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Research article

Evaluation of livestock feed supply and demand in districts surrounding Bale Mountain National Park, Ethiopia: A strategy for biodiversity conservation

Mohammed Mussa Abdulahi[1], Flintan Fiona[2] and Ayana Angassa[3*]

[1]College of Agriculture and Environmental Science, Haramaya University, Haramaya, Ethiopia
[2]International Livestock Research Institute, Addis Ababa, Ethiopia
[3]Department of Range and Forest Resources, Botswana University of Agriculture and Natural Resources, Gaborone, Botswana
[*]Corresponding author email: aabdeta@buan.ac.bw

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Abstract
The escalating human activities in and around Bale Mountain National Park (BMNP) present a considerable risk to the park's biodiversity and ecological balance. The study evaluated the livestock feed balance and stability in the three districts —Adaba, Dinsho, and Goba, surrounding the BMNP in Ethiopia. A random sampling technique was employed to select the 263 households from the three districts. Data were collected by administering semi-structured interviews using a cross-sectional survey method and analyzed using SPSS version 20. Results displayed the annual feed supply and the amount required per household in terms of dry matter (DM = 23.69 ± 1.61 tonnes), metabolizable energy (ME = 207628.3 MJ/kg), and digestible crude protein (DCP = 1377.7 kg). The annual feed production in the study districts was limited to 41%, 60.65%, and 60.71% of the total required dry matter (DM), digestible crude protein (DCP), and metabolizable energy (ME) per household, respectively. The findings indicated that the total yields of dry matter, digestible crude protein, and metabolizable energy were adequate for only 6.3 months on average per district. It was suggested that effective strategies be implemented to support local communities in mitigating feed scarcities and enhancing land use for sustainable livestock production and biodiversity conservation in the study areas.

Keywords: Digestible crude protein, Dry-matter, Feed balance, Metabolizable energy

Introduction
Bale Mountain National Park is recognized as a significant biological hotspot, characterized by a gradual transformation in its vegetation and landscape over the past two decades (Williams *et al*., 2004). It represents Africa's largest expanse of Afro-alpine vegetation and is home to a considerable diversity of native flora and fauna. It is one of the 34 International Biodiversity Hotspots and was recognized as a World Heritage Site by UNESCO in 2009 (Hotspots by Region, 2007; FDRE, 2014). However, the BMNP currently faces numerous challenges due to human activities including extensive settlement, rising livestock populations and fires caused by human actions. Consequently, the fragmentation of extensive habitats has led to a decline in the biodiversity of the BMNP and the loss of smaller habitat patches within the park.

Previous studies (Frankfurt Zoological Society and BMNP, 2013) indicated that the Bale Mountain area was largely uninhabited before the 1950s. The same sources report that farmers began to periodically bring their livestock to the mountain between the 1950s and 1960s to obtain vital minerals for their livestock. Presently, both year-round and seasonal grazing by livestock is on the rise throughout the park. This has resulted in a significant increase in the livestock population since the park's establishment (Vial *et al*., 2011). Vial (2010a) reported that grazing intensity in the Afro-alpine regions can increase by 1.5 to 10 times during the rainy season. The pressure from livestock grazing in the northwestern areas greatly exceeds sustainable levels. In Afro-alpine regions, it is recommended to restrict livestock numbers to a maximum of 0.3 Tropical Livestock Unit (TLU) ha^{-1} (BMNP, 2018), although the reasons behind the substantial rise in livestock populations within the park remain unexplored.

Excessive grazing by livestock is recognized as a significant factor contributing to the degradation of vegetation, adversely affecting wildlife habitats and the overall function and structure of ecosystems (Anagaw and Leif, 2013; Choudhury *et al*., 2017). This degradation leads to a decline in plant diversity and soil organic matter, resulting in soil compaction and the disruption of natural nutrient recycling processes (Vial *et al*., 2011). The increasing pressure from livestock grazing poses a substantial threat to biodiversity conservation, ecosystem services, and the stability of food chains, particularly as the populations of small animals, which are vital for the Ethiopian wolves' diet, continue to diminish (Anagaw and Leif, 2013). Furthermore, the interaction between wild animals and livestock heightens the risk of disease transmission (Vial, 2010b; Vial *et al*., 2011). Therefore, it is imperative to implement immediate strategic changes in livestock management practices to avert habitat fragmentation and the decline of biological diversity in the affected areas.

Understanding the current balance of livestock feed in these areas is vital for evaluating its effects on biodiversity conservation. This knowledge is essential for formulating effective strategies aimed at reducing biodiversity loss. Additionally, assessing the available feed resources is important for maximizing their use in sustainable animal production while simultaneously supporting biodiversity conservation initiatives (Oba *et al*., 2008; Makkar and Ankers, 2014). Such insights are invaluable for park managers and various development organizations in designing conservation strategies that harmonize with livestock farming, ultimately aiding communities adjacent to parks in adopting sustainable land use practices beyond park boundaries (Agena *et al*., 2016; BMNP, 2018). Nonetheless, there is a lack of information regarding these studies, despite their critical importance for Ethiopia.

The only research cited in this context is that conducted by Giday *et al*. (2018), which assesses the livestock feed balance surrounding the Desa'a forest protected area in Ethiopia. However, there is a scarcity of information regarding livestock feed balance in the districts neighboring the BMNP in Ethiopia. This lack of information hinders the ability to make timely conservation and management decisions that are crucial for safeguarding biodiversity, wildlife habitats, and the ecosystem services they provide. This study aimed to evaluate the current annual livestock feed resources, the demand for livestock feed, and the overall livestock feed balance in the districts adjacent to the BMNP in Ethiopia. This analysis was intended to provide a basis for determining the optimal number of grazing livestock that can be sustainably supported in the area, thereby preserving the diversity of life forms.

Materials and Methods

Study area: The study was conducted in three adjacent districts (Adaba, Dinsho and Goba) near the BMNP in Ethiopia. These districts were selected due to their proximity to the central area of the BMNP, the Afro-alpine ecosystem, which is the main focus of the study. The ecosystem supports more than half of the worldwide population of Ethiopian wolves, the rarest canid species, facing a significant risk due to unsustainable livestock production practices. Adaba, Dinsho, and Goba districts constitute the western, northern, and northeastern parts of the BMNP (BMNP, 2018). The districts are located in the southeastern part of Ethiopia, within the Oromia Regional State in the Bale Zone. Adaba, Dinsho, and Goba are situated at distances of 313 km, 400 km, and 446 km from Addis Ababa, the capital city of Ethiopia, respectively.

Dinsho district is situated at an elevation of 3207 meters above sea level, with its coordinates ranging from 6°53′30″ to 7°15′30″ N and 39°38″0″ to 39° 54″ 30″ E (Kefa, 2020). The Goba district is situated within the 5˚57′30″N to 7˚12′00″ N and 39˚35′00″ E to 40˚15′00″ E. Generally, the elevation of the Goba district varies between 2400 and 4377 meters above sea level. The district covers a total area of 1,674 km^2. The monthly temperature varies between 4˚C and 25˚C. The Goba district undergoes a bimodal rainfall pattern in the summer and spring seasons. The average yearly precipitation ranges from 900 mm in the low-lying areas to 1400 mm in the elevated regions. The geography of the Goba district is defined by mountains, plateaus, and varying soil textures, including black, white, and red (Legesse *et al*., 2019). The agricultural system in the Adaba district is defined by a mixed farming system approach that encompasses both crop cultivation and animal production. According to the Ethiopian National Meteorology Agency's weather data between 1995 and 2013, the mean minimum and maximum temperatures of Adaba district are 3.6 and 24.3°C, respectively (Muluken *et al*., 2015).

Data collection: A multistage sampling technique was employed to select the sample households engaged in grazing livestock in the three districts. The districts are source areas for livestock seasonal and permanent grazing. The study Kebeles (representing the lower administrative structure in Ethiopia) and households were selected using purposeful and random selection methods. Those Kebeles, which used to graze their livestock in the Afro-alpine area of the park, had the potential for involvement in the degradation of the Afro-alpine habitat through the impacts of livestock grazing, and were purposely selected. Bucha, Koma, Lencha-Washa, Meskel-Darkina, and Wege-Harenna Kebeles (only the Afro-alpine part) were selected from Adaba district, Geremba-Dima, Hora-Soba, Karrari, Ayida, and Gojera were selected from Dinsho district as well as Fasil-Angeso, Itittu-Sura, and Shedem Rira Kebeles (only the Afro-alpine part) were selected from Goba district because these were the surrounding communities' seasonal and permanently grazing areas for their livestock in the Afro-alpine area of the park (BMNP, 2018; Debeko *et al*., 2024).

Randomly selected farmer households (HHs) from the 11 Kebeles were interviewed to obtain information related to the study objectives. The interview followed the complete list of farmers' HHs from the selected Kebeles. The Cochran (1977) formula $n = \frac{z^2 p(1-p)}{d^2}$ was used to determine the representative sample size from the selected areas at a 95% confidence interval, where n was the sample size, z was static for a level of confidence, and p was the expected prevalence or proportion (in the proportion of 10%), and d was the level of precision, which was 5%. Finally, 263 representative sample households were purposefully chosen by using a simplified formula ($\left(n1 = \frac{no}{1 + \frac{no}{N}} \right)$) from the households involved in the livestock production system mentioned in the selected kebeles.

Before being administered, a structured questionnaire was developed and pre-tested. Then, refining and correction were made based on the respondents' perceptions from the preliminary survey. The cross-sectional survey was used to collect the data needed for the research. The interviews were conducted at the farmer's residence to allow for cross-checking of the farmer's responses regarding the type of available feed resources and quality in order of importance, what type of crop residues are available in the study area, seasonality effect on feed resource availability and quality, scarcity of feed, identifying opportunities with available feed. Secondary data or additional information was gathered from the livestock development and health care agency, the district agricultural office, the land and environmental protection district office, Kebele leaders, and the agricultural development agents.

Estimation of annual feed availability (supply): The amounts of available feed resources in the study areas were estimated from the major feed resources, including crop residues, crop aftermath (stubble remaining after harvest), and various land uses, using data gathered from respondents (Ayele *et al*., 2022). Data on annual and perennial crops, as well as the number of grains produced by respondents were collected, and the amounts of crop residues and byproducts used as a source of animal feed were estimated using the conversion factors that have already been developed.

The crop residue's dry matter was derived from grain yield, harvest indices, and area covered by crop, based on the total cultivated land. The conversion factors derived from the harvest indices, a multiplier of 2 for maize, 2.5 for sorghum, 1.5 for teff, wheat, and barley, 1.2 for faba bean, field pea, and haricot bean, 2.0 for finger millet, 0.3 for sweet potato, and other root and tubers, 4 for Niger locally known as Noug (*Guizotia abyssinica*) and linseed, 0.25 for vegetable waste, and 8 for banana were used to estimate the dry matter of crop residues from grain yields (Tolera, 1990; Funte *et al*., 2010; Assefa and Nurfeta, 2013; Ayele *et al*., 2022). According to Tolera (1990), approximately 10% of crop residues would be wasted during utilization. The total quantity of crop residues estimated was multiplied by 0.9 to arrive at a more realistic value that remains for actual utilization by animals.

The feed DM productivity on Grazing land (GL), Wetland (WL) and Forest land (FL) was estimated based on a multiplier of 2, 2, and 1.2 t/ha, respectively (Amsalu and Addisu, 2014). The factors used for converting land area in hectares to biomass in tonnes for woodland, bushland, and shrubland were 1.2 tonnes per hectare (Yeshitela, 2008). The conversion factors of 3.0 tonnes/ha for private grazing land, 1.8 t/ha for fallow land, 2.0 tonnes/ha for communal grazing, 0.50 tonnes/ha for stubble crops, and 8 t/ha for improved forages were used. A utilization factor of 50% using the principle of taking half and leaving half principle to avoid degradation, for different land uses, was used to quantify the dry matter that would be utilized by livestock (Schulz *et al*., 2019).

The available feed DM from GL was estimated by taking the private and communal ownership patterns into account. Farmers are eligible to use the whole of the available feed on their entitled private GL but can only share a certain amount of feed from openly accessible communal GL (Tahir *et al*., 2018). According to the same authors, the amount of share from communal grazing is a function of livestock density, which is ascribed to the size of livestock ownership that had access to the communal resources. A livestock density of 14.8 TLU/ha, derived based on data on the size of livestock and GL area, was used to allocate the communal grazing land to each livestock owner relative to livestock possession. The total area of privately owned and part of the communal grazing land (GL) allocated for communal use was considered to estimate the available feed dry matter (DM) from GL per household per year.

The quantities of metabolizable energy (ME) and digestible crude protein (DCP) of feed resources were calculated based on the in vitro digestibility of organic matter in dry matter (IVDOMD) and crude protein (CP) contents of each feed type reported by Gashaw and Defar (2017) in the study area. The following equations were used to estimate the annual energy and protein supply at the household level, considering the type of feed resource and the amount obtained per year (Church and Pond, 1982; MAFF, 1984).

ME (MJ/kg DM) = 0.015 ∗ IVDOMD (g/kg);

DCP (g) = 0.929 ∗ CP (g) − 3.48.

Estimation of livestock feed requirements (demand): The livestock feed requirements (demand) in the study area were estimated from the total livestock holdings per household by converting the livestock number of different species using conversion factors (Tahir et al., 2018; Ayele et al., 2022). The livestock number of different livestock species was converted to Tropical Livestock Units (TLU; 250 kg = 1 TLU) by taking factors of 0.7, 0.1, 0.1, 1, 0.5, 0.7, and 0.9 for cattle, sheep, goat, camel, donkey, mule and horse, respectively (Yadessa et al., 2016). The dry matter demand (DMD) was estimated based on the expected daily dry matter intake (DMI) suggested for the standard TLU of 250 kg at 2.5% of the body weight of the individual animal, which was equivalent to 6.25 kg/day or 2280 kg/year (Jahnke, 1982). For one tropical livestock unit, the digestible crude protein requirement for maintenance was 160g of digestible protein per day (body weight: 250 kg) (FAO, 1986). A standard method was also used to estimate the metabolizable energy and livestock maintenance requirements (King, 1983). The maintenance energy requirement was calculated according to the equation, whereby ME was (MJ kg/day/animal) for maintenance; LW was the live body weight; km (MJkg^{-1}) was the efficiency with which ME is used for maintenance and related to the average forage metabolizable energy and always tends to lie 0.64 to 0.70 (Ayele et al., 2022). The live body weight of livestock on the farm was determined by calculating the mean number of livestock each household possesses. These numbers were then converted to Tropical Livestock Units (TLU) as indicated above. This approach ensured an accurate and comprehensive assessment of the livestock body weight and feed demand in the study area. Thus the metabolizable energy (ME) of one tropical livestock unit was 29.84 MJ kg/day/animal. The household-level DM, ME, and DCP requirements for maintenance per year were extrapolated relative to the livestock ownership per household.

Estimation of livestock feed balance: According to Tahir *et al*. (2018), livestock feed balance at the individual household level per year was determined as the difference between the annual feed DM, ME and DCP supply and the demand for the annual average livestock holding of households. In addition, the potential stocking capacity of the grazing land in the areas was calculated to determine the optimum number of grazing livestock that can be sustainably retained in the study area to maintain the ecological balance of the BMNP and support nature conservation. Determining carrying capacity consists of calculating the total amount of forage at the end of the growing season, multiplying this by a correction factor (use factor), and then dividing it by the average yearly feed requirements of a livestock unit (Meshesha *et al*., 2019). Based on the forage production capacity of the areas and the number of livestock units grazing in the forests, the stocking rate for the study area was determined as follows (Giday *et al*., 2018):

Stocking rate = ADM kg per study area/DC*365 days.

Where ADM = available dry matter. DC = daily consumption by one Tropical Livestock Unit, which was 6.25 kg of dry matter/day (Giday *et al*., 2018). This study also accounted for the environmental conditions that were not equally accessible when estimating the stocking rate. The rate for the study areas was determined based on the forage production capacity of the areas and the number of livestock units grazing in the areas. Available dry matter was determined based on the ‘take 70% and leave 30% method’ (Petmak, 1983); 70% of the total biomass produced per hectare and year will be available to livestock, with the rest left on the pasture to avoid overgrazing and protect the soil from erosion.

Statistical analysis: The questionnaire's validity was ensured using Pearson product-moment correlations, which were conducted using SPSS software to connect each questionnaire score with the total values. The item questionnaire association demonstrated a significant correlation with the total score, showing that each questionnaire item was valid. After confirming the data's validity, reliability was evaluated using Cronbach's Alpha in the Statistical Package for the Social Sciences (SPSS). The dependability statistic yielded a score of 0.72, exceeding the cut-off value of 0.600, indicating that the current research instrument was dependable. The data were then analyzed using SPSS (version 20, 2015). To characterize qualitative variables, descriptive statistics such as frequency, mean and standard error were used.

Results and Discussion

Estimated annual available feed production in the study areas: The anticipated quantities of feed production and their availability in each category for the maintenance of the entire livestock population owned by each household were recorded (Table 1). The findings revealed the various feed production options available (i.e., natural forage, crop residues, and stubble grazing), categorized based on their nutritive value in terms of annual dry matter (DM) production per household (Table 1). The results further showed that the production of crop residues was the primary source of total dry matter (DM) production per household per year in each district, at 12.42 ± 0.84 tonnes. Generally, the results revealed that

Table 1. Estimated available mean dry-matter production (ton), ME (MJ/kg), and DCP (kg) per household per annual feed resource category according to agro-ecological differences (N = 263)

Feed resources	Districts											
	Adaba			Dinsho			Goba			Overall mean (N=127)		
	TDM	TME	DCP	TDM	TME	DCP	TDM	TME	DCP	TDM	TME	DCP
Natural grazing	8.6 ± 0.58	83985.23	617.76	1.99 ± 0.13	19418.34	142.95	17 ± 0.15	153000	1184.47	9.20 ± 0.62	85467.86	648.39
Crop residue	9.31 ± 0.63	77424.87	437.1	6.94 ± 0.47	57468.6	325.83	21 ± 1.42	173894.5	986	12.42 ± 0.84	102929.3	582.98
Aftermath grazing	1.92 ± 0.13	18697.02	137.92	0.38 ± 0.03	3716.34	27.92	3.92 ± 0.27	35280	273.12	2.07 ± 0.14	19231.12	146.32
Total	19.83 ± 1.34	180107.1	1192.78	9.31 ± 0.63	80603.28	496.7	41.92 ± 2.84	362174.5	2443.59	23.69 ± 1.61	207628.3	1377.7

TLU: Tropical livestock unit; TDM: Total digestible matter; TME: Total metabolizable energy; DCP: Digestible crude protein; ME: Metabolizable energy; HH; Household

the produced crop residues constituted more than 50% of the annual feed supply, with the production of natural forage (9.20 ± 0.62 tonnes) and aftermath grazing (2.07 ± 0.14 tonnes) in descending order. The current results also found that the total DM production obtained from the existing feed resources was 23.69 ± 1.61 tonnes per household per year. The present findings are consistent with those reported earlier by Ayele et al. (2022), who identified a total DM availability of 16.22 tonnes annually per household in the Ethiopian midland area of Lalo Kile districts.

The quantities of feed nutrients available from various feed sources produced for the 263 households were estimated (Table 1). The findings indicated that the annual total available dry matter (DM) production or feed supply was 19.83, 9.31, and 41.92 tonnes of DM per household annually in Adaba, Goba, and Dinsho districts, respectively (Table 1). The current findings align with previous research conducted by Assefa and Nurfeta (2013) and Ayele et al. (2022), who found a total available dry matter (DM) yield of 11.72 tonnes annually per household in Adami Tullu, Jiddo Kombolcha, and Lalo Kile districts.

Based on the current findings, the average annual dry matter (DM) production and the availability of digestible crude protein and metabolizable energy per household were calculated as 1,192.78 kg, equivalent to 1,807.11 MJ in Adaba district. In Dinsho district, the figures stood at 496.7 kg, equivalent to 80603.28 MJ, while in Goba district, the values were recorded at 2443.59 kg, equivalent to 362174.5 MJ. However, the findings suggested that the available feed resources had poor quality due to their high fiber content, causing the animals to be unable to fulfill their protein and calorie requirements. A study conducted in the central Rift Valleys of Ethiopia by Wondatir *et al*. (2011) corroborates our findings, revealing that each household annually had access to greater amounts of total digestible nutrients (TDM), digestible crude protein (DCP), and metabolizable energy (ME), with respective yields of 21.3 tonnes, 725.4 kg, and 146,393 MJ. The inconsistencies in feed production noted across the study areas could be due to disparities in land management, land tenure situations and differences in the quality of feed resources produced.

Estimated TLU and annual feed requirements: The TLU and anticipated maintenance requirements for feed nutrients for all livestock were estimated in 263 households (Table 2). The livestock unit was calculated based on the households' average number of livestock. In Adaba, the average TLU per household was 21.4, with a standard deviation of ± 1.84. In Dinsho, the average TLU per household was 22.2, with a standard deviation of ± 1.90. In Goba, the average TLU per household was 26.85, with a standard deviation of ± 2.31. The findings indicated the approximate annual total dry matter yield,

Table 2. Estimated dry matter, digestible crude protein, and metabolizable energy annual maintenance requirements for tropical livestock unit

Variables		TLU	Daily requirements/ TLU	Annual requirement/ TLU/HH
Adaba				
	TDM	21.4 ± 1.84	6.25 kg	48.82 ± 3.77 tonnes
	DCP	21.4 ± 1.84	160 g	1,249.76 kg
	ME	21.4 ± 1.84	29.84 MJ	233,183 MJ
Dinsho				
	TDM	22.2 ± 1.90	6.25 kg	50.64 ± 3.43 tonnes
	DCP	22.2 ± 1.90	160 g	1,296.48 kg
	ME	22.2 ± 1.90	29.84 MJ	241,655 MJ
Goba				
	TDM	26.85 ± 2.31	6.25 kg	61.24 ± 4.14 tonnes
	DCP	26.85 ± 2.31	160 g	1,568.04 kg
	ME	26.85 ± 2.31	29.84 MJ	292,542 MJ

TLU: Tropical livestock unit; DCP: Digestible crude protein; TDM: Total digestible matter; ME: Metabolizable Energy; HH: Household

digestible crude protein, and metabolizable energy required for maintaining livestock for Adaba was 48.82 tonnes (TDM), 1,249.76 kg (DCP), and 233,183 MJ (ME); for Dinsho will be 50.64 tonnes (TDM), 1,296.48 kg (DCP), and 241,655 MJ (ME) and for Goba will be 61.24 tonnes (TDM), 1,568.04 kg (DCP), and 292,542 MJ (ME), respectively. The current study indicated that the Goba district exhibited a higher demand for total dry matter in comparison to the Adaba and Dinsho districts. The disparity in livestock populations between the Goba district and the other two districts might be a significant factor in this situation. Estimates indicated that the indigenous livestock in Goba district are consuming less protein and energy than the recommended daily allowances of 160 g (FAO, 1986) and 29.84 MJ (MJ/TLU). Overall, the results of this study were consistent with previous research (Kassa and Gashe, 2018; Yisehak and Janssens, Ayele *et al*., 2022). Consequently, the findings underscore the necessity of supplementing improved forages to meet the protein and energy needs of livestock in the study areas.

Estimated annual feed gap between supply and requirements: A summary of the annual nutrient supply, maintenance nutrient requirements, and feed deficiencies for livestock on a per-household basis within the studied districts was recorded (Table 3). In Adaba district, the estimated feed supply fulfilled approximately 35.63% of the total digestible matter (TDM), 68% of the digestible crude protein (DCP) and 83.7% of the metabolizable

Table 3. Average estimated annual TDM (tons), ME (MJ), and DCP (kg) available, demand, and balance per household for maintenance of the tropical livestock unit in the study area.

Districts			Annual nutrient available			Annual nutrient demand			Annual nutrient balance (% fulfilled)		
	N	TLU	TDM	TME	DCP	TDM	TME	DCP	TDM	TME	*DCP*
Adaba	104	21.4 ± 1.84	19.83 ± 1.34	180107.1	1192.78	55.66 ± 3.77	265026.9	1424.96	-35.83 ± 2.55 (35.63%)	-84919.8 (68%)	-232.18 (83.7%)
Dinsho	101	22.2 ± 1.90	9.31 ± 0.63	80603.28	496.7	50.51 ± 3.43	241131	1292.92	-41.2 ± 2.03 (18.43%)	-160527.72 (33.43%)	-796.22 (34.42%)
Goba	58	26.85 ± 2.31	41.92 ± 2.84	362174.5	2443.59	61.08 ± 4.14	291638.26	1563.74	-19.16 ± 3.49 (68.63%)	70536.24 (80.52%)	879.85 (64%)
Overall mean	87.7	23.39 ± 2.02	23.69 ± 1.61	207628.3	1377.69	55.8 ± 3.78	265932.1	1427.21	-32.1 ± 2.69 (40.9%)	-58303.76 (60.65%)	-49.52 (60.71%)

TLU: Tropical livestock unit; TDM: Total dry matter; TME: Total metabolizable energy; DCP: Digestible crude protein; N: Number of households; Figures in parentheses indicate the % nutrient balance fulfilled to satisfy the requirements of animals.

energy (ME) maintenance needs for livestock per household annually. Conversely, in Dinsho district, the estimated feed supply satisfied around 18.43% of the TDM, 33.43% of the DCP and 34.42% of the ME maintenance requirements for livestock per household each year. In Goba district, the projected feed supply accounted for about 68.63% of the TDM, 80.52% of the DCP and 64% of the ME maintenance needs for livestock per household annually.

In the study areas, the supply of TDM, DCP, and ME was met for only 4.3, 8, and 10 months in Adaba district, 2, 4, and 4 months in Dinsho district, and 8, 10, and 8 months in Goba district. On average, livestock experienced a significant feed shortage for the subsequent 7.7 months across the study areas. This finding aligned with earlier studies conducted in Ethiopia's diverse agro-ecological zones (Admassu, 2008; Dawit *et al*., 2013; Tikabo and Shumuye, 2023). The pronounced deficit observed in Dinsho district was linked to the low nutritional value of the main feed sources and the region's elevated livestock population. To address this deficiency, livestock from Adaba, Dinsho, and Goba districts utilized the park for grazing for 8, 10, and 2 months, respectively.

Conclusion

The current study concluded that the feed produced and dietary needs in terms of DM, ME, and DCP did not sufficiently meet the dietary requirements of livestock in the park-adjacent districts around BMNP. In the study areas, the feed provided annually fulfilled only 41%, 60.65%, and 60.71% of the DM, DCP, and ME needs per household, respectively. Consequently, livestock face feed shortages, which might adversely affect livestock productivity in the region and force local communities to relocate their livestock to the park. The current evidence suggests that if the feed deficit is not addressed through enhanced feed availability and quality, along with the implementation of strategic feeding practices, the productivity of livestock, habitat management, and biodiversity conservation will face significant adverse effects. The findings further revealed that the livestock population in the study areas exceeded the land's carrying capacity by 59% and needs implementation of appropriate measures/strategies.

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