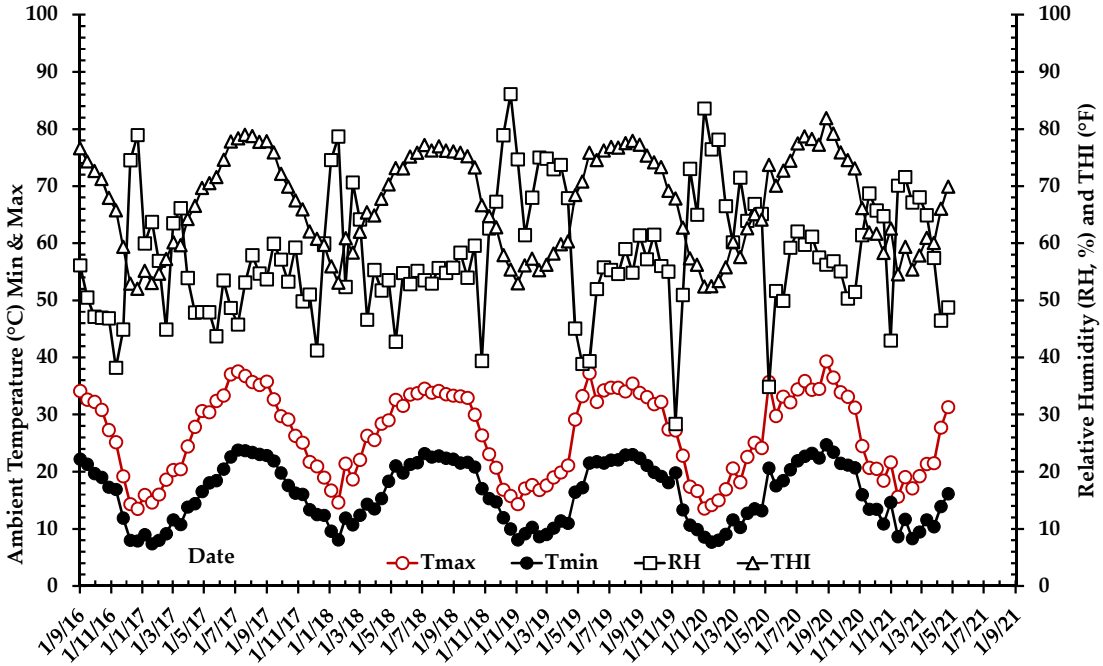

Figure S1. Ambient temperature maximum (max, o) and minimum (min, ●), relative humidity (RH, %, □), and thermal humidity index (THI, °F, Δ). Values are presented for 2-week averages throughout the study period. Dates are given as day/month/year.

The amounts of precipitation and their distribution during the rainy season (winter) had a great impact on grazing forage production. A monthly summary of the precipitation that accumulated during the rainy seasons of the study years is presented (Table S1)

Table S1. Precipitation (mm) accumulated monthly during the years of the experiment.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
2016-17		10	241	308	339	364	377		
2017-18	8	22	42	271	364	375	420	445	452
2018-19	26	76	273	462	631	792	839		
2019-20		5	209	485	569	651	684	707	
2020-21		146	230	387	492	522	547		

Forage plant nutritional values

Forage plant nutritional values (**Table S2**) are mainly followed the start and end of the rainy season, its rhythms and intensity. Forage quality was highest in winter and lowest in autumn before the consecutive rains. Forage quality (ME) was significantly correlated with its protein concentration ($p < 0.001$, $r_p = 0.864$).

ADG and daily BCS changes of cows with collars and cows without collars

The study herd ADG and BCS daily changes, of cows with collars and cows without collars were tested throughout the four full reproductive cycles during the study, from 9/5/17 to 25/5/21 (Figure S2). The study rationale was that all the study cows are mange as one group (according to the HMS information), consequently, we don't expect to observe differences between the two groups in the above-measured variables.

The yearly seasons (rain and temperature) are significantly affecting forage quality and availability and consequently the entire energy balance. In addition cow's reproductive state significantly affects the cows' energy status. Consequently, we tested the above difference between the cow's groups by Paired T-test.

Table S2. Supplemental file. Nutritional values of forage plant samples along the study and of the poultry litter (PL) supplemented feed

Date	Ash %	NDF %	ADF %	ADL%	Protein %	ME (MJ/kg DM)
29/9/16	8.52	73.6	43.96	2.51	3.54	6.08
25/10/16	8.88	72.63	43.73	2.99	3.47	6.43
21/11/16	7.56	75.37	46.76	3.41	3.44	5.51
11/12/16	6.18	77.86	50.22	5.19	3.43	4.22
23/5/17	8.72	71.91	42.3	3.93	4.09	7.84
28/6/17	9.7	72.19	41.76	2.88	3.62	8.12
25/7/17	10.16	71.11	42.21	2.98	3.38	7.83
4/9/17	10.79	70.1	41.85	2.96	3.56	7.97
4/10/17	9.51	71.17	41.86	3.22	3.2	7.99
8/11/17	9.7	74.96	47.41	2.86	3.1	6.44
26/11/17	10.9	70.27	44.85	4.02	4.79	7.01
31/12/17	8.12	74.21	49	6.87	4.34	5.04
25/2/18	13.1	38.87	19.96	2.53	21.31	11.26
25/3/18	10.56	46.75	26.71	2.74	16.15	11.69
4/5/18	8.72	62.62	33.3	3.91	9.03	9
29/5/18	10.4	65.62	35.6	2.75	6.64	7.95
26/7/18	9.87	68.56	38.8	4.25	4.04	6.97
7/10/18	8.1	72.21	41.73	4.1	3.67	6.51
16/1/19	14.43	30.73	19	3.19	22.22	11.56
3/3/19	12.24	37.71	22.85	3.41	17.32	11.76
23/7/19	5.37	69.14	40.12	4.17	4.65	7.48
27/8/19	5.87	73.62	43.99	2.79	4.59	6.85
25/9/19	5.98	73.71	45.42	4.79	3.69	6.82
4/11/19	6.19	77.35	48.92	4.75	3.46	6.09
19/2/20	16.03	38.67	20.34	3.32	19.58	10.39
5/4/20	13.53	66.16	38.67	2.97	4.75	6.86
20/9/20	18.02	63.79	38.58	0.94	5	5.35
28/10/20	10.32	70.74	42.67	2.94	3.83	7.23
20/12/20	15.42	41.07	23.44	2.97	21.82	12.1
3/2/21	16.31	44.53	26.15	2.74	20.18	11.89
29/3/21	11.02	54.41	31.42	3.58	11.03	10.91
19/5/21	10.18	71.06	39.14	2.58	3.64	8.83
Poultry Litter	16.14	37.81	22.91	16.94	30.48	6.52

NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin. PL ME according [18]

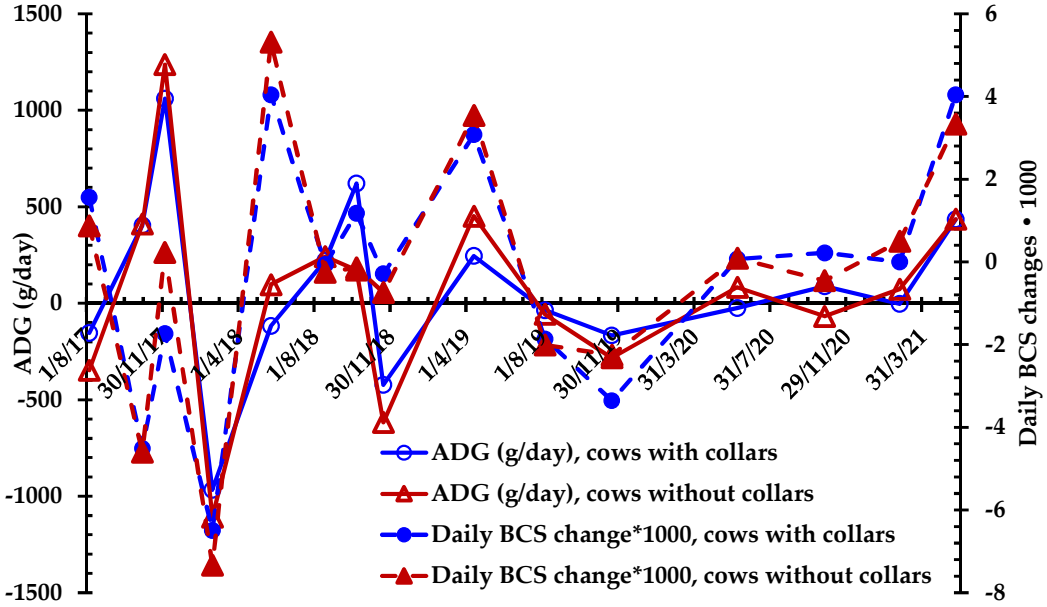

Figure S2. The ADG and the daily BCS changes of cows with collars (circle symbols continuous line(vs. cows without collars (triangle symbols fragmented line), along the four fully' yearly reproductive cycles (from weaning to weaning, from 9/5/17 to 25/5/21.

The trend of the changes in the ADG and the BCS were the same in both variables. The ADG and the BCS daily changes values were not different between cows with collars and cows without collars, p = 0.701 and p = 0.788 respectively, and their respective Pearson Correlation was very high r_p = 0.943 and r_p = 0.960 (df=13), i.e. a highly significance correlations (p < 0.001) between the two groups of cows in each tested variable.

Kari Deshe farm grazed-land and cows' herd

(The following information represent the farm without the study' cows and the plot)

The total area of Kari Deshe farm and its' number of cows was 1372 ha and 614 cows respectively, i.e. a stocking rate of 2.23 ha per cow which is very similar to the stocking rate of the study herd (1.96 ha/cow). The farm cow's average age in 2018 was 6.43 ± 0.17 years which was similar to the age of the cows of the study herd (5.78 ± 0.20 years). The study herd was part of the farm herd (Simmental mixed breed cows). Farm herd cows BW in 2018 was 491 kg, which was similar to the average study cow's BW of 503 kg.

As was presented in the main manuscript (MMS), the farm herd' grazed land variation (soil, and weather) was not high, and the study' grazed-land variation has well represented the variation of the entire farm herd.

The basic reproductive management of the study vs. farm herds was similar, i.e. the number of cows per breeding bull, the dates the breeding bulls stay in the herd, and the weaning date, are mainly the same.

Consequently, we suggest that the herd performance (the yearly weaning rate) can be compared between the study herd and the farm herd. The present research finding can give a primary indication of the effect of using the remote system on herd performance. This test was done over five years with a full yearly reproductive cycle of four years. Surely more studies should be done to significantly validate it.