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Data Article

Data describing cattle performance and feed characteristics to calculate enteric methane emissions in smallholder livestock systems in Bomet County, Kenya

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ABSTRACT

This dataset describes the performance of cattle in smallholder livestock systems of Bomet county in western Kenya. Information on live weight, milk production and quality, herd dynamics, and other production parameters were collected from field visits. Animals were weighed on scales; milk yield was recorded using a Mazzican® milk collection and transport vessel provided to each farm and milk was analyzed for butterfat content (%). Pasture biomass yield was determined, and feed samples collected for each agro-ecological zone and nutrient composition was determined for nitrogen (N) using the Kjeldahl method and gross energy (GE) using a bomb calorimeter. Distance covered while grazing was determined using GPS collars fitted to several animals for three consecutive days per area. Enteric methane (CH_4) emissions factors (EF) were estimated for five animal classes to develop site-specific EFs as per the Intergovernmental panel on cli-

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mate change (IPCC) protocol. This dataset has the potential to be used, amongst other purposes, for animal-scale life cycle assessment (LCA) to evaluate the efficacy of various greenhouse gas (GHG) mitigation options.

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Specifications Table

Subject	Agricultural Sciences
Specific subject area	Livestock Science
Type of data	Tables Figure
How data were acquired	On-farms data collection for live weights, feed quantity and quality and animal productivity and modeling for emission factors
Data format	Primary (animal demographics, live weight, milk production, milk butterfat, feed N and GE), filtered (calving, weaning, and mortality rate, distance covered during grazing), and analyzed (enteric CH_4 EFs)
Parameters for data collection	131 smallholder farms selected through random stratification by location in Bomet County including 1,135 cattle in four agro-ecological zones (AEZs)
Description of data collection	9 farm visits over a 12-month period, 5 live weight measurements per animal, 4 pasture sample collections per locality, 4 milk quality assessments done (one per lactating female every three months), 2 farm surveys done after six months, daily grazing distance estimated once and daily milk production recording.
Data source location	Bomet (0°48′0.00″ N 35°13′59.88″ E) in Western Kenya
Data accessibility	Data is included in this article Repository name: Mendeley Data (https://data.mendeley.com/) Data identification number: 10.17632/j5b9d7dd2b.2 Direct URL to data: https://data.mendeley.com/datasets/j5b9d7dd2b/2
Related research article	Goopy, J. P., Ndung'u, P. W., Onyango, A., Kirui, P., & Butterbach-Bahl, K. (2021). Calculation of new enteric methane emission factors for small ruminants in western Kenya highlights the heterogeneity of smallholder production systems. Animal Production Science, 61(6), 602-612. doi: https://doi.org/10.1071/AN19631

Value of the Data

- Uniquely high-resolution dataset combining animal characteristics, animal performance, feed quality, and the enteric methane emission factor (EF).
- Among the first reliable source of primary data to investigate African livestock systems' contribution to climate change at the individual animal scale.
- The EFs from this dataset can be used to evaluate the environmental impacts of these systems and facilitate the identification of contributing factors.
- The datasets can also be used to estimate the carbon footprint (CF) of smallholder livestock systems using the life cycle assessment (LCA) approach, thereby elucidating mitigation options across the supply chain.
- This dataset presents the differences between region-specific activity data and emission factors (known as Tier 2) factors and the Intergovernmental Panel on Climate Change (IPCC) default values (Tier 1) and activity data used to develop these default values.

1. Data Description

Data provided here describes the activity data of smallholder livestock systems. The climatic conditions of the agro-ecological zones (AEZ) in Bomet, Kenya are shown in Table 1. Table 2

Table 1
Description of Agro-ecological Zones (AEZ) in Bomet County.

Agro-Ecological Zone	Description	Mean Annual Temperature (°C)	Annual Rainfall (mm)	Elevation range (meters above sea level)
Lower Highland 1 (LH1)	Moderately cool and humid	15.0 – 18.0	1,500 – 2,100	
Lower Highland 2 (LH2)	Moderately cool and sub-humid	15.0 – 18.0	1,300 – 1,800	1,800/1,900 to 2,200/2,400
Lower Highland 3 (LH3)	Moderately cool and semi-humid	15.7 – 18.0	1,280 – 1,650	
Upper Midlands 1-4 (UM1-4)	Temperate and humid/sub-humid/semi-humid/transitional	18.0 – 21.0	1,200 – 1,850	1,300/1,500 to 1,800/1,900

Source: [5]

Table 2
Population dynamics of cattle showing sales, purchases, deaths, and births of the animals in smallholder farms in Bomet county.

		Herd size and dynamics (numbers)									
AEZ	Animal Class	S1	S2	S3	S4	Sale	Purchase	Death	Birth	Relocated	Calf to young adult
LH1	Female adults (>2yrs)	144	136	125	120	25	13	4	na	3	na
	Male adults (>2yrs)	5	5	6	6	3	5	1	na	0	na
	Heifers (1-2yrs)	35	45	50	60	10	16	0	na	3	23
	Young males (1-2yrs)	5	5	9	14	9	5	0	na	1	11
	Calves (<1yr)	75	75	75	71	25	12	3	68	4	34
LH2	Female adults (>2yrs)	142	137	136	130	21	15	3	na	3	na
	Male adults (>2yrs)	18	15	11	10	11	2	3	na	0	na
	Heifers (1-2yrs)	30	45	54	53	11	16	0	na	9	24
	Young males (1-2yrs)	11	14	20	18	8	2	0	na	3	13
	Calves (<1yr)	70	75	60	61	12	16	10	45	6	37
LH3	Female adults (>2yrs)	74	66	65	65	16	12	6	na	1	na
	Male adults (>2yrs)	23	17	14	13	12	3	3	na	5	na
	Heifers (1-2yrs)	9	19	27	29	2	13	0	na	2	12
	Young males (1-2yrs)	12	11	12	13	4	3	0	na	3	5
	Calves (<1yr)	32	40	32	21	6	8	8	16	3	17
UM1-4	Female adults (>2yrs)	103	104	94	92	31	20	2	na	6	na
	Male adults (>2yrs)	5	5	4	3	2	4	0	na	3	na
	Heifers (1-2yrs)	9	15	18	25	7	13	1	na	2	11
	Young males (1-2yrs)	12	15	15	20	10	11	0	na	5	14
	Calves (<1yr)	60	67	61	46	18	8	6	39	5	25
Total Bomet	Female adults (>2yrs)	463	443	420	407	93	60	15	na	13	na
	Male adults (>2yrs)	51	42	35	32	28	14	7	na	8	na
	Heifers (1-2yrs)	83	124	149	167	30	58	1	na	16	70
	Young males (1-2yrs)	40	45	56	65	31	21	0	na	12	43
	Calves (<1yr)	237	257	228	199	61	44	27	168	18	113

na = not applicable to that animal class. S1= season 1, S2= season 2, S3= season 3, S4, season 4.

shows herd dynamics, and the movement of animals in and out of farms through sales and purchases according to AEZs. Table 3 presents the cattle herd production parameters. The seasonal average live weight (LW) (Table 4) and seasonal live weight changes (see Fig. 1). There was the seasonal effect on weight change i.e., negative weight changes among the adult cattle and lower weight gains in the growing herd during the dry season due to feeding shortages while in subsequent wet seasons, there was a positive weight change. Table 5 shows the area of land allocated to the main animal feed resources and pasture biomass yield (Table 6) determined because it

Table 3
Summary of production performance parameters for Bomet cattle herd.

Production Parameter		Yield/Rate
Milk production (liters/day)		4.44
Milk butterfat (%)		4.20
Average distance walked during grazing (km/day)		8.05
Birth rate (%)		33.3
Weaning rate (%)		28.3
Mortality rate (%)		
	Females (>2yrs)	3.0
	Males (>2yrs)	12.1
	Heifers (1-2yrs)	0.01
	Young males (1-2yrs)	0.0
	Calves (<1yr)	6.8

Table 4
Live weights (kg, mean ± standard error of means) for females and males (>2years), heifers and young males (1–2 years) and calves (<1year) under four seasons ad 4 agro-ecological zones in Bomet County.

AEZ	Animal Class	S1 (LW, kg)	n	S2 (LW, kg)	n	S3 (LW, kg)	n	S4 (LW, kg)	n
LH1	Female adults (>2yrs)	310.4±6.16	144	313.3±6.21	136	321.8±6.40	125	320.1±6.77	120
	Male adults (>2yrs)	267.7±46.79	5	235.0±58.99	6	244.8±49.91	6	248.7±49.53	6
	Heifers (1-2yrs)	176.1±9.44	35	180.2±10.26	45	192.9±10.88	50	196.6±10.34	60
	Young males (1-2yrs)	169.3±18.71	5	162.9±22.49	5	158.4±21.55	9	161.1±14.60	14
	Calves (<1yr)	68.6±3.65	77	71.8±3.19	76	72.6±4.27	76	65.1±3.68	72
LH2	Female adults (>2yrs)	254.2±4.56	140	252.9±4.13	136	265.9±3.97	135	267.9±4.11	129
	Male adults (>2yrs)	239.3±14.45	18	248.0±17.58	15	299.2±19.95	11	314.6±23.29	10
	Heifers (1-2yrs)	143.0±8.46	30	147.8±6.46	45	155.8±6.13	54	170.1±5.79	53
	Young males (1-2yrs)	115.0±7.12	11	130.2±7.32	11	137.6±5.95	12	151.5±6.55	13
	Calves (<1yr)	67.2±3.56	69	68.7±3.37	74	70.5±4.30	65	77.4±4.86	60
LH3	Female adults (>2yrs)	266.4±8.02	74	266.0±8.51	65	270.6±9.33	64	266.8±9.21	65
	Male adults (>2yrs)	220.5±13.66	23	284.7±15.41	16	284.7±20.92	14	291.6±28.10	13
	Heifers (1-2yrs)	146.8±20.55	9	143.9±13.29	19	143.9±12.68	27	149.2±11.69	29
	Young males (1-2yrs)	120.9±8.91	12	125.4±9.76	11	125.4±10.81	12	133.0±10.85	13
	Calves (<1yr)	62.2±3.63	32	58.8±4.59	40	59.4±6.31	32	75.6±9.94	21
UM1-4	Female adults (>2yrs)	263.2±5.08	103	268.1±5.20	103	275.7±5.81	94	272.9±5.98	92
	Male adults (>2yrs)	183.1±12.97	5	206.4±19.37	5	253.9±35.22	4	224.0±82.97	3
	Heifers (1-2yrs)	148.5±18.14	10	171.5±15.43	16	196.9±12.28	19	186.7±12.85	26
	Young males (1-2yrs)	130.9±13.64	12	132.2±11.04	15	139.6±8.90	15	138.7±8.98	20
	Calves (<1yr)	65.3±3.72	60	71.5±4.08	67	69.4±5.02	61	73.6±5.88	46
Total Bomet	Female adults (>2yrs)	275.7±3.12	461	277.0±3.12	440	285.5±3.22	418	284.3±3.31	406
	Male adults (>2yrs)	228.1±9.43	51	246.8±11.32	42	278.9±13.83	35	284.4±17.83	32
	Heifers (1-2yrs)	157.9±5.97	84	162.4±5.32	125	171.1±5.32	150	178.5±5.14	168
	Young males (1-2yrs)	128.3±6.13	40	132.9±5.57	45	138.9±5.24	56	145.9±5.09	65
	Calves (<1yr)	66.5±1.88	238	68.8±1.88	257	69.4±2.41	235	71.9±2.63	199

n = sample size; S1= season 1, S2= season 2, S3= season 3, S4, season 4.

Table 5
Average land size allocation for animal feed resource in Bomet.

Feed type	Average land size (ha)
Pasture	0.94
Napier	0.21
Rhodes	0.27
Maize*	0.54
Banana Pseudostems	0.09
Sweet potatoes	0.17

* Maize is grown primarily for grain yield and animals benefit from the crop residue.

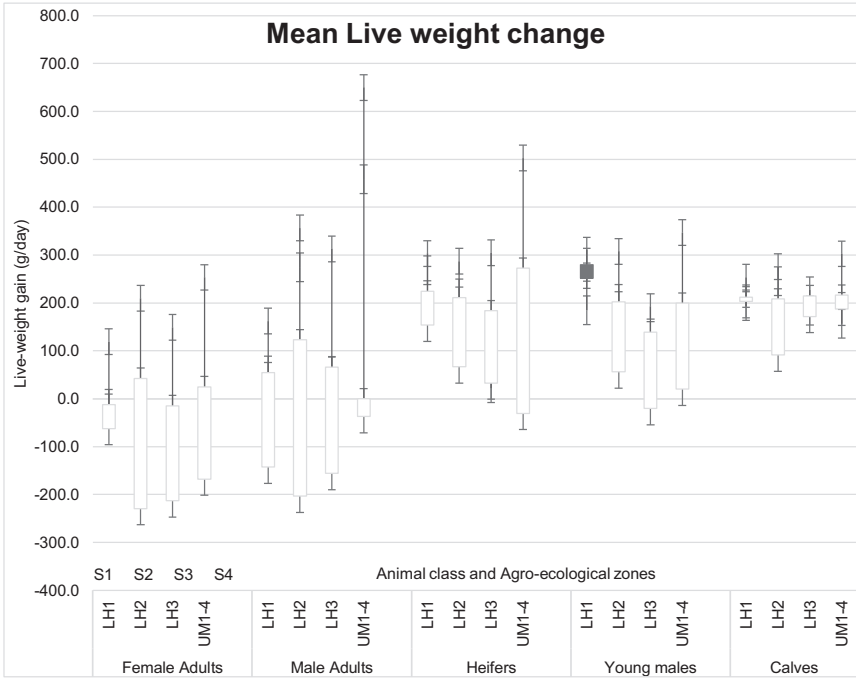

Fig. 1. Mean live weight gains (g/day) for females and males (>2years), heifers and young males (1-2 years), and calves (<1year) in seasons 1, 2, 3, and 4 and four agro-ecological zones in Bomet.

Table 6
Pasture biomass yield (tonnes of dry matter (DM) per ha) ± standard error of means for the 4 agroecological zones in Bomet County across four seasons.

	Pasture Biomass Yield (Tonnes of DM/ha)			
Agro-ecological zones	Season 1	Season 2	Season 3	Season 4
Lower Highland 1	2.20±0.225	4.43±0.548	3.91±0.682	3.83±0.362
Lower Highland 2	1.05±0.114	2.68±0.522	1.61±0.195	2.70±0.360
Lower Highland 3	1.49±0.154	3.39±0.555	2.74±0.656	3.05±0.545
Upper Midlands 1-4	1.94±0.402	3.38±0.749	2.47±0.536	3.92±0.367

formed the highest proportion in the feed basket as shown together with the feed nitrogen content in Table 7 and gross energy in Table 8 of individual feedstuff and the whole feed baskets in each of the agro-ecological zones across four periods of the year (otherwise referred here as seasons). A comprehensive dataset of feed basket information containing the different feedstuff available in Bomet, the altitudes of the location of sampling, nutrient composition (i.e., nitrogen, acid detergent fibre, gross energy) of individual feedstuffs, and the dry matter digestibility of the feed-baskets grouped per AEZ are provided by [1]. These activity datasets were then used in calculations of the energy expenditure estimates i.e., metabolizable energy requirements (MER, MJ/day) for maintenance, growth (weight gain or loss), lactation, and locomotion for individual animals per household. All MERs were then summed up to estimate dry matter intake (DMI, kg/day) that was then used to estimate daily methane production (DMP, g/day) and ultimately emissions factors (EF) as shown by [1]. The estimated enteric methane EFs are presented in Table 9. Table 10 presents a comparison between the estimated EFs with the IPCC default values for Africa [2] and EFs from Nandi, Kenya [3], a region in close proximity to Bomet. The differences in EFs may be due to differences in live weights of all the animal classes, dry matter

Table 7
Feedstuff composing the feed-basket with their individual and cumulative feed nitrogen (g/100g).

		Season 1			Season 2			Season 3			Season 4		
AEZ	Feedstuff	Proportion (%)	Feed N (g/100 g DM)	Feed N Ration (g/kg DM)	Proportion (%)	Feed N (g/100 g DM)	Feed N Ration (g/kg DM)	Proportion (%)	Feed N (g/100 g DM)	Feed N Ration (g/kg DM)	Proportion (%)	Feed N (g/100 g DM)	Feed N Ration (g/kg DM)
LH1	Pasture	39.7	2.44	9.68	56.9	2.27	12.92	64.7	2.42	15.66	64.7	2.49	16.12
	Napier	33.0	2.40	7.92	23.6	2.40	5.66	30.3	2.40	7.27	31.0	2.40	7.43
	Rhodes grass	3.3	0.96	0.32	2.4	0.96	0.23	3.0	0.96	0.29	3.1	0.96	0.30
	Maize Stover	22.8	1.19	2.71	16.3	1.19	1.94	na	-		na	-	
	Banana Pseudo stems	1.0	2.26	0.23	1.0	2.26	0.23	1.0	2.26	0.23	1.0	2.26	0.23
	Sweet potato vines	1.0	3.52	0.35	1.0	3.52	0.35	1.0	3.52	0.35	1.0	3.52	0.35
	Total	**100.0**		**21.20**	**100.0**		**21.32**	**100.1**		**23.80**	**100.0**		**24.43**
LH2	Pasture	31.3	2.53	7.91	53.8	1.94	10.43	64.7	2.22	14.36	75.4	2.08	15.69
	Napier	21.0	2.12	4.46	14.2	2.12	3.00	28.4	2.12	6.01	19.7	2.12	4.18
	Rhodes grass	4.6	0.89	0.41	3.1	0.89	0.27	6.2	0.89	0.55	4.3	0.89	0.38
	Maize Stover	42.5	1.39	5.91	28.6	1.39	3.98	na	-		na	-	
	Banana Pseudo stems	0.6	2.79	0.17	0.4	2.79	0.11	0.8	2.79	0.23	0.6	2.79	0.16
	Total	**100.0**		**18.86**	**100.0**		**17.79**	**100.0**		**21.14**	**100.0**		**20.41**
LH3	Pasture	35.9	2.65	9.51	56.1	2.05	11.49	71.1	2.48	17.62	73.2	2.16	15.81
	Napier	16.8	2.24	3.77	11.5	2.24	2.58	19.4	2.24	4.34	18.0	2.24	4.02
	Rhodes grass	8.9	0.82	0.73	6.1	0.82	0.50	9.5	0.82	0.78	8.8	0.82	0.72
	Maize Stover	38.4	1.50	5.76	26.3	1.50	3.95	na	-		na	-	
	Total	**100.0**		**19.77**	**100.0**		**18.52**	**100.0**		**22.75**	**100.0**		**20.56**
UM1-4	Pasture	32.8	2.65	8.69	45.9	2.01	9.23	59.0	2.80	16.51	70.7	2.30	16.25
	Napier	23.8	1.80	4.28	19.1	1.80	3.44	33.6	1.80	6.05	23.7	1.80	4.27
	Rhodes grass	4.8	0.85	0.41	3.8	0.85	0.33	6.7	0.85	0.57	5.1	0.85	0.43
	Maize Stover	38.2	1.28	4.89	30.7	1.28	3.93	na	-		na	-	
	Banana Pseudo stems	1.0	2.16	0.22	1.0	2.16	0.22	1.0	2.16	0.22	1.0	2.16	0.22
	Total	**100.0**		**18.47**	**100.0**		**17.15**	**100.0**		**23.35**	**100.0**		**21.17**

na= not applicable.

Table 8
Feedstuff composing the feed-basket with their individual and cumulative gross energy (MJ/kg DM).

		Season 1			Season 2			Season 3			Season 4		
AEZ	Feedstuff	Proportion (%)	GE (MJ/kg DM)	GE Ration (MJ/kg DM)	Proportion (%)	GE (MJ/kg DM)	GE Ration (MJ/kg DM)	Proportion (%)	GE (MJ/kg DM)	GE Ration (MJ/kg DM)	Proportion (%)	GE (MJ/kg DM)	GE Ration (MJ/kg DM)
LH1	Pasture	39.7	17.25	6.84	56.9	17.01	9.68	64.7	17.00	11.00	64.7	16.91	10.95
	Napier	33.0	16.08	5.31	23.6	16.08	3.79	30.3	16.08	4.87	31.0	16.08	4.98
	Rhodes grass	3.3	18.00	0.60	2.4	18.00	0.43	3.0	18.00	0.55	3.1	18.00	0.56
	Maize Stover	22.8	17.05	3.88	16.3	17.05	2.77	na	-	-	na	-	-
	Banana Pseudo stems	1.0	19.18	0.19	1.0	19.18	0.19	1.0	19.18	0.19	1.0	19.18	0.19
	Sweet potato vines	1.0	16.13	0.16	1.0	16.13	0.16	1.0	16.13	0.16	1.0	16.13	0.16
	Total	**100.0**		**16.98**	**100.0**		**17.02**	**100.1**		**16.78**	**100.0**		**16.84**
LH2	Pasture	31.3	16.80	5.25	53.8	17.08	9.19	64.7	17.23	11.15	75.4	17.16	12.94
	Napier	21.0	16.27	3.42	14.2	16.27	2.30	28.4	16.27	4.61	19.7	16.27	3.21
	Rhodes grass	4.6	17.57	0.80	3.1	17.57	0.54	6.2	17.57	1.08	4.3	17.57	0.75
	Maize Stover	42.5	17.40	7.40	28.6	17.40	4.98	na	-	-	na	-	-
	Banana Pseudo stems	0.6	17.91	0.11	0.4	17.91	0.07	0.8	17.91	0.14	0.6	17.91	0.10
	Total	**100.0**		**16.98**	**100.0**		**17.08**	**100.0**		**16.99**	**100.0**		**17.01**
LH3	Pasture	35.9	17.31	6.21	56.1	17.23	9.66	71.1	17.51	12.44	73.2	17.22	12.61
	Napier	16.8	16.41	2.76	11.5	16.41	1.89	19.4	16.41	3.18	18.0	16.41	2.95
	Rhodes grass	8.9	17.46	1.55	6.1	17.46	1.06	9.5	17.46	1.67	8.8	17.46	1.54
	Maize Stover	38.4	17.40	6.68	26.3	17.40	4.58	na	-	-	na	-	-
	Total	**100.0**		**17.21**	**100.0**		**17.19**	**100.0**		**17.29**	**100.0**		**17.10**
UM1-4	Pasture	32.8	17.46	5.72	45.9	17.07	7.84	59.0	17.46	10.30	70.7	17.01	12.02
	Napier	23.8	16.30	3.88	19.1	16.30	3.12	33.6	16.30	5.47	23.7	16.30	3.86
	Rhodes grass	4.8	17.95	0.86	3.8	17.95	0.69	6.7	17.95	1.21	5.1	17.95	0.91
	Maize Stover	38.2	17.73	6.77	30.7	17.73	5.44	na	-	-	na	-	-
	Banana Pseudo stems	1.0	18.19	0.18	1.0	18.19	0.18	1.0	18.19	0.18	1.0	18.19	0.18
	Total	**100.0**		**17.40**	**100.0**		**17.27**	**100.0**		**17.16**	**100.0**		**16.98**

na= not applicable, "- "represents no data.

Table 9
Live weight (mean ± standard error of means, LW kg) and emission factors (mean ± standard error of the mean, Kg CH_4/head/year) for females and males (>2yrs), heifers and young males (1-2yrs) and calves (<1yr) in four agro-ecological zones in Bomet.

	Females (>2yrs)		Males (>2yrs)		Heifers (1-2yrs)		Young males (1-2yrs)		Calves (<1yr)	
AEZ	Mean LW (kg)	EF (kg CH_4/ head/yr.)	Mean LW (kg)	EF (kg CH_4/ head/yr.)	Mean LW (kg)	EF (kg CH_4/ head/yr.)	Mean LW (kg)	EF (kg CH_4/ head/yr.)	Mean LW (kg)	EF (kg CH_4/ head/yr.)
LH1	316.4±0.14	58.8±2.10	249.3±1.23	34.2±5.43	186.5±0.30	31.8±1.82	162.9±1.77	30.0±2.72	69.9±0.23	18.7±0.86
LH2	260.2±0.11	44.3±1.25	275.3±1.87	38.4±2.99	154.2±0.60	26.6±1.23	133.6±0.31	27.2±1.71	71.0±0.35	18.7±1.03
LH3	267.4±0.31	42.8±2.11	264.7±3.25	36.9±3.52	146.7±2.03	24.0±2.64	125.8±0.47	23.4±1.82	64.0±1.39	17.2±1.44
UM 1-4	270.0±0.22	51.6±1.82	216.8±15.82	39.1±7.74	176.9±1.34	29.3±2.72	135.3±1.12	26.4±1.98	70.0±0.49	18.1±0.99
All Bomet	280.6±0.05	50.1±0.98	259.5±1.83	37.1±2.09	167.5±0.18	28.3±0.95	136.5±0.23	26.4±1.03	69.3±0.18	18.3±0.52

Table 10
Comparison between Intergovernmental Panel on Climate Change default values for grazing systems in Africa, estimated values from Nandi study and Bomet, Kenya for enteric methane emission factors (EF, kg CH_4/head/year) and average live weight (LW, kg) for females and males (>years), heifers and young males (1 – 2 years) and calves (<1 year).

	IPCC [2] default values		Nandi Study [3]		Present study (Bomet)	
Cattle category	Average LW (kg)	EF	Average LW (kg)	EF	Average LW (kg)	EF
Females (>2 years)	275	67	307	47.8	280.6	50.1
Males (>2 years)	340	67	266	37.2	259.5	37.1
Heifers (1–2 years)	204	46	187	28.5	167.5	28.3
Young males (1–2 years)	204	46	157	27.2	136.5	26.4
Calves (<1 year)	82	31	73	25.8	69.3	18.3

digestibility for Bomet as reported by [4], and methane conversion factor (Y_m). Nandi's study and the present study both used the same Y_m which was 10% higher than IPCC. The activity data was collected at 3 months intervals and the periods identified as seasons 1, 2, 3, and 4 and described below and the MERs, DMI, and DMP were also calculated per season.

- Season 1: 01/12/2016 to 28/02/2017 – Partly wet, warm, and dry
- Season 2: 01/03/2017 to 31/05/2017 – Cold and wet
- Season 3: 01/06/2017 to 31/08/2017 – Cold and dry
- Season 4: 01/09/2017 to 31/11/2017 – Warm, dry, and partly wet

2. Experimental Design, Materials and Methods

Bomet (Latitude: 0°48′0.00″ N, Longitude: 35°13′59.88″ E) is located in the western part of Kenya [6] occupying an area of 2,037km^2. Smallholder farms were selected using a sampling protocol described by [3]. Farms were visited 9 times in 12 months between December 2016 and January 2018 at an interval of 1.5 months. Animals were weighed at 0, 3, 6, 9, and 12th months using a cattle weight scale. Age of adult animals was determined using dentition while that of young cattle and parity was obtained from farmer recalled. Milk yield was recorded daily using uniform Mazzican (http://www.mazzican.com) provided to each farm and samples collected at 1.5, 4.5, 7.5, and 9th month for butterfat analysis using Gerber method, conducted in a local milk factory. Pasture biomass was determined by using exclusion cages set at grazing paddocks and grass was harvested at 3, 6, 9, and 12 months. Feed samples were collected at the first three months of the project, dried at 50°C, and analyzed for dry matter (DM), nitrogen (N) content using the Kjeldahl method [7], and gross energy (GE) using a bomb calorimeter. Feed N and GE of the feed baskets were determined using an existing procedure to estimate the proportional contribution of different feedstuff to the overall feed basket [8].

The data were grouped into seasons (S1, S2, S3, and S4), AEZs (lower highland 1, 2, 3 (LH1, LH2, LH3) and upper midlands 1-4, (UM1-4)) and age groups of females and males >2years, heifers and young males 1-2years and calves <1year. This information was used to estimate MER for maintenance, growth, lactation, and travel based on equations from [9] and then summed up to obtain the total MER. Finally, using total MER, dry matter digestibility (DMD) [8], and GE of feed, DMI was estimated (see Eq. 1) and used to estimate the DMP using [10] prediction equation (Eq. 2);

$$\text{DMI (kg/day)} = \frac{\text{MER}_{\text{Total}}(\text{MJ/day})/[\text{GE (MJ/kg DM)}*(\text{DMD}/100)]}{0.81} \quad (1)$$

$$\text{DMP (g/day)} = 20.7*\text{DMI (kg/day)} \quad (2)$$

Ethics Statement

All animal data used in this study were collected as part of standard farming practices. As such, no part of this research was subject to the approval of an ethics committee.

CRediT Author Statement

Phyllis Ndung'u: Data analysis and interpretation, drafting the paper, critical revision of the paper; **Peter Kirui:** Data Collection; **Taro Takahashi:** Data interpretation, critical review of the paper, final approval of the version to be published; **Cornelius Jacobus Lindeque Du Toit**: Critical review of the paper; **Lutz Merbold:** Critical review of the paper; **John Goopy:** Conceptualizing and designing of the study, data interpretation, drafting of the paper, critical review of the paper, final approval of the version to be published.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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