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Feed Gaps Among Cattle Keepers in Semiarid and Arid Southern African Regions: A Case Study in the Limpopo Province, South Africa

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Abstract

Rural livestock farmers in the semiarid and arid areas of Southern Africa face large uncertainties due to a high intraseasonal and year-to-year variability in rainfall patterns which affect forage resources. Creating resilient communal livestock farming systems will require the understanding of feed gaps as perceived by livestock farmers as well as an assessment of available feed resources. In this chapter, we estimated the annual feed balance (i.e., forage supply minus forage demand) based on statistical data and described the perception of feed gaps across 122 livestock farmers in Limpopo province, South Africa. In addition, we analyzed available feed and soil resources during the dry season across land use types. We found a negative feed balance, an indication of feed gaps for livestock farms, mainly during the winter and spring seasons. Farmers perceived a combination of factors such as drought, infrastructure, capital, and access to land as the major causes of feed gaps. Furthermore, our analyses of feed and soil

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resources point to low crude protein (e.g., ~5% in rangeland biomass) and poor soil nutrient contents (e.g., %*N* < 0.1). To support rural policies and improve the performance of communal livestock systems, there is a need to combine the most appropriate site-specific options in optimizing the feed supply.

19.1 Introduction

> ... And also the effects of global warming, we are feeling it here. This drought, it might take long, it can be here for a very long time. We experience it almost every year and every year it's a little bit harsher than in the previous year. (farmer from Maruleng Municipality, Limpopo Province)

In many parts of southern Africa, livestock plays a very important role in the livelihood of rural dwellers (Nyamushamba et al. 2017). According to a report by Köhler-Rollefson (2004), livestock contributes, in cash only, up to 38% to the agricultural Gross Domestic Product in the region, and about 90% of the livestock keepers can be classified as smallholders. A smallholder is often characterized as a resource-constrained farmer that operates livestock primarily for subsistence purposes but also as a major risk-alleviating activity (Köhler-Rollefson 2004). Keeping livestock has been reported to improve household income through sales of animals, milk, and dairy products (Maleko et al. 2018). Smallholders also depend on cattle production for household consumption and, in a mixed-crop livestock system, the integration of cattle also provides benefits such as dung for manure, and draught power for tillage cropping and transport (Thornton and Herrero 2015). In the Limpopo province of South Africa, keeping livestock in the smallholder context remains a cultural-based strategy important for financial security (Marandure et al. 2020). With respect to the smallholder livestock farming sector in the province, Stroebel et al. (2011) reported small herd size (for instance, less than 10 head of cattle) with low or no-input management and poor breeding objectives. Hence, the sector is generally characterized by low productivity (Mapiye et al. 2019). Despite the already challenged livestock production systems, climate change and variability pose an additional threat, representing a major concern (Nardone et al. 2010). Throughout the southern African region, there is evidence of negative effects of lower rainfall, increased temperature, and prolonged droughts (Archer et al. 2019; Makuvaro et al. 2018; Simelton et al. 2013; Ziervogel et al. 2014) with adverse effects on livestock and the livelihoods of smallholder farmers in the arid and semiarid areas (Batisani et al. 2021; Descheemaeker et al. 2016). In South Africa, Ziervogel et al. (2014) and Archer et al. (2019) have explicitly demonstrated climate anomalies such as exacerbated weather events (e.g., prolonged drought, extended heat waves, change in the distribution and frequency of rainfall, drying up of water bodies). Such changes have significant negative impacts, particularly for smallholder livestock and mixed-crop livestock systems that are associated with natural grazing on communal rangelands and rain-fed agriculture (Thornton and Herrero 2015). Prolonged drought, as a result of annual or seasonal variation in the rainfall patterns, is reported to be the most challenging or damaging by its effect on rangelands (Godde et al. 2020; Vetter et al. 2020) and on rain-fed agricultural systems (Meza et al. 2021). It is now widely accepted that alterations in forage provision will increase with climatic variability (Godde et al. 2021) leading to feed gaps.

For livestock, a feed or a forage gap generally addresses a period during which the animal's feed/forage demand is higher than the feed/forage supply. As explained by Moore et al. (2009), a feed gap is a consequence of the combination of bio-economic factors such as seasonal forage growth, livestock feed intake, farmers' objectives, and financial capacities. In the communal smallholder livestock context, a feed gap is also dependent on additional factors such as herd size, structure, and management, or natural resource governance (Vetter et al. 2020). A feed balance may undergo considerable seasonal variation within one year or vary considerably from one year to another due to environmental factors (e.g., high interannual rainfall variability) that govern rangelands' biomass productivity. Therefore, two types of feed gaps occur which can be referred to as a "regular" feed gap and an "irregular" feed gap. A regular feed gap occurs every year on account of the seasonal changes in forage growth (e.g., autumn to winter, winter to spring, or summer to autumn), while an irregular feed gap typically occurs once every few years due to a year-to-year variability (e.g., years of severe drought in 2015–2016 and recently 2018–2020). In livestock production systems, feed gaps are important phenomena setting the potential for farm productivity. As argued by Bell (2009) and Moore et al. (2009), the capacity of a livestock-keeping enterprise to maintain or sustain animals during periods of feed gaps is regarded as the safe carrying capacity of the enterprise that could improve profitability. This is because feed gaps, whether regular or irregular, may affect the livestock directly or indirectly, consequently affecting productivity.

A direct effect of a feed gap according to Moore et al. (2009) reduces the forage intake by livestock, forcing the animals to lose weight. According to Schlecht et al. (1999), the variation of the forage availability from the rainy to dry seasons not only leads to a decline in feed quantity but also in its nutritive quality. For instance, during a feed gap, the energy provided to cattle from the dry and fibrous (i.e., less nutritious) pasture is not sufficient leading to a catabolism of their body tissue. Therefore, a feed gap, when it occurs, does not only contribute to the decline in the maintenance of the cattle energy status but also has economic implications for the farmer (return on sales).

Moore et al. (2009) further argued that feed gaps may affect livestock indirectly through decreased and poor sperm production, and ovulation rates all of which have significant effects on breeding performance. For instance, beef bull calves that are fed below their maintenance requirements (in terms of energy and protein) may encounter sexual immaturity with decreased sperm production (Thundathil et al. 2016). Therefore, nutrition deficiency caused by feed scarcity during the dry season would first affect the livestock's residual feed intake. This would cause a decline in feed efficiency in relation to cattle growth rate, consequently affecting morphological development. Additionally, nutrition deficiency is also known to impact lactation and embryo survival affecting the reproductive capacity of the livestock systems (Thundathil et al. 2016).

A very recent integrated drought risk assessment by Meza et al. (2021) revealed that the Limpopo province of South Africa is one of the most exposed provinces to extreme drought, resulting in decreased rangeland productivity and crop yields. Thus, the frequent and major drought periods facing cattle keepers could be considered extended feed gap periods. A sound assessment of the seasonal livestock feed gaps through the perceptions of vulnerable livestock farmers, and data on available feed resources during the dry period (quality and utilization) may be crucial for the development of adequate recommendations. Providing adequate supplementary nutrients to nutritionally-challenged livestock in periods of feed gaps will be crucial in improving livestock production and increasing profitability (Bell et al. 2017). For this, we assessed the contribution of crop residues to the feeding regime of cattle, to clearly identify periods where feed is unavailable to meet animal's demand.

One of the urgent priorities is to find a proper way to deal with the seasonal feed gaps for rural livestock farmers to facilitate resilience towards improved livestock systems. The principal goal of this chapter is to inform the general public and policy makers on climate-induced feed gaps that represent a threat during periods of feed scarcity, particularly to communal livestock production.

19.2 Materials and Methods

19.2.1 Study Area

The study was conducted in Limpopo, the northernmost province of South Africa which is characterized by semiarid climatic conditions with low and variable precipitation (Mpandeli et al. 2015). The province receives about 600 mm of rainfall per annum, most of which occurs between October and April. The summer season (December–February) is hot and wet with an average maximum temperature of about 27°C while the winter (June–August) is cool and dry with an average minimum temperature of 15°C. Soils in the study area are predominantly reddish-brown loamy sand soils of low nutrient content (Munjonji et al. 2020). The typical natural vegetation is an open bush savanna woodland and natural grasslands, i.e., rangelands, dominated by C_4 grass species. Based on a recent survey, the population increased from 5.4 million to nearly 6 million by 2016 with 38.2% of all households involved in agricultural activities and 36% in livestock production (Stats SA 2018). However, livestock keeping is mostly integrated with cropping activities where maize (*Zea mays L.*), cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*), butternut (*Cucurbita moschata*), spinach (*Spinacia oleracea*), and water melon (*Citrullus lanatus*) were the most frequently and simultaneously cultivated crops. The vast majority of cattle farmers (95%) are users of communal lands with variable herd sizes (5–80) due to resource endowment. Moreover, the several government-owned natural reserves (e.g., rangelands) in the province remained a constraint as it reduces the availability of agricultural and grazing areas for livestock farming (Rootman et al. 2015). The most widespread breed is a cross-breed between Nguni and Brahman cattle and the respective pure breeds. Other popular breeds include Bonsmara and Afrikaner.

19.2.2 Data Collection and Analysis

Data used for this chapter were collected from two sets of surveys and a focus group discussion conducted at different stages of a research project. Firstly, the preliminary survey was conducted from September to November 2018 across 32 cattle farms in the arid and semiarid areas of the Limpopo province on the basis of communal livestock keeping (Klinck et al. 2022). A follow-up survey was carried out from June to September 2019 across 90 cattle farms (see more details in Lamega et al. 2021) (Fig. 19.1). The surveys were conducted using a semistructured questionnaire instrument (KoBoToolbox) (Deniau et al. 2017) which was delivered on a basis of a personal interview with the farmers. The questionnaire mainly assessed farmers' perception of (i) months of feed unavailability; (ii) feeding regimes and strategies; (iii) weight losses during feed gaps and (iv) adaptation responses/constraints to adaptation. Additionally, open-ended interviews with selected farmers were conducted to further explore the perceived feed gap challenges. The responses were recorded, transcribed, and reported based on Miles et al. (2014). In 2020, a one-day online feedback workshop was conducted with a few key farmers to discuss research results and identify management options. Selected results are averaged and reported in this chapter.

Secondly, aside from the perceptions of farmers on the seasonality of feed gaps and their effects on livestock production, the likelihood of winter feed gaps was further evaluated through the assessment of grazed rangeland biomass, crop residues, feed supplements, and selected soil nutrient levels. For instance, on communal rangelands and cropping lands, rangeland biomass and crop residues were sampled respectively by cutting from inside a 50 cm by 50 cm quadrat along a longitudinal transect (5 m apart). At the farm-level, we collected whenever possible (i.e., if the farmer had access), supplemental feed residues that may be used to feed cattle during that period. Collected feed samples were oven-dried at 60°C, ground, and then analyzed for the relative abundance of stable isotopes of nitrogen using an elemental analyzer (NA 1110; Carlo Erba, Milan) interfaced (ConFlo III; Finnigan MAT, Bremen) to an isotope ratio mass spectrometer (Delta Plus; Finnigan MAT). The nitrogen content in the feed samples is given as mass ratio in dry matter (%N) which was then multiplied by 6.25 to obtain crude protein concentration in the respective feed sample. In addition, soil samples (0–10 cm, diameter 2 cm) were taken after the removal of biomass on rangelands or cropping lands. Per quadrat, three samples were taken, which consist of 15 subsamples from one transect at a particular site. The soil was homogenized, cleared of any foreign materials, dried at 105°C, sieved (2 mm), and analyzed using the Calcium Acetate Lactate (CAL) extractable method (Schüller 1969). Soil pH was determined in water

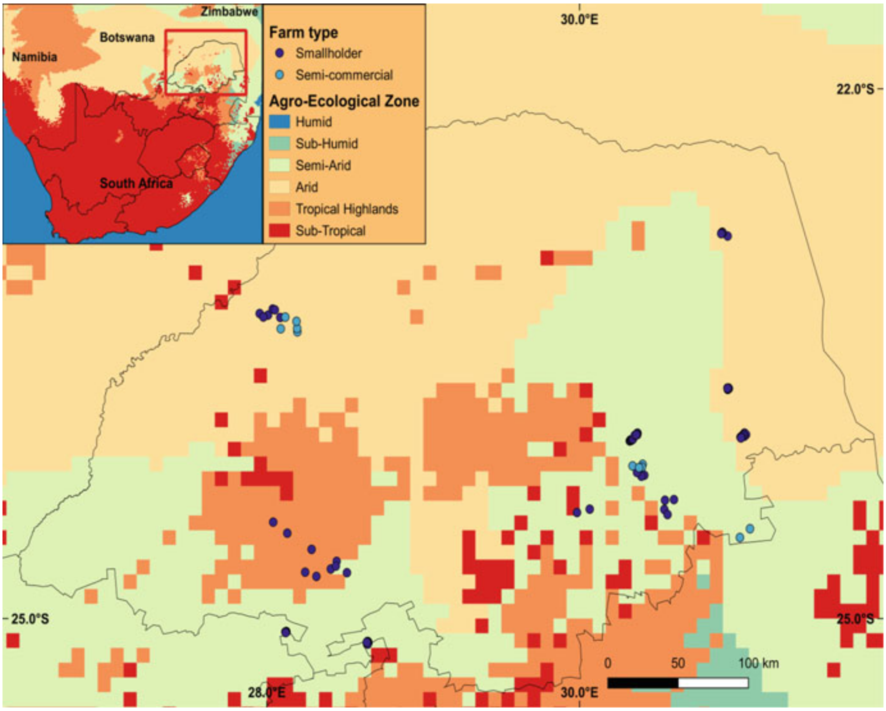

Fig. 19.1 Locations of sampled farms across semiarid and arid zones in Limpopo. In total, $N = 122$ livestock farms including 11 semicommercially oriented livestock farms (dotted light blue). Classification data for agroecological zones obtained from (HarvestChoice and IFPRI 2015)

while the concentrations of P and K were determined in continuous flow analysis coupled to a UV/VIS spectrophotometer (San System, Skalar, the Netherlands). The remaining nutrient concentrations were determined using atomic absorption spectrometry (AAnalyst 400, Perkin Elmer Inc., Waltham, USA).

Finally, we calculated feed balances based on statistical data. However, an uncertain number of young and old livestock is kept in the smallholder sector of Limpopo. According to (DAFF 2021), a total of 860,000 heads of cattle were kept in the Limpopo province in 2020. We assumed an average live weight of 450 kg cattle to obtain an estimate of tropical livestock units (TLU = 250 kg live weight) with every TLU consuming 10 kg dry matter daily. These values consequently represent the cattle livestock forage demand. We further derived an estimate of crop residue yields from maize production as based on Kutu (2012) who reports a stover proportion of 0.41 for maize production in Limpopo. The so-calculated maize residue amount was added to an estimate of rangeland biomass, as extracted from Martens et al. (2020) and Avenant (2019), to obtain an estimate of the forage supply. The survey data was analyzed in R using descriptive statistics to report on the perception of feed gaps across farmers and characterize the quality of feed and soil resources across sites.

19.3 Results

19.3.1 Estimation of Feed Balance in the Limpopo Province

The severity of feed deficit in the cattle livestock sector of Limpopo was derived by calculating feed balances. According to our calculation, about 1,484,753 TLU are kept in Limpopo per year. With a daily forage demand of 10 kg DM per day and TLU, an estimated annual forage demand of about 5.7 million tons for cattle is expected (see Table 19.1).

In many parts of southern Africa, major forage resources for cattle livestock may constitute rangeland biomass and maize residues from cropping lands (Homann-Kee Tui et al. 2015; Masikati et al. 2015). On the supply side we, consequently, used maize production and rangeland biomass production to estimate forage supply. According to Avenant (2019), approximately 7.4 million ha of rangeland is available for grazing in the Limpopo province. Maize is the most commonly grown crop, especially on smallholder farms. Statista (2021) estimated a total volume of 231.000 t maize in 2020 (Table 19.1). According to Kutu (2012), who has analyzed maize production systems in two locations in the Limpopo province, a stover proportion of 0.41 of total aboveground maize biomass can be assumed. Using this proportion, we estimated a total of 160,525 t of maize stover biomass that is potentially available to be used as forage when maize is harvested which usually takes place in March (autumn) at the end of the wet season. A reliable calculation for the productivity of rangeland is far more complex. We used the results of

Table 19.1 Annual forage balance for the Limpopo region as derived from official maize production amounts, an estimate for the stover production, and an estimate for the whole rangeland dry matter accumulation on an annual basis (tons) and compared to the forage demand of all cattle livestock as expressed in tropical livestock units (TLU). *DM* dry matter

Year	What	Value	Reference
2020	Maize grain yield (*t*)	231,000	(Statista 2021)
	Stover % (total aboveground maize)	0.41	(Kutu 2012)
	Total maize biomass total (*t*)	391,525	Calculated
	Stover biomass total (*t*)	160,525	Calculated
Mean 2011–2019	Rangeland biomass supply (*t* DM/ha)	0.54	(Martens et al. 2020)
	Rangeland available for grazing (ha)	7,400,000	(Avenant 2019)
	Rangeland biomass supply (*t*)	4,015,968	Calculated
	Annual feed demand cattle (*t*)	470,850	Calculated
	Feed supply total (*t*)	4,176,494	Calculated
	Feed demand total (*t*)	5,650,200	Calculated
	Balance: supply – demand (*t*)	**−1,473,706**	Calculated

modeled rangeland productivity for the province and for our study sites (Martens et al. 2020) to calculate the seasonal rangeland productivity across the arid and semiarid zones which gave an annual estimate of 0.228 t C/ha per year. Assuming that dry matter (DM) biomass contains 42% C giving an annual value of 0.54 t DM/ha of rangeland which was applied to a rangeland area of 7.4 million ha (76% of the total rangeland area Table 19.1). Not all of the rangeland area in Limpopo is considered suitable for grazing, because of shrub and tree cover, area protection, or urbanization. Consequently, we found an annual feed supply of 4,176,494 t that is unable to sustain the demand of cattle (5,650,200 t), resulting in a negative feed balance (Table 19.1).

Avenant (2019) used a different approach to calculate the carrying capacity of rangeland in the study area. Using the estimated values for rangeland production in that study, 0.488 t DM/ha is very close to the value used in our approach (0.54 t DM/ha). According to our estimation, we found a shortage in feed supply on an annual basis, taking into account that there are two major constraints underlying our calculations. Firstly, we only used predominantly statistical data, and we did not consider livestock species other than cattle although small ruminants are also important forage consumers in the region. In addition, we did not account for forage quality which is likely limiting the utilization capacity of maize residues and rangeland biomass during a large part of the year. According to Descheemaeker et al. (2018), the requirements of metabolizable energy (ME) range from 45 to 65 MJ ME/day per animal. As known from other studies, maize residues never reach values >6 MJ ME/kg DM when harvested at physiological maturity (Terler et al. 2019). In addition, grass ME concentration ranges usually between 6.5 and 10.3 MJ/kg DM in the dry and the wet season respectively, which points to a shortage of forage with sufficient quality in the dry season. But not only quality is likely limiting in the dry season. When using the annual forage balance data for monthly calculations, we found strong support for a serious shortage in feed supply during winter and spring (Table 19.2). Forage quantity and likely quality are, consequently, critical issues for the livestock sector.

Moreover, to check the assumptions made for the calculation of the feed balance, a sensitivity analysis was carried out where, under a constant average live weight of 450 kg, the daily forage DM intake was varied from 10 to 5 kg (Fig. 19.2a) or, under a constant average forage intake of 10 kg per day, the live weight varied from 450 to 300 kg (Fig. 19.2b). These calculations have an effect on the annual feed requirement. The result show that already at about 7 kg DM intake per day a negative balance is no longer to be expected (Fig. 19.2a). On the other hand, a positive balance can only be expected at an average herd weight of 300 kg DM which is unusually low. The assumption made about live weight, consequently, underestimates the problem of the feed gap evaluation. For the exact forage requirement, however, it would be good to generate accurate information on the variation of forage intake of the cattle in Limpopo which is the prerequisite to understanding the contribution of other potential forage sources.

Table 19.2 Derived seasonal feed balance as monthly feed supply from rangeland and maize stover (*t*) against the seasonal feed demand by cattle livestock (*t*). *TLU* Tropical livestock units, *DM* dry matter

Season	Month	DM demand cattle TLU (*t*)	Maize stover (*t*)	Rangelands (*t*)	Feed balance
Summer	Jan	470,850	0	1,866,444	1,395,594
Summer	Feb	470,850	0	1,866,444	1,395,594
Autumn	Mar	470,850	160,525	1,571,619	1,261,294
Autumn	Apr	470,850	53,508	1,571,619	1,154,277
Autumn	May	470,850	17,836	1,571,619	1,118,605
Winter	Jun	470,850	0	108,063	**−362,787**
Winter	Jul	470,850	0	108,063	**−362,787**
Winter	Aug	470,850	0	108,063	**−362,787**
Spring	Sep	470,850	0	469,254	**−1596**
Spring	Oct	470,850	0	469,254	**−1596**
Spring	Nov	470,850	0	469,254	**−1596**
Summer	Dec	470,850	0	1,866,444	1,395,594

19.3.2 Feed Gap as Perceived by Livestock Farmers

Across the arid and semiarid zones, winter and spring are the seasons of feed deficit according to the farmers. While feed shortages are perceived to be most severe during September and October (spring), the duration of experienced shortages was generally one month longer for some farmers (3.4 vs. 2.4 months) (see Lamega et al. (2021)). The heterogeneity between farms plays an important role in the perceptions of the seasonal patterns of feed gaps. For instance, farmers' perceptions of feed gaps did not differ significantly during winter as both mixed-crop livestock and specialist livestock-only farmers were equally affected. However, the perceptions of feed gaps in autumn and spring differed between both farming systems irrespective of their locations.

Cattle livestock farmers did not follow a controlled mating schedule for selective breeding but allowed for natural breeding instead. Animals from farmers that are little endowed (> 50 cattle head) were reported to be weaned at around 7 months, whereas typical smallholder farmers (< 20 cattle head) reported a weaning age of about 11 months. Calves commonly wean later when they receive milk of poorer nutritive value from their dams. During drought, pregnant and lactating cows suffer from nutrient deficiency which is likely mirrored in the lower reproductive performance of the offspring. Furthermore, limited flexibility in securing water availability is a limiting factor in the feed-drought nexus. Access to water sources is tightly linked to access to land and thus taps, boreholes, dams, or streams.

Smallholder farmers in our study area perceived the phenomenon of "drought" particularly manifesting in its biophysical dimension, that is, the perception in the decline in water availability and rangeland productivity. Thus, livestock husbandry under (semi)arid conditions requires a form of adaptive capacity that allows farmers and herders to respond flexibly. For example, by producing their own feed or seeking

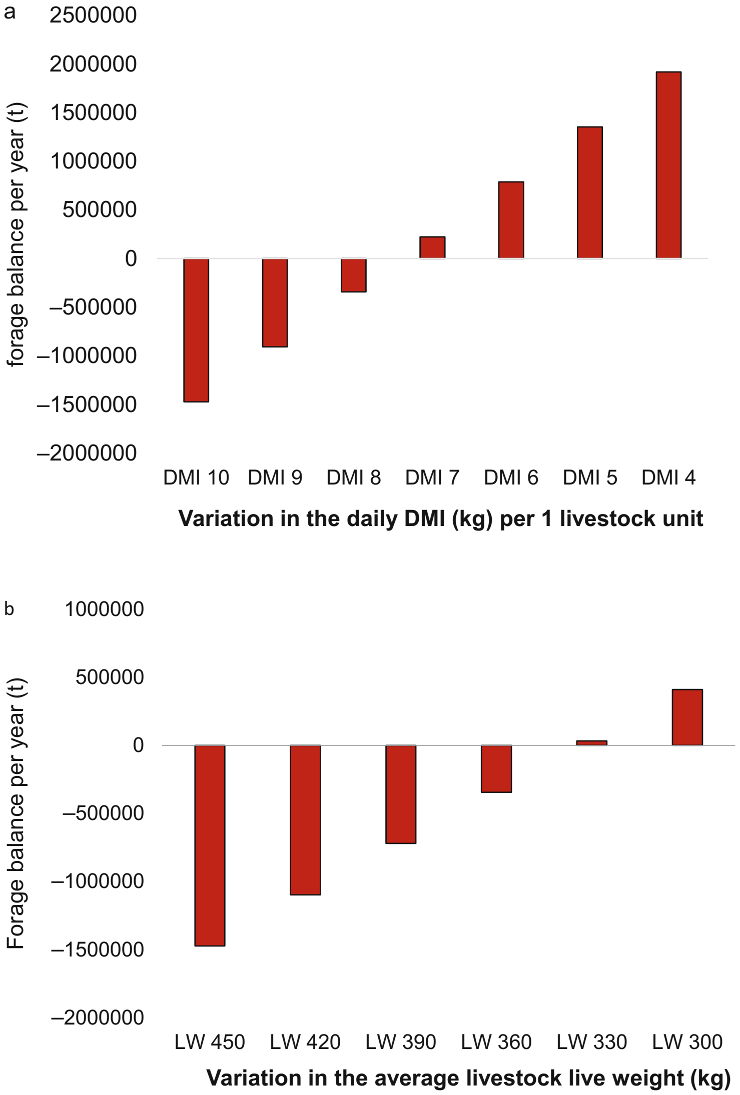

Fig. 19.2 Sensitivity analysis of forage balance calculation as affected by a) the variation in daily dry matter intake (DMI) (4–10 kg) per 1 livestock unit (450 kg) and b) the variation in cattle live weight (300–450 kg) consuming a daily dry matter of 10 kg

out extensive grazing lands, they could face the harsh climatic condition. Access to and utilization of extensive rangelands is crucial when animals (and herders) are required to cover greater distances to water sources, during prolonged droughts when dams and communal watering holes dry up. Farmers would then move their animals to alternative water sources further away or fetch water with motorized vehicles. If feed in the dry period is already critically limited, the additional caloric costs, i.e., animals covering extra distances for pasture and water, may translate into poor livestock health (Ouédraogo et al. 2021).

A rough on-farm assessment of the body condition score (BCS) demonstrated that animals relying solely on communal rangelands are indeed on average closer to drought-induced starvation (BCS of ~2.01 with 0 = emaciated and 5 = over-fat). In many cases, in communal livestock systems, livestock farmers or managers do not look into maximizing operating profit, instead maximizing or maintaining herd size, remains the priority (Stroebel et al. 2011; Tavirimirwa et al. 2019). Therefore, the risk of feed gaps may not only be associated with the unproductivity of rangeland during the dry season but it may also be related to the high costs of producing/purchasing feed, concentrates, and or conservation of forage. It is likely that farmers that have access to capital are more flexible in their modes of feed provision (Chikowo et al. 2014). Such farmers may draw from a variety of on-farm produced crops, forage, silage, and commercial supplements. To some extent, these livestock farmers that are more endowed may dispose of private boreholes and wells to alleviate the impacts of feed gaps. Moreover, in areas with sufficient annual rainfall, ground water may be important in maintaining the productivity of rangeland biomass, hence reducing feed gap risks significantly. In the arid zones of Western Limpopo, some farms even employed water-intensive fodder crops like sugar cane (*Saccharum officinarum*) or Blue Buffalo Grass (*Cenchrus ciliaris*). Also, in the arid zones of Eastern Limpopo, livestock may graze on Mopane tree leaves (*Colosphospermum mopane*), which are available on the rangelands but become scarce with the extended dry period.

Furthermore, farmers perceived feed shortages not directly as a result of bio-physical drought, but rather linked to low overall farm profitability and low returns in investments (Fig. 19.3). Aside from the obvious climate-induced drought, farmers mentioned a variety of limitations including insufficient technical extension support, poor local beef demand, poor access to external markets, and contract farming. These limitations were all perceived as impediments to profitability and business growth.

One farmer related the exclusive nature of contracts in the retail sector to favoring commercially-oriented farmers only:

> We [small – semi farmers] don't get access to Spar [supermarket] . . . direct straight. We are under someone else, it's a middleman. We can't grow. From 1914 to today, no successful farming in here, we just do farming for pleasure or whatever, to make a living.

Commercially-oriented cattle production, on the other hand, requires high-caloric and nutritious feed throughout the year for regular off-take to auctions and abattoirs. Supplements thus play a crucial role, whether produced on-farm or bought off-farm and it requires a certain financial margin for investments in feedstuffs (Fig. 19.3). In contrast, in the communal setup, a feed gap is essentially linked to the availability of grazing areas that accommodate community-level stocking density. Additional feed is rather linked to farm types (if the farmer engages in cropping) or capital (if the farmer can purchase feed). Since smallholders are mostly financially

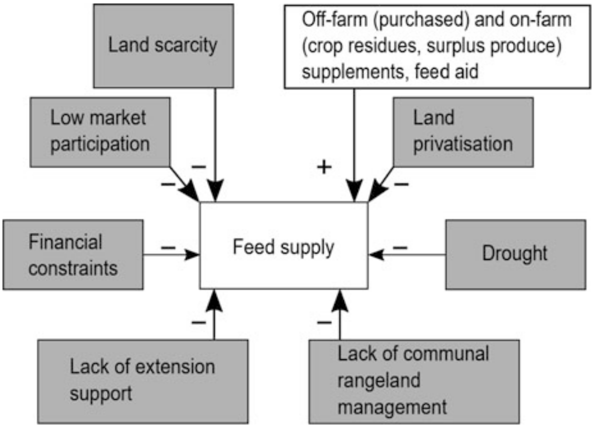

Fig. 19.3 Concept map summarizing perceived root causes (gray) and feed gap mitigation strategies (white) for livestock farmers during feed gaps. Relational arrows indicate enhancing (+) or reducing (−) effects on feed supply

constrained, they tend to be low adopters of feed gap strategies. The most common strategy is the use of readily available crop residues during autumn (Table 19.2), which serves as an additional feed input for livestock farms at no cost. Under severe drought conditions, where crop residues alone are not enough, farmers may reduce their livestock number to balance feed requirements. These strategies are associated with the socioeconomic challenges of the smallholder livestock sector that render it vulnerable to feed gaps (Lamega et al. 2021; Mapiye et al. 2009; Marandure et al. 2020).

19.3.3 Results of Available Feed and Soil Resources

19.3.3.1 Feeding Resources

Cattle rely heavily on the productivity of rangelands. In the study area in particular, rainfall patterns have created a vegetation gradient that may differ from the arid to the semiarid zones. According to Mpofu et al. (2017), the veld type (an indigenous grazing and or browsing vegetation composed of any sort of plant species capable to reproduce itself undecidedly under existing environmental conditions) varies from sweet and mixed in arid areas to sourveld in semiarid areas with prevailing grass species such as *Panicum maximum*, *Aristida transvaalenesis*, *Eragrostis curvula*, and *Themeda triandra*. A sweet veld according to Trollope et al. (1990) is a veld that retains acceptable nutritive values of its forage plants after maturity, utilizable throughout the year by livestock while a sourveld shows sharp declines in forage quality with ongoing maturation. A mixed veld is an intermediate veld between the sour and sweetveld with an acceptable quality supply of forage to the livestock.

Our analysis in terms of crude protein (CP) concentration of the dry rangeland biomass in winter showed low herbage quality across the studied sites in the Limpopo province with a maximum of 5.3% (Table 19.3). Hence, the quality of the fibrous and dead herbage is poor. Even lower values of 2.7% CP were reported in a previous study by Moyo et al. (2012) in the winter period due to low growth

Table 19.3 Cattle feeding resources and their crude protein concentration (%) during the winter dry season: Site regroups about two to three villages where rangeland biomass is collected on communal rangelands, crop residues, and supplements are collected from selected farms

Feed resource	Site	Number of samples	Crude protein (%)
Rangeland biomass	Site 1	10	5.3 ± 1.7
Rangeland biomass	Site 2	10	4.6 ± 1.8
Rangeland biomass	Site 3	26	4.2 ± 1.4
Crop residues	Site 1	5	9.7 ± 1.3
Crop residues	Site 2	10	4.5 ± 0.9
Crop residues	Site 3	–	–
Feed supplements	Site 1	7	11.3 ± 3.3
Feed supplements	Site 2[a]	1	10.7
Feed supplements	Site 3	12	12.2 ± 9.4
Tree leaves	Site 1	10	9.1 ± 1.5

[a] Only one farmer at Site 2 had access to feed supplements

and senescence. Nevertheless, in situations where there is hardly any herbage to consume, mineral nutrients may help livestock to cover some of its elemental demand irrespective of low protein or energy concentrations. The mineral nutrient concentration is likely insufficient to meet the livestock's nutritional demand (Lamega et al. 2021). In response to the dry and fibrous pasture during the dry season with low CP concentration, cattle may increase the selective retention time for feed particles in the rumen, hence improving fiber digestion. However, this response to the feed gap is hardly adequate to avoid the loss in body tissue which is associated with reduced nutrient supply and metabolic processes (Moore et al. 2009; Schlecht et al. 1999). The scarcity of grazing resources in terms of quality (Table 19.3) and quantity (Tables 19.1 and 19.2, Fig. 19.2) along with increasing bush encroachments on the grazing rangelands (Mogashoa et al. 2021) is, therefore, a call for supplementary feeding.

Crop residues are the first source of additional feed across the study sites. In mixed-crop livestock systems in particular, crop residues represent supplementary feed for livestock in the dry season (Masikati et al. 2015). Therefore, the management of these residues may differ significantly in relation to the utilization as feed (Rusinamhodzi et al. 2016). Generally, the availability of crop residues coincides temporally with times when rangeland productivity declines (in terms of quantity and quality, see Fig. 19.4), making them a valuable feed resource. Crops such as maize, pumpkin, groundnut, and cabbage are found in the fields and the straw and stover left at harvest are used for livestock feed. In line with this, Mapiye et al. (2009), explored the cattle keeping system among 218 smallholder farmers in the study province and showed that about 70% of the total farmers used crop residues to cope with the feed shortages during the dry season. The importance of crop residues is further demonstrated in Fig. 19.5 as a farmer collects and stores for use in periods of feed gaps.

Fig. 19.4 The communal grazing resource during the dry seasons in the arid and semiarid areas of Limpopo. Left picture shows cattle browsing on shrubs, and right picture shows the scarcity of rangeland biomass in the dry period during winter

Fig. 19.5 A farmer's supplemental feed made up of dry crop residues and tree leaves. An option for feed gap mitigation

The crop residues in the present study showed higher CP concentration than the rangeland biomass sampled (Table 19.3) or the CP concentration of 4% obtained for maize residues in a study by Mudzengi et al. (2020). It is likely that crop residues are a mixture containing at least parts of C_3 plants such as legumes with higher CP concentration (~ 10%). Low protein concentration during a feed gap may be associated with low digestibility and, hence, poor livestock performance (Mudzengi et al. 2020). Despite disagreements presented by the utilization of crop residues on smallholder farms, i.e., "mulching or no mulching" (Valbuena et al. 2012), a mixture of crop residues may serve as a good source of additional feed. However, the quality and quantity of the residues should be more in balance with animals' demand especially in periods of pasture scarcity (winter, spring), to significantly contribute to feed gap mitigation.

Supplementary feed plays a crucial part in livestock production as it can greatly improve the productivity of the livestock (Bell 2009; Bell et al. 2017). In South Africa, different conventional supplements and agroindustrial by-products are available for purchase (Marandure et al. 2020). However, such feed purchase depends on the socioeconomic status of a farm, but also on the intensity of the livestock production. For smallholder livestock farming that is often financially constrained, first-choice supplementary feeds constitute crop residues and agricultural or household waste. However, our results of CP concentration show that feed supplements are more valuable than anticipated particularly when compared to rangeland biomass, which should be beneficial for the livestock enterprise during feed gaps overall.

However, since the quantity of supplementary feed may depend on herd size, resource-constrained farmers may fail to purchase enough to sustain production. In this case, a farmer will strategically feed animals that are too weak to search for herbage intake on rangelands. On the other hand, focus could be given to high-performing livestock such as lactating cows. Additionally, browse trees can also provide supplementary feed during the dry season (Mudzengi et al. 2020). Here, we found that indigenous species such as *Colophospermum mopane* (common on rangelands) are rich in crude protein (Table 19.3) and likely other nutrients.

19.3.3.2 Soil Resources

In relation to soil fertility, evidence from the literature demonstrated that the majority of smallholder farmers in the southern African region face land degradation (Rufino et al. 2011; Zingore et al. 2007), and this phenomenon is particularly true among smallholder farmers in South Africa (Kolawole 2013). We collected soil samples across land use (rangelands and cropping lands) to get an insight into the fertility status (Table 19.4). We are aware that site-specific nutrient allocation in soils, for instance, around home gardens, or fields close to homesteads have caused soil fertility gradients, problematic in terms of sustainable land use (Mtambanengwe and Mapfumo 2005; Rowe et al. 2006; Zingore et al. 2007).

Basing on Kotzé et al. (2013) who evaluated basic soil properties across different land use types and management situations, all the soil nutrients may be limiting plant production. Under communal set up, Kotzé et al. (2013) discussed low nutrient content (e.g., <2% C, < 0.2% N, < 10 mg/kg P). We found similar results for our study (Table 19.4) which demonstrates poor land use conditions. The C/N ratio of c. 10 points to organic matter quality which potentially readily supplies nitrogen to crops. However, both the N and C contents are very low demonstrating issues with soil quality. Soil degradation is also a reflection of grazing effects on rangelands as previously discussed by Descheemaeker et al. (2010) and Linstädter

Table 19.4 Selected soil chemical properties across different land use types in the studied Limpopo region. $n = 18 \pm 5.3$ soil samples (0–10 cm) per site

Site	Land use	pH	N total (%)	C total (%)	P (mg kg^{-1})	K (mg kg^{-1})	Mg (mg kg^{-1})
Site1	Cropland	6.5 ± 0.8	0.06 ± 0.01	0.66 ± 0.09	<1.00	17.45 ± 3.97	17.53 ± 2.25
Site1	Rangeland	6.3 ± 0.6	0.07 ± 0.03	0.80 ± 0.35	2.40 ± 1.6	20.88 ± 6.02	20.56 ± 9.16
Site 2	Cropland	5.4 ± 0.7	0.10 ± 0.02	1.18 ± 0.16	<1.00	6.56 ± 6.20	24.82 ± 3.42
Site 2	Rangeland	5.3 ± 0.5	0.12 ± 0.04	1.55 ± 0.83	<1.00	5.53 ± 3.77	31.43 ± 12.8
Site 3	Rangeland	5.0 ± 0.7	0.06 ± 0.03	0.62 ± 0.31	<1.00	9.98 ± 8.60	8.58 ± 13.26

et al. (2014), thus an issue of stocking intensity (Kotzé et al. 2013). Additionally, in an aerial cover study conducted under similar conditions in South Africa, Dlamini et al. (2014) showed from initially nondegraded soils, that grazing decreased soil organic carbon by 94% while nitrogen decreased by 40% on communal rangelands managed by smallholder livestock farmers. Such degradation was found under fine sandy loamy soils in the semiarid zones in South Africa. Most soils in the region where the present study was conducted refer to such soil textures (Swanepoel et al. 2015). Carbon is important for soil nutrient cycling and water storage. Nutrient limitation is generally potentially restricting herbage production. Therefore, soil fertility initiatives with an emphasis on C, N, and P through future research may be essential for improving pasture forage supply.

19.4 Discussion

19.4.1 Dealing with Feed Gaps

Though the variability in the supply of feed to livestock is linked to the variability in the rainfall patterns that restricts rangeland productivity, the vulnerability of communal livestock farmers to feed gaps may also depend on the adaptive capacities of rural communities. Therefore, the effects of feed gaps can highly be site-specific (Godde et al. 2021). Having this in mind, any strategies designed to deal with either a regular or an irregular feed gap must be context-specific with direct and indirect effects on livestock production. Moore et al. (2009) proposed two main approaches to deal with the occurrence of feed gaps: tactical and strategical approaches. According to these authors, a tactical response is implemented when needs arise. For instance, a farmer could buy or sell livestock depending on the balance between the number of herds and the available feed. A tactical response could also involve the application of fertilizers to pastures to boost seasonal production in the rainy season. This approach is usually preferable for irregular feed gaps where the supply of feed is less predictable in terms of its magnitude and timing (Bell 2009). Such management aims at the provisioning of conserves obtained during times of excess feed supply. The advantages of tactical responses are that these can easily be implemented without changing the existing land-use or farming patterns and that opportunity costs are generally low in years when the tactical response is not executed. On the other hand, a strategic approach can be deployed for situations with regular feed gaps and requires structural adjustments to the livestock farming system. A strategic response involves the introduction of multiyear permanently available forage shrubs as a feed base.

In a communal setup, a more efficient approach in alleviating feed gaps among resource-constrained livestock keepers in Limpopo should have benefits for the natural resources (e.g., rangelands). However, many approaches to improve the common grazing resources among livestock farmers through improved management have failed as demonstrated in other semiarid and arid areas (e.g., Tavirimirwa et al. 2019). Nevertheless, insights from systems evaluation emphasize farming system flexibility as a prerequisite for risk adaptation (Thornton and Herrero 2015). Particularly in the smallholder South African context, in the light of the absence of effective rangeland governance, clear tenure policies and entrenching inequalities in access to land and resources; smallholders' current drought responses are likely to continue (Müller et al. 2015; Vetter 2013). This echoes Atkinson's (2013) call for flexibility in both tenure and smallholder-oriented commercialization policies. We concur with Vetter (2013) that the involvement of livestock keepers in any solution-oriented debate is mandatory and critical in developing a contextual understanding of locally nuanced challenges. For this to happen, policy makers need to have a sense of accountability and interest in co-framing the needs of and with smallholding livestock keepers. Managing the political framework, thus, begins with understanding and recognizing the concerns and importance of communal livestock for local food security, cultural value, and livelihood asset (Ainslie 2013).

19.4.2 Managing Rangeland Stocking Density: Destocking to Reduce Pressure on Natural Resources

In their understanding of "better" rangeland management, stakeholders from our group discussion maintained that communal rangelands were unquestionably overgrazed. Thus, destocking or resting periods may be the only reasonable options to restore productivity and close dry-season feed gaps. The role of stocking densities and overgrazing in debates about the management of southern Africa's rangelands remains a very controversial topic. Despite its persistent promotion to ameliorate Africa's rangelands from degradation, the technocratic approach to destocking the rangelands is not a universal panacea that fits every social-ecological context (Godde et al. 2020; Tavirimirwa et al. 2019). Farmers persistently resisted to comply with such top-down approaches that were far from addressing their realities (Tavirimirwa et al. 2019). This is because farmers mainly seek to maximize herd size; hence, destocking initiatives fail to be implemented. Furthermore, grazing schemes or resting periods should not be recommended in this context as they reduce the flexibility of the common grazing resource (Tavirimirwa et al. 2019). However, as argued by Lamega et al. (2021), destocking can be attained if it is subsidized to be in balance with the seasonal feed budget. The longstanding debate still appears to be grounded on different understandings between top-down-oriented policies and stakeholders.

19.4.3 On-Farm Feed Production

Maize stover is particularly an important feed resource on smallholder farms. To improve livestock productivity using maize stover Dejene et al. (2021) demonstrated that upper maize stover fractions had higher total N concentrations and lower fiber content, and varied among different genotypes. The production of dry season (winter) forages, such as protein-rich legumes as cover crops, is a traditional practice across southern Africa, for example, Bennett et al. (2010) have reported that C_3 species such as oats (*Avena sativa L.*) and barley (*Hordeum vulgare L.*) can be intercropped with maize during the dry season. Such species can do well under the South African winter climate (cool season with low temperature), but with limited water during the winter period, irrigation schemes are crucial for high and effective production. Also, legumes have always been of interest to rural development agendas but their implementation also met with skepticism among smallholder farmers (Sumberg 2002, 2004). For instance, dual-purpose winter forage crops may provide higher feed availability during feed gaps, which can maintain livestock or accommodate higher stocking density. While the "sustainable intensification" narrative promotes cover crop legumes to close yield and thus feed gaps, the upscaling and practical implementation has been of limited success among smallholding mixed-crop livestock farmers (Tittonell and Giller 2013). It is important that feed improvement interventions fully address the quality and quantity of forage (Balehegn et al. 2020). From an agronomic point of view, however, recent field trials prove the underutilized and drought-tolerant legume lablab (*Lablab purpureus*) promising when grown in Limpopo under rain-fed conditions (Rapholo et al. 2019). Additionally, forage brassicas have the potential to alleviate regular feed gaps due to high productivity (Bell et al. 2020) if integrated as feed-base strategies in drier or mixed farming systems. However, feeding *Brassica rapa* has been associated with liver disease in Holstein cows in South Africa (Davis et al. 2021). Therefore, more research is needed in the context of feeding brassicas to local cattle breeds.

19.4.4 Feed Aid Schemes

Drought emergency support programs subsidize farmers during severe drought with supplementary feed obtained from commercial forage growers according to the farmers. A smallholder farmer commented on the present design of supplementary feeding support:

> I think the other challenge is, if we can get supplements from the government, that will help us a lot. But now they do sometimes, just as I said, I got 20 cattle and then they gave me 5 bags.

According to the farmers, feed aid comes rarely in periods of severe feed deficit. The program follows no specific criterion for acquiring such feed aids. Hence, farmers with very small herds (e.g., 5) may receive a one-time and free of charge supply, the same amount of feed (usually two to five bags of 25 kg) as a farmer that owns 20 plus cattle. In effect, such an approach to feed gap alleviation on smallholder farms is considered among farmers as not responding to the actual issue. A regular reception of such aids may help the livestock enterprise, but the question arises whether such programs can serve as a long-term sustainable adaptation strategy for smallholder farmers.

The need of strengthening the nutritional status of animals during seasonal feed gaps, through feed quality enhancement, may be achieved using combinations of different options. To make sure that farmers adopt strategies to reduce the impact of feed gaps, combined options should be considered, taking into account sociocultural factors associated with the smallholder livestock systems.

Farmers in Limpopo may learn from the pastoralists in the dry areas of Burkina Faso that deal with feed gaps by employing conservation methods such as building up fodder bundles from mowing grasses or plants when they are plentiful (Ouédraogo et al. 2021). Anyway, the success of feed interventions or any interventions to alleviate feed gaps on smallholder farms is highly dependent on specific local conditions (Balehegn et al. 2020), which cannot be overstated. Moreover, as argued by Balehegn et al. (2020), we need to also consider other related challenges that face smallholder farmers such as market access for selling stock, improved water or irrigation schemes, improved livestock breeding techniques, and diseases, all of which could reduce the effects of feed gaps and improved farm profitability. For scientists, there is also the need to develop proper research objectives, and set up necessary experiments (surveys, field trials, modeling exercises) as suggested by Garrett et al. (2017) that are site and context-specific to the subject of seasonal feed gaps.

19.5 Conclusions

As presented in this chapter, feed gaps are generally governed by the environmental conditions that regulate the demand for, and the supply of energy but also the capacity of livestock managers to utilize diverse feed sources. Feed gaps will remain a key issue for livestock farmers in the dry areas of Limpopo amid climate variability. Therefore, developing multiple options for farmers may be beneficial in sustaining livestock throughout the year. The success, however, of any given recommendations must consider location and farm type specificity but also include sociocultural values associated with livestock keeping. To support rural policies in the face of climate uncertainties, there is a need to reconfigure and restructure the livestock systems in a way that feed sources become more in balance with smallholder livestock and their demand on communal rangelands throughout the year. For instance, if the farmer engages in cropping, with access to irrigation, dual-purpose C_3 crops may serve as an option for alleviating winter feed gaps or may be used for trading. A cost-benefit analysis in relation to feed production and utilization may be helpful in evaluating adequate feeding strategies. However, the use of modeling to integrate different components of the system and management options as stated by Rötter et al. (2021) will become critical to determine ideal solutions for management issues against feed gaps.

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