Feed resources for small ruminants in Yemen: Assessment and recommendations

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1. General context

Agriculture is one of the main pillars of Yemen's economy, contributing about 17% to the total Gross Domestic Product (GDP), providing income for more than half of the population, and employing more than 50% of the workforce, while sustaining people whose livelihoods depend directly or indirectly on agricultural activities (FAO, 2024; FAO, 2021; Alyamani et al., 2020). It plays a central role in food security and rural livelihoods, with cereal production accounting for roughly 15% of total agricultural production (FAO, 2024; Alyamani et al., 2020).

Animal husbandry is practiced by nearly 80% of farming households and contributes around 20% to agricultural GDP (FAO, 2024; Alyamani et al., 2020), making it a key component of food and nutrition security and household income, particularly through milk and other animal products. It also functions as economic capital that can be mobilized in times of need, strengthening household resilience during crises. The animal production subsector including cattle, sheep, goats, camels, equines, and poultry ranks second after crop production in its contribution to agricultural GDP and is critical for poverty reduction in rural areas. According to the Agricultural Statistics Book (2021), the population reached 10,359,317 sheep, 10,043,023 goats, and 1,872,516 cattle. Small ruminants account for the majority of animals and are particularly important in highland and desert areas, where they contribute substantially to meat and milk production and serve as a key source of income (FAO, 2025; NAFSIP, 2023; Alyamani et al., 2020).

However, livestock producing households in Yemen face a complex and interlinked set of challenges that severely constrain agricultural productivity and household food security. Limited access to animal feed, grazing areas, and water; high prices for feed and veterinary inputs; widespread animal diseases and mortality; and inadequate veterinary and extension services are major constraints (FAO, 2025; NAFSIP, 2023), all intensified by recurrent droughts, irregular rainfall, desert locust infestations, and environmental degradation (NAFSIP, 2023). Poor rural infrastructure, inefficient irrigation, fragmented landholdings, weak breeding and feeding practices, deteriorating livestock genetics, and low adoption of modern technologies further reduce crop and livestock productivity, pushing many households to adopt negative coping strategies such as distress sales that shrink herd sizes (FAO, 2025; NAFSIP, 2023). These production constraints are compounded by marketing challenges, including low farm-gate prices, weak demand, high transportation costs, limited market information, post-harvest losses, inefficient input supply chains, and minimal investment in research and development, all of which reduce incomes and resilience (FAO, 2021).

At the same time, Yemen's heavy dependence on imported live animals and meat, mainly from the Horn of Africa, combined with its strategic location, active livestock trade, and migratory bird routes, heightens the risk of zoonotic and transboundary diseases such as brucellosis and tuberculosis, a risk exacerbated by weak quarantine and surveillance systems (FAO, 2025; FAO, 2023B).

The vulnerability of Yemen's agricultural sector is severely exacerbated by the interaction of a prolonged armed conflict that has persisted since 2015, fragmented supply chains, and limited access to essential inputs, mostly imported, such as seeds, fertilizers, fuel, and agricultural equipment, which have become costly and scarce (FAO, 2021). The conflict has severely disrupted watering and feeding systems and limited access to veterinary services, causing an increase in animal diseases and further exposing households that depend on animals for their livelihoods and food security (FAO, 2021). These structural fragilities are compounded by successive shocks, including the COVID-19 pandemic, the surge in global food and energy prices linked to the conflict in Ukraine, and the depreciation of the Yemeni rial, which has reduced purchasing power and undermined the availability of agricultural inputs (NAFSIP, 2023; FAO, 2021). Recent natural disasters, particularly the torrential rains of August 2024, have caused major flooding affecting more than 210,000 people, damaging nearly 98,726 ha of cultivated land and impacting around 279,400 small ruminants, while destroying key irrigation systems, storage facilities, and agricultural machinery (Aklan, 2024; FAO, 2024).

In response to rising production costs, the scarcity of water and agricultural land, and the chronic shortage and high prices of commercial animal feeds, farmers increasingly shift toward low yield rainfed crops and depend largely on local resources and seeds that are often of poor quality and are cultivated on reduced areas. The strong dependence on local resources is also reflected in limited access to concentrate feeds, compelling farmers to rely mainly on rangelands, locally available forage, crop residues, and occasional supplements to maintain their herds and safeguard their income (FAO, 2024; FAO, 2021). The low productivity of herds and local breeds reflects insufficient investment in genetic improvement, rangeland management, and technical training, further exacerbated by climate change, declining soil fertility, parasitic pressure, and the lack of good agricultural practices.

2. Overview of livestock and farming systems in Yemen

Livestock is the main source of livelihood and plays a key role in food security in Yemen. Most rural households keep animals, mainly sheep and goats, which can be sold to cover basic needs such as cereals and other household expenses (Alyamani et al., 2020; FAO, 2024; FAO, 2021). Livestock production is dominated by extensive systems, especially in the rainfed highlands, but it also includes traditional pastoralist and agro-pastoral practices as well as small-scale intensive farms (NAFSIP, 2023). Feeding relies on natural rangelands as well as cultivated or purchased forage (Amad et al., 2023). Across Yemen’s main agro-ecological zones, agricultural and livestock systems are strongly shaped by geography and climate. In the Central and Northern Highlands, agriculture is mainly rainfed, with sorghum, wheat, and barley as the major crops, and animals are fed cut fodder during the rainy season before grazing on stubble after harvest (FAO and WFP, 2009). In the Tihama Plain, fodder, particularly sorghum, is produced locally in large quantities and traded throughout the country (FAO and WFP, 2009). Along the Southern Coast, from Aden to the border with Oman, smallholder farmers mainly rely on rainfed maize, barley, and sorghum, while in the Middle Plateau of Shabwah and Hadramaut, agriculture depends on both rainfall and irrigation (FAO and WFP, 2009). Despite the diversity of systems, productivity remains low due to climatic variability, limited feed resources, and the low productive performance of local breeds, contributing to persistent poverty and food insecurity in rural areas (FAO, 2025; Alyamani et al., 2020).

3. Nutritional constraints and environmental challenges to livestock development in Yemen

Livestock development in Yemen is shaped by a complex interaction of nutritional, environmental, and socioeconomic factors that collectively influence animal productivity and health. Among these, poor nutritional conditions are the primary constraint, driven by the scarcity of natural pastures and cultivated forages (FAO, 2025; Amad et al., 2023).

In the country's predominantly arid and semi-arid zones, the chronic shortage of feed resources throughout the year remains one of the leading causes of low livestock productivity (Ben Salem, 2010). Nutritional constraints are further exacerbated by prolonged conflict and economic deterioration, which have disrupted agricultural systems and supply chains (FAO, 2025). These disruptions have caused severe shortages of feed, water, and veterinary services, resulting in widespread malnutrition among livestock. Inadequate nutrition weakens animals' resistance to disease, reduces reproductive performance and milk yield, and increases mortality rates (Colburn et al., 2025; FAO, 2025; Amad et al., 2023). Limited investment in agricultural infrastructure and modern farming technologies further restricts access to high-quality feed resources such as alfalfa or improved grass species (FAO, 2025; NAFSIP, 2023). Consequently, most farmers rely on low-cost, low-nutrient feedstuffs, including straw and crop residues, which perpetuate low productivity and poor animal health (FAO, 2025).

Environmental challenges further aggravate the situation. Water scarcity, declining rangeland areas, and recurrent droughts have drastically reduced feed and water availability for livestock (FAO, 2025). Both the highlands and lowlands are affected: the former face extreme pasture scarcity, while the latter suffer from rangeland degradation (FAO, 2025). The absence of strategic feed and forage reserves increases vulnerability to climatic shocks (FAO, 2025).

Additionally, declining rainfall, unpredictable precipitation patterns, falling groundwater levels, and soil salinization contribute to ongoing environmental degradation and declining agricultural productivity (FAO, 2025; NAFSIP, 2023).

Political instability and institutional fragmentation compound these challenges (FAO, 2025). The shortage of key agricultural inputs, including fertilizers, irrigation equipment, pesticides, machinery parts, and fuel, has intensified the food and water crisis. Collectively, these factors undermine the livelihoods of small-scale farmers and herders, heightening poverty and food insecurity across rural Yemen (FAO, 2025).

4. Feed resources for livestock production in Yemen

4.1. Crops

Crops used for animal feeding are dominated by cereals and forage crops, which together account for the largest share of the cultivated area (58%) (FAO, 2009). Yemen is largely self-sufficient in sorghum, millet, and barley, which play a central role in animal feeding systems through both grain and crop residues. However, wheat remains highly import-dependent, with 85–90% of domestic consumption supplied through imports, limiting its contribution to locally available feed resources (NAFSIP, 2023; FAO, 2009). Forage crops, mainly forage sorghum, represent an important feed resource, especially in mixed crop animal systems, followed by maize, barley, and millet, while pulses play a minor but complementary role (FAO, 2009).

Sorghum is widely cultivated across diverse agroecological zones under predominantly rainfed conditions. Sorghum leaves and stalks are valued as essential fodder for farm animals. Despite its importance, sorghum productivity remains low due to climate variability, declining soil fertility, poor seed quality, pest pressure, and limited adoption of improved agronomic practices (NAFSIP, 2023).

Maize and millet also contribute to animal feeding systems, mainly through grain and crop residues. However, their productivity has declined markedly over recent decades. Maize yields fell from 2.2 t/ha in 1970 to about 1.2 t/ha in 2021, while millet yields dropped from 1.6 t/ha to less than 0.5 t/ha over the past five years.

Barley, particularly in highland areas, is used both as a feed grain and as straw, although yields remain low and highly variable (NAFSIP, 2023).

Pulses, though occupying a limited share of cultivated land, contribute to animal feeding through grains and haulms and play a complementary role in improving diet quality and soil fertility.

Production of feed crops is strongly constrained by insufficient and erratic rainfall, recurrent droughts, severe water scarcity, and weak water management practices. These constraints are exacerbated by land degradation, small and fragmented plots, pest outbreaks, especially locust infestations, limited access to modern agricultural technologies, and poorly developed infrastructure, resulting in chronically low feed availability and quality.

4.2. Natural rangelands

Natural rangelands represent the most important feed resource for small ruminants in Yemen and play a fundamental role in sustaining pastoral systems and rural livelihoods. They provide, on average, about 40% of the annual feed requirements of sheep and goats, while access to croplands for grazing is generally restricted and sometimes regulated through the sale of grazing rights. Permanent natural rangelands cover approximately 16.95 million ha, accounting for nearly 29% of the national territory. They are distributed across the central highlands, the coastal Tihama plains, and the eastern desert, with overall productivity estimated at about 8.6 million tons per year and strongly dependent on rainfall.

In the highlands, mountain plains constitute the most suitable grazing areas and are dominated by perennial grasses with relatively long growth periods. In the wetter western central plains, species such as *Themeda triandra*, *Heteropogon contortus*, *Andropogon greenwayi*, *Eleusine floccifolia*, and *Elonurus muticus* are common, with standing biomass around 500 kg/ha, whereas in the drier eastern central plains, vegetation is dominated by *Chrysopogon plumulosus*, *Aristida adscensionis*, *Enneapogon schimperianus*, and *Tetrapogon villosum*, and biomass declines to about 400 kg/ha

(Esmail, 1991). Mountain ranges are less favorable for grazing because of steep slopes and rough terrain. Vegetation consists mainly of unpalatable shrubs and succulents, although perennial grasses such as *Microchloa indica* and *Pennisetum setaceum* may occur, making grazing physically demanding and risky for sheep and generally limited to specific periods following heavy rainfall or favorable microclimatic conditions (Esmail, 1991).

Despite their central role, Yemeni rangelands are generally characterized by low productivity and degraded species composition, structure, and biomass due to excessive grazing pressure on palatable species, uncontrolled grazing, tree cutting, and the absence of comprehensive rangeland management policies. These pressures, compounded by climate change, recurrent droughts, rising temperatures, deforestation, political instability, and economic constraints, have led to soil erosion, desertification, and biodiversity loss. As a result, forage availability and diversity have declined, forcing animals to consume less nutritious plants. This contributes to poorer health, reduced reproductive performance, and lower milk and meat production, especially during the long dry season when forage scarcity and high feed prices further constrain the sustainability of small ruminant production systems (Louhaichi et al., 2024).

4.3. Cultivated green fodder

Cultivated green forages in Yemen mainly include maize forage, forage sorghum, and alfalfa, which are grown to support animal feeding when natural pastures are insufficient, particularly during the dry season. Maize forage, alfalfa and forage sorghum are widely cultivated during the rainy season, when green fodder is harvested from cultivated terraces and fed fresh or conserved as hay for later use. Sorghum fodder is transported and sold in large quantities in markets across several governorates, highlighting its role as an important supplemental feed resource. In addition to traditional field-grown forages, innovative approaches such as hydroponic green fodder production (e.g., sprouted barley in controlled systems) have been introduced, providing high-quality forage while requiring limited land and water resources and reducing dependence on seasonal conditions. These cultivated fodder crops help supplement grazing and crop residues, although overall green fodder production remains limited relative to livestock demand. According to the 2020 Agricultural Statistics Book, total cultivated green fodder production reached approximately 1,789,006 tons, including 1,452,856 tons of maize forage, 580,025 tons of alfalfa, and 56,124 tons of other grasses (Yemen-NIC).

4.4. Concentrates

In Yemen, concentrate feeds for small ruminants are primarily based on imported cereals, supplemented with local by-products such as wheat bran and oilseed cakes, and mineral blocks. The production of compound feeds remains limited, with minimal private-sector involvement, leaving farmers largely dependent on natural pastures and crop residues. Locally produced concentrates are often of low nutritional quality, often lacking essential nutrients and other key ingredients, which reduces their effectiveness and contributes to deficiencies in the animal feeding system (Yemen-NIC).

4.5. Supplementary feeds

Supplementary feeds are widely used for small ruminants in Yemen due to the low productivity of natural pastures and limited forage cultivation. Farmers supplement grazing with crop residues, alfalfa, and sorghum stover, with commonly used residues including sorghum and millet stalks, wheat and barley straw, and dry legume residues (Maderova et al., 2025). During the long dry season, when forage is scarce, these feeds can make up to 80% of the daily ration, helping animals maintain basic nutrition, support growth, and reduce pressure on rangelands (Kessler, 1988). However, their use is constrained by high costs, irregular availability, seasonal fluctuations, and difficulties in storage and distribution. Even with supplementation, animals often lose weight during prolonged periods of feed shortage.

4.6. Fodder trees and shrubs

Fodder trees and shrubs play a crucial role in Yemen's livestock feeding systems by supplying nutrient-rich leaves, twigs, fruits, and pods that are high in protein, minerals, vitamins, energy, and fiber. They become especially important during the dry season and periods of drought when herbaceous grasses are scarce and nutritionally deficient.

Forest and shrub resources, concentrated mainly in the mountainous western regions and dominated by Acacia species such as *Acacia senegal*, *A. seyal*, *A. tortilis* (including subspecies raddiana), *A. mellifera*, and *A. bentii*, together with species like Prosopis (*P. juliflora*, *P. chilensis*, *P. cineraria*), *Balanites aegyptiaca, Calotropis, Olea africana, O. spinosa*, and juniper trees, supply more than 50% of livestock fodder and serve as significant browse for goats, camels, and some wildlife in arid rangelands and interior wadis (NAFSIP, 2023; Zaroug). *Atriplex nummularia* (old man's saltbush) is an important feed resource in Yemen, providing forage with relatively high crude protein content throughout the dry season and constituting about 16–25% of a sheep's diet (Kessler, 1990).

As a perennial shrub used in rangelands, *A. nummularia* contributes to maintaining animal condition during periods of feed shortage. Livestock owners often rely on traditional practices such as pruning branches or shaking trees to make leaves and pods accessible. Chopped leaves and twigs, including partially wilted Calotropis, can be fed directly without adverse effects. These woody species, particularly Acacia and Prosopis, provide the main source of roughage where herbaceous vegetation is scarce (Zaroug). Despite constraints related to pod collection and storage, variable animal preferences, and limited herbaceous availability, mixed livestock farming helps maximize the use of available forage, maintain plant balance, and contribute to the long-term stability of vegetation cover in traditional grazing systems.

5. Nutritive values of the main animal feed in Yemen

Feed resources for small ruminants in Yemen are highly variable, and their chemical composition and nutritional value remain largely unknown due to limited local research. Table 1 summarizes the main feed types (green forages, hay, straw, cereals, by-products, crop residues, mineral blocks, and shrubs/trees) commonly used in small ruminant systems, with nutritional values drawn from studies in neighboring countries.

Table 1. Nutritive values of the main animal feed in Yemen

	Feed	DM (g/kg DM)	Nutritive value				Organic components (g/kg dm)				Fiber (g/kg dm)			Protein (g/kg dm)		Energy (kcal)			Mineral components (g/kg dm)			
			FUL	FUM	DCP (g/kg DM)	Ash (g/kg DM)	OM	CF	CP	Fat	NDF	ADF	ADL	PDIN	PDIE	RE	DE	ME	P	Ca	K	Na
Green forage	Maize green forage	233			39.26	70	930	287	79	19	632	311	43	53.57	66.46	4,349.8	2,796.3	2,294.4	2.1	3.6	15.8	0.5
	Sorghum forage	281			49.61	91	909	336	82	19	579	350	33	55.54	62.06	4,325.9	2,605.1	2,103.2	2	4.1	19.3	2.5
	Barley	250			72.82	115	885	281	110	38	576	327	24	74.1	73.83	4,134.7	2,724.6	2,198.8	1.7	4.9	14	
	Pearl millet	194			79.48	123	877	292	124	20	648	345	42	83.39	76.91	4,206.4	2,748.5	2,198.8	2.8	5.5	31.5	
Hay	Sorghum hay	900			38.17	88	912	323	75	14	687	440	62	50.89	61.06	4,278.1	2,485.6	2,007.6	1.7	1.8	15.6	0
	Pearl millet hay	901			44.16	107	893	412	96	14	760	477	71	64.82	59.39	4,302	2,127.1	1,696.9	4.2	3.7	39.4	
	Wheat hay	901			31.81	80	920	351	54	13	542	392	56	36.96	52.6	4,206.4	2,294.4	1,864.2				
	Alfalfa hay	894	0.66	0.59	131.04	107	893	289	182	21	448	334	76	121.92	96.92	4,349.8	2,533.4	2,007.6	2.6	16.8	24.6	0.3
Straw	Sorghum straw	930	0.6		11.1	75	925	395	37	12	766	482	73	25.68	43.95	4,325.9	2,127.1	1,744.7	7	3.1	12.9	0.2
	Pearl millet straw	931	0.42		3.64	86	914	418	52	7	800	529	107	35.62	46.19	4,230.3	1,840.3	1,505.7	1.5	2.5	23.8	
	Barley straw	909			8.66	75	925	405	38	14	805	483	65	26.34	43.48	4,349.8	1,912	1,553.5	1	4.6	14.4	0.9
	Wheat straw	910	0.45	0.34	1.47	67	933	415	42	14	775	500	72	29.01	44.51	4,421.5	1,983.7	1,625.2	0.7	4.8	11.2	0.1
Cereals	Barley grain	871	0.97	0.97	78.59	26	974	52	118	20	217	64	11	79.52	100.85	4,397.6	3,537.2	2,963.6	3.9	0.8	5.7	0.1
	Sorghum grain	874	1.06	1.08	73.87	21	979	28	108	34	110	43	11	72.89	99.89	4,493.2	3,824	3,226.5	3.3	0.3	4.3	0.2
	Maize grain	872	1.11	1.14	64.31	15	985	26	97	42	132	44	14	65.59	96.92	4,469.3	3,847.9	3,226.5	3.4	0.7	4.3	0.1
	Pearl millet	896	1.18	1.21	65.25	28	972	32	125	48	172	45	10	84.17	104.56	4,564.9	3,178.7	2,652.9	3.3	0.5	4.1	0.1
	Finger millet	890	0.96	0.97		40	960	57	89	15	238	97	15	60.25	90.15	4,230.3	3,346	2,820.2	3.4	4.9	5.3	
By products	Wheat bran	870	0.8	0.75	118	56	944	104	173	39	452	134	38	116.01	112.33	4,517.1	3,226.5	2,629	11.1	1.4	13.7	0.1
	Sesame meal	928	1.24	1.25	352.02	119	881	73	449	113	246	135	17	299.19	199.35	4,923.4	3,967.4	2,987.5	12.6	19.7	10.4	0.1
	Cottonseed cake	929	0.96	0.9	275.4	59	941	147	340	28	335	236	74	226.89	162.46	4,684.4		2,670	9.7	2	14.5	0.16
Crop residues	Maize stover fresh	296	0.45		25.16	68	932	300	68	18	699	396	56	46.27	62.02	4,349.8	2,461.7	2,007.6	1.6	3.3	16.8	0.06
	Maize stover dry	928			6.04	71	929	407	39	9	750	496	74	27.01	43.91	4,349.8	2,031.5	1,649.1	0.8	3.2	14	0.24
	Alfalfa stover	906			128.46	117	983	286	183	27	459	327	85	122.69	103.68	4,302	2,557.3	2,031.5	2.7	22.1	25.6	0.2
	Lentil haulms	920			28.28	89	911	343	70	15	606	398	97	47.57	57.78	4,278.1	2,198.8	1,792.5	1.4	23.1	11.5	
	Chickpea haulms	904			25.54	74	926	410	54	10	656	469	119	36.97	48.3	4,325.9	1,792.5	1,457.9	1.6	9.4		
	Faba bean haulms	897			28.34	88	912	392	74	13	596	515	103	50.23	55.21	1,888.1		1,529.6	1.1	11.1		
Block	Mineral blocks																					
Shrubs/tree	*Panicum turgidum* Forssk	449			16.31	78	922	406	62	19	749	466	68	42.27	50.92	4,394.84	2,221.305	1,791.375	1.9	5	13.4	1.2
	Atriplex halimus	381			108.05	270	730	267	167	22	388	216	88	111.76	82.64	3,487.21	1,910.8	1,528.64	2	19.9	54.6	47
	Atriplex nummularia	287			101.28	246	754	201	147	26	403	225	96	98.51	83.13	3,630.52	1,743.605	1,409.215	2.2	9.6	27.6	65.3
	Acacia senegal	408			190.4	120	880	182	238	36	365	207	70	159.09	122.62	4,323.185	3,463.325	2,722.89	27.4	2	12.9	
	Acacia seyal	449				83	917	152	156	42	267	173	58	104.68	101.16	4,347.07	3,343.9	2,722.89	1.6	22.6	10.4	0.5
	Acacia (tortilis subsp. Raddiana)	454				110	890	184	167	43	378	249	111	111.96	100.29	4,299.3	3,152.82	2,555.695	1.8	18.7	11.4	0.5
	Acacia mellifera	341				96	904	181	205	35	333	231	70	137.2	113.72	4,370.955			1.2	19.3	15.2	0.5
	Acacia bentii																					
	Balanites aegyptiaca	440				146	854	183	160	37	330	226	114	107.26	95.63	4,132.105			1.2	27.8	20.5	0.4
	Calotropis aerial part, fresh	146				200	800	180	162	67	272	251	76	108.53	92.8	4,036.565			2.6	21.5	28.6	13.1
	Prosopis juliflora	367				89	911	269	169	31				113.31	95.57	4,394.84	2,866.2	2,292.96	2	17	15.1	
	Prosopis chilensis leaves, fresh	312				47	953	247	225	29				150.54	118.26	4,633.69	3,128.935	2,484.04	2.5	8.6		
	Prosopis cineraria aerial part, fresh	473			42.39	100	900	205	139	35	506	344	184	93.38	90.28	4,323.185	1,910.8	1,552.525	3.7	20.8		
	Olea africana leaves, fresh	501				80	920	179	98	63	461	341	201	66.18	80.53	4,370.955	2,340.73	1,934.685	0.9	21.5		
	Olea spinosa																					
	Salvadora persica	308				341	659	105	142	18	231	142	33	95.08	82.66	3009.51			1.1	69	16.9	1.3

* DM: Dry matter; OM: Organic matter; CF: Crude fiber; CP: Crude protein; NFE: Nitrogen-free extract; RE: Raw energy; DE: Digestible energy; ME: Metabolizable energy; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; and ADL: Acid detergent lignin.

UFL: Forage unit for lactation; UFM: Forage unit for meat production; DCP: Digestible crude protein; PDIN: Digestible protein in the small intestine allowed by the nitrogen provided by the feed; and PDIE: Digestible protein in the small intestine allowed by the energy supplied by the feed

6. Ration formulations

Based on the animal nutritional requirements outlined by the National Research Council (2007), several example ration formulations were developed for different physiological stages, body weight, and average daily gain to ensure adequate supply of energy, digestible protein, and essential minerals (Ca, P).

Maintenance (Mature ewes – dry season)

- Sorghum straw (60%)
- Sorghum grain (22%)
- Acacia (18%)

Reproduction (Moderate flushing)

- Sorghum hay (60%)
- Barley grain (34%)
- *A. nummularia* (6%)

Early gestation (Single fetus)

- Pearl millet hay (60%)
- Sorghum grain (14%)
- Lentil haulms (17%)
- *A. halimus* (9%)

End of gestation

- Sorghum hay (40–42%)
- Pearl millet (25%)
- Wheat bran (15%)
- *A. halimus* (18–20%)

Early lactation

- Sorghum straw (35%)
- Sorghum grain (25%)
- Wheat bran (20%)
- *A. halimus* (20%)

Mid-lactation

- Sorghum straw (40%)
- Sorghum grain (25%)
- Wheat bran (15%)
- *A. halimus* (20%)

End of lactation

- Sorghum straw (45%)
- Sorghum grain (25%)
- Wheat bran (10%)
- *halimus* (20%)

Growing lambs – Maturity 0.3 (late maturing)

- Pearl millet hay (45–55%)
- Chickpea haulms (20–25%)
- Sorghum grain (25–32%)

7. Yemen's main seasonal feed calendar

Yemen's main seasonal feed calendar reveals pronounced seasonal fluctuations in animal feed availability, driven primarily by rainfall patterns and crop growth dynamics. It also highlights strong temporal complementarities among irrigated fodder, rainfed fodder, natural pastures, and crop residues (Table 2). Feed availability is generally low from January to mid-March and again from October to December, reflecting dry conditions, limited biomass production, and the depletion of natural pastures and stored residues. During these periods, irrigated fodder, mainly available in the cool and relatively dry months (December–January) and again in June, plays a strategic role in supplying green feed when rainfed options are scarce. In contrast, feed availability peaks from March to April and from mid-August to September, coinciding with rainfall-driven growth of rainfed fodder and natural rangelands, which support grazing from February to June before becoming scarce toward the end of the year. In parallel, cereal crops such as sorghum/millet, wheat, barley, and maize are harvested mainly between September and November, generating crop residues that are crucial for sustaining animals during the subsequent dry and feed deficit period (FAO, 2025, 2024B, 2021).

Table 2. Yemen seasonal feed calendar

Activities\Monthly\Seasonal events	January	February	March	April	May	June	July	August	September	October	November	December
Fodder: Irrigated	Wheat fodder				Wheat\Alfalfa fodder					Crop waste		Fodder – irrigated
Fodder: Rainfed			Rainfed fodder					Rainfed fodder				
Natural vegetation (pastures)	Pastures for grazing - scarce		Pastures for grazing	Pastures for grazing - scarce				Pastures for grazing - scarce				Pastures for grazing - very Scarce
Sorghum\millet										Harvest & threshing		
Zea maize									Harvest & threshing			
Wheat										Harvest & threshing		
Barley										Harvest & threshing		
Crop residues				Crop residues				Crop residues				

8. Feeding practices of small ruminants

In Yemen, small ruminant feeding practices are largely based on extensive agro-pastoral systems, adapted to the challenges of conflict and food insecurity. Feeding strongly depends on seasonal availability. During the rainy season, abundant green vegetation provides high-quality forage, and animals are fed green fodder such as forage sorghum and alfalfa, rarely needing supplemental feed (Kessler,1990). In the dry season, however, natural pastures become scarce, and herders increasingly provide supplementary feed to meet nutritional requirements (Amad et al., 2023). Goats often receive a varied diet that includes tree leaves and bark, crop residues such as straw and tubers, grains, leftover human food, and occasionally commercially available feeds. Unconventional items, such as dried fish or fibrous materials, are sometimes added to supply protein, vitamins, and minerals, helping maintain productivity during periods of forage scarcity (Maděrová et al., 2025). Traditional practices, such as lopping branches or beating trees to access leaves and pods, are commonly used. Sheep mainly rely on daily grazing, supplemented with small amounts of food waste provided after grazing (Amad et al., 2023).

9. Gaps in small ruminant feeding systems in Yemen

Livestock feeding systems in Yemen face multiple interconnected gaps that severely constrain animal nutrition and productivity. These gaps are mainly driven by strong seasonal fluctuations in feed availability, poor nutritional quality of local feed resources, and structural weaknesses in feeding systems.

Small ruminant production relies heavily on natural pastures and rangelands, leaving flocks highly vulnerable to droughts and recurrent feed shortages. Natural pastures, which constitute the main feed source for most sheep, are seasonal, low in quality, and deficient in energy and protein, particularly during the dry season (Amad et al., 2023). Cultivated fodder and concentrate feeds are scarce, as local compound feed production remains limited and imported feeds are either too expensive or irregularly available. Consequently, seasonal feed deficits are common, resulting in weight loss, nutritional deficiencies, reduced milk and meat yields, and low fertility. Sheep feeding practices depend almost entirely on daily grazing supplemented by small amounts of household food waste, which fails to meet maintenance and growth requirements (Amad and TerMeulen, 1997).

Insufficient and undiversified forage sources force livestock owners to purchase feed at high, often unaffordable prices, while access to pasture and water remains limited in many areas. Available supplements, mainly crop residues such as wheat straw and sorghum stubble, and agro-industrial by-products, are nutritionally poor and lack essential protein and minerals. The absence of effective feed conservation practices further aggravates feed shortages, as surplus forage is rarely stored for use during the dry season. Adoption of improved feeding strategies, such as integrating fodder trees, shrubs, or cultivated forages, remains very limited. Most farmers lack formal feed management systems, relying on traditional knowledge rather than technical guidance for ration formulation or feed storage. Yemen also lacks locally produced balanced rations, adequate processing capacity for feed blocks and silage, and proper storage facilities. This increases the risks of contamination and spoilage. Limited farmers’ knowledge and financial constraints further hinder the adoption of improved feeding practices (FAO, 2025).

Additionally, continued conflict and economic instability disrupt feed and water supply systems, restrict livestock mobility, weaken access to veterinary services, and aggravate the overall vulnerability and inefficiency of small ruminant feeding systems in Yemen (FAO, 2021; FAO, 2018).

Beyond feeding limitations, Yemen's small ruminant production faces critical gaps in genetic potential, policy frameworks, institutions, and environmental management that further reduce productivity and resilience. Local sheep breeds exhibit inherently low productivity due to negligible genetic improvement programs, absent breed selection systems, and minimal conservation of disease and climate resilient genotypes. Policy frameworks fail to prioritize investments in animal health, feed production, disease surveillance, rangeland rehabilitation, or drought preparedness, leaving no structured feed reserve systems and exposing herders to recurrent shortages across highlands and lowlands (FAO, 2025). Weak institutional coordination is exacerbated by the non-operational National Livestock Research Institute, creating a research vacuum in feeding optimization, nutrition, and resource-efficient practices, while private sector engagement in feed manufacturing, breeding services, and market linkages remains minimal. Human capacity gaps persist in animal nutrition, breeding, epidemiology, and forage development, compounded by limited access to finance, technical training, data collection, and innovation infrastructure for small-scale farmers and pastoralists (FAO, 2025). Cross-cutting environmental gaps including poor management of rangelands, overgrazing, and feed resource depletion contribute to environmental degradation, while the loss of ecosystem services increases exposure to zoonotic and vector-borne diseases (FAO, 2025).

10. Recommendations

10.1. Alternative feed resources

Given Yemen's costly feed imports, farmers should prioritize cultivating locally adapted fodder crops (sorghum, maize, alfalfa, Vicia sativa) and utilizing agro-industrial by-products (sesame cake, cottonseed cake, brewery waste, crop residues) as immediate alternatives to imported concentrates. These accessible resources, combined with non-conventional feeds like prickly pear (*Opuntia*) and high-protein indigenous species (*Clitoria ternatea*, *Acacia* spp., *Senegalia mellifera*), offer nutritious, cost-effective solutions for sheep and goats, while reducing pressure on natural rangelands and conventional feeds. Further research is needed to evaluate the nutritional value, availability, animal preference, digestibility, and growth performance of underutilized feeds available across different regions of Yemen.

10.1.1. Common Vetch (*Vicia sativa*) as sustainable fodder crop

Common vetch (*V. sativa*), a drought-tolerant annual legume rich in protein and minerals (Matic et al., 2008), offers Yemen's mixed crop-livestock farms a highly viable fodder solution across diverse agroecological zones including the Upper Highlands, Tihama Plain, Red Sea coast, and Arabian Sea regions. This heat-tolerant crop can be effectively utilized as grazing forage, harvested as dry hay, or integrated into cereal rotations, providing essential nutrition while supporting soil fertility (Orser, 2020). Rural households and small-scale farmers facing acute fodder shortages should be prioritized for vetch cultivation programs, as it addresses livestock nutritional deficiencies and reduces grazing pressure on degraded rangelands (Orser, 2020). Further localized research confirming its adaptation and performance under Yemeni conditions would accelerate adoption and maximize benefits for pastoral communities.

10.1.2. Prickly Pear (Cactus) as locally available feed resource

Prickly pear (*Opuntia* cactus), with its 16% dry matter content and high palatability, serves as a valuable, locally available feed resource for sheep that can be safely incorporated into concentrate rations alongside other ingredients. This practical option effectively addresses feed shortages in Yemen's arid regions while reducing pressure on scarce natural pastures.

10.1.3. Hydroponic fodder production

Hydroponic barley fodder production offers substantial potential to enhance livestock feed security and generate income opportunities in Yemen. Building on existing experience through projects implemented by the Agricultural Research and Extension Authority (AREA), this technology should be scaled up to provide high-quality, nutrient-dense green fodder for livestock. It can provide a reliable feed source in water-scarce areas while reducing dependence on traditional pasture systems.

Yemen is rich in plant biodiversity, with six major ecological zones hosting species with strong potential for animal feed. These range from Tihama coastal halophytes (*Salsola* spp., *Suaeda monoica*, *Atriplex* spp., *Aeluropus lagopoides*) and species of the southern coastal plains to eastern desert xerophytes (*Salsola vermiculata*, *Tamarix nilotica*, *Leptadenia pyrotechnica*, *Salvadora persica*, *Panicum turgidum*), as well as mountain and highland fodder trees such as *Acacia* spp., *Dobera glabra*, *Grewia* spp., and *Crotalaria* spp.

10.1.4. Valorization of indigenous forage species

Yemen is rich in plant biodiversity, with six major ecological zones hosting species with strong potential for animal feed. These range from Tihama coastal halophytes (*Salsola* spp., *Suaeda monoica*, *Atriplex* spp., *Aeluropus lagopoides*) and species of the southern coastal plains to eastern desert xerophytes (*Salsola vermiculata*, *Tamarix nilotica*, *Leptadenia pyrotechnica*, *Salvadora persica*, *Panicum turgidum*), as well as mountain and highland fodder trees such as *Acacia* spp., *Dobera glabra*, *Grewia* spp., *Crotalaria* spp.

These species can be grouped into three functional categories: drought-tolerant shrubs, protein-rich legumes, and fibrous grasses. Together, they provide complementary sources of protein, energy, and fiber for livestock feeding systems.

Findings from Lahij rangelands indentified 25 indigenous species with promising nutritional value. Top-performing species included *Clitoria ternatea* (≈21.4% CP), *Senegalia mellifera* (≈18.4% CP), *Ornithopus sativus* (≈18% CP), *Vigna sinensis* (≈17.2% CP), and *Acacia etbaica* (≈17% CP), together with *Lycium barbarum*, *Albizia lebbeck*, and several *Acacia* species containing more than 16% crude protein. These species can be grouped into three functional categories: drought-tolerant shrubs, protein-rich legumes, and fibrous grasses. Together, they provide complementary sources of protein, energy, and fiber for livestock feeding systems (Louhaichi et al., 2024).

A national strategy combining ecological surveys, nutritional trials (including assessment of tannins in woody legumes), fodder banks, agroforestry, rotational grazing, and conservation techniques can transform this biodiversity into sustainable feed. Such an approach could reduce shortages and import dependency, while improving small ruminant productivity and resilience of small-ruminant systems.

10.1.5. Promoting local production of urea-treated straw and complete pellets

Promote the local production of urea-treated straw (4–5% urea) and complete pellets using readily available ingredients such as molasses, sesame cake, and brewery by-products.

10.1.6. Phosphorus supplementation strategy

It is recommended to implement systematic phosphorus supplementation programs in high-rainfall, high-biomass areas (e.g., central highlands), using phosphorus-rich mineral mixes or concentrates to balance low-phosphorus, high-calcium forages. These interventions should be integrated into broader rangeland improvement programs and farmer training on mineral nutrition (Esmail, 1991).

10.1.7. Wild weedy grasses utilization

Promote the utilization of six wild weedy grasses (*Alopecurus myosuroides*, *Brachiaria ramosa*, *Chrysopogon aucheri*, *Phalaris minor*, *Pennisetum orientale*, and *Stipa capensis*) as alternative forage resources to help alleviate national fodder shortages (Khan et al., 2017).

10.2. Feed resource diversification

Diversify livestock diets through strategic mixing of available resources according to seasonal availability: crop residues (cereal straws, legume haulms), fodder tree/shrub leaves (*Acacia*, *Albizia lebbeck*), cultivated forages, and supplementation (e.g., urea-molasses blocks, mineral licks). This climate-smart approach helps ensure balanced nutrition, enhance digestibility, and improve animal productivity. Feed resource diversification should be supported with scientific evaluation of new feedstuffs, including their availability, palatability, digestibility, and effects on growth performance. Farmer training on optimal feed combinations can further strengthen resilience to feed shortages and climate variability.

10.3. Rangeland improvement

Conduct ecological surveys to classify rangelands by zone and protect natural areas from farming expansion, while implementing regulated rotational grazing systems to optimize traditional practices and reduce overgrazing pressure. Reintroduce productive, nutritious, locally-adapted, and palatable species, alongside expanding fodder tree plantations to compensate for the limited number and low nutritive value of native vegetation, while addressing fuelwood cutting through community forestry programs.

10.4. Improved seeds

Farmers should be provided with improved fodder crop seeds that can be reproduced locally for long-term self-sufficiency in fodder production.

10.5. Farmer training and feed conservation

Farmers require comprehensive training on the production, conservation, and efficient use of cultivated fodder resources, coupled with improved access to climate information and adaptive practices through established farmer networks to enhance climate resilience. Efforts should also focus on protecting natural feed resources and raising awareness of proper conservation, storage, and feed preparation techniques to minimize losses. In addition, farmer training on improved grazing management should be promoted to support sustainable rangeland rehabilitation, enhanced vegetation productivity, and improved livestock performance.

10.5.1. Women's training

Given the crucial role of women in agriculture, targeted training programs should be organized to strengthen their technical knowledge and promote good agricultural practices.

10.5.2. Veterinary training

In addition, community animal health workers should receive training in the use of veterinary kits for vaccination and treatment of livestock against endo- and ectoparasites to strengthen animal health services at the local level.

10.6. Legislative protection and investment in feed resources

Long-term sustainability requires legislation to protect feed resources and the revival of traditional community agreements that prevent overgrazing and excessive wood cutting in mountainous areas. Greater use should also be made of locally available by-products, including spoiled fish, as alternative feed resources. In addition, stronger coordination between the Ministry of Agriculture, Irrigation and Fisheries and the General Investment Authority is needed to create investment incentives that encourage private-sector participation in local feed manufacturing and improve affordable livestock feed.

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