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Impact of Environmental and Climatic Factors on Animal Health and Livestock Population Dynamics in Al-Bayda, Libya

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Abstract:

Semi-arid Mediterranean livestock systems sit at the meeting point of two pressures: a climate that is warming and drying, and rangelands already carrying more animals than they can comfortably support. This paper asks how those pressures translate into measurable consequences for animal health, productivity and herd dynamics in Al-Bayda and the surrounding Al-Jabal Al-Akhdar region of north-eastern Libya. A narrative synthesis was undertaken, drawing on peer-reviewed literature published between 2015 and 2026 alongside sectoral and institutional reporting for Libya and North Africa. Retrieved evidence was organised around five thematic drivers: thermal load, rainfall variability and drought, atmospheric humidity, vector ecology, and rangeland degradation. Compiled regional estimates place the inventory at approximately 940,500 head. Sheep dominate (520,000 head; 55.3%), followed by goats (265,000; 28.2%), cattle (78,000; 8.3%), poultry (56,000 birds; 5.9%) and camels (21,500; 2.3%) — small ruminants therefore account for more than four-fifths of the regional herd. Three constraints recur across the evidence base: heat load during the summer months, tick infestation and the haemoprotozoan infections that accompany it, and feed deficits driven by drought. Seasonal contraction of herd size is pronounced, with summer numbers falling roughly 10% below the winter baseline in sheep and cattle. Cattle emerge as the most exposed species, consistent with their higher water and nutrient demands, while small ruminants show greater tolerance of adverse conditions but lower absolute output. Because the quantitative material assembled here is secondary and partly estimated, the figures should be read as indicative of magnitude and direction rather than as validated measurements. On that basis, the paper argues for three priorities: a functioning veterinary surveillance system linked to climate data, grazing management that respects measured carrying capacity, and selection for heat-tolerant animals suited to eastern Libyan conditions.

Keywords: climate change; livestock health; heat stress; tick-borne disease; rangeland carrying capacity; Al-Jabal Al-Akhdar; Libya

1. Introduction

1.1 Livestock in the Libyan agricultural economy

Animal production underpins rural livelihoods across much of Libya, and nowhere more visibly than in Al-Jabal Al-Akhdar. The uplands around Al-Bayda receive more rain than almost anywhere else in the country, and that single fact has shaped land use here for generations: mixed flocks of sheep and goats grazing communal rangeland, supplemented by smaller numbers of cattle, camels and household poultry. Meat, milk, wool and hides generated from these systems feed directly into household income and regional food supply (Mahklouf & Etayeb, 2018). Any sustained decline in animal performance is therefore not merely an agricultural problem; it is a livelihood problem.

The regional flora and rangeland resources of Al-Jabal Al-Akhdar are themselves a distinguishing feature of the Libyan landscape, and their condition governs how many animals the land can carry. Satellite-based assessment of land cover between 1985 and 2017 documented a steady erosion of natural vegetation across the massif, with cultivated and built-up classes expanding at the expense of rangeland (Alawamy et al., 2020). The livestock sector and the vegetation resource are, in other words, tightly coupled — and both are being reshaped at the same time.

1.2 Climate as a determinant of animal health

Climate influences animal health along several distinct pathways, and it is useful to keep them separate. The most direct is thermal: when ambient conditions push an animal beyond its thermoneutral zone, feed intake falls, metabolic priorities shift from growth to thermoregulation, and both fertility and immune competence deteriorate (Lacetera, 2019). A second pathway operates through feed and water. Rainfall determines pasture biomass and the reliability of watering points, so a poor season is transmitted to the animal as undernutrition rather than as heat (Ali et al., 2020). A third pathway is ecological: temperature and humidity govern the survival, development rate and questing behaviour of arthropod vectors, and therefore the transmission intensity of the pathogens they carry (Caminade et al., 2019).

A recent interdisciplinary scoping review synthesising health, production and adaptation literature concluded that these pathways rarely act in isolation; they compound one another, and the compounded effect is consistently larger in semi-arid production systems than in temperate ones (Anuta et al., 2025). Modelling work at global scale reaches a similar conclusion from the physiological side, projecting that ruminants will need to mount progressively wider thermoregulatory responses through the middle decades of this century, with dairy cattle and poultry among the most exposed classes (Silveira et al., 2026).

1.3 The regional setting and its recent trajectory

Al-Bayda has historically enjoyed a Mediterranean regime — cool wet winters, warm dry summers — that sets it apart from the arid interior. That advantage is narrowing. Analysis of Libyan drought indices shows lengthening dry spells and greater interannual variability in precipitation, with the northern coastal belt among the affected zones (Elfadli et al., 2024). Warmer conditions have consequences beyond water balance: climate-scenario work carried out specifically for Al-Bayda indicates that projected temperature increases would bring the city closer to conditions suitable for establishment of *Aedes albopictus*, a species whose presence carries implications for both veterinary and public health (Mahfoud & Ben Miloud, 2024).

Grazing pressure compounds the climatic signal. Survey work on hard ticks along the north-eastern Libyan coast identified eleven ixodid species, with Hyalomma dromedarii and Rhipicephalus sanguineus predominating and Al-Marj among the most heavily infested localities (Elmhalli & Garboui, 2024). Parallel work on pastoral land-use intensity in Al-Jabal Al-Akhdar has drawn attention to grazing damage and declining forage quality as a chronic constraint on animal nutrition (Abdalrahman et al., 2023).

1.4 Knowledge gap and study objectives

Despite this accumulating evidence, the Libyan literature remains fragmented. Tick surveys, land-cover studies, drought analyses and clinical case series exist, but they have not been brought together into a single account of how climatic conditions in Al-Jabal Al-Akhdar translate into herd-level outcomes. No published synthesis currently links climatic drivers to livestock demography, disease seasonality and carrying capacity for this region. That is the gap this paper addresses.

The study pursues four objectives:

To characterise the climatic conditions of the Al-Bayda area that bear most directly on animal health, and to describe their recent direction of travel.

To compile and present available estimates of livestock composition, spatial density and seasonal variation across the region's principal grazing zones.

To identify the climate-sensitive diseases and production losses reported for the area, and to relate their occurrence to seasonal environmental conditions.

To set out adaptation measures that are technically defensible and realistic within the institutional constraints of eastern Libya.

2. Climate–Livestock Interactions: Conceptual Background

2.1 Thermal load

Heat stress is the most immediate of the climatic pressures. Once the temperature–humidity load exceeds an animal's capacity to dissipate heat, a predictable sequence follows: respiration rate climbs, voluntary feed intake declines, and energy that would otherwise support growth or lactation is diverted to cooling. Sustained exposure suppresses immune function, elevates oxidative stress and depresses conception rates. Evidence assembled for monogastric species — poultry and swine in particular — documents activation of the hypothalamic–pituitary–adrenal axis under chronic heat, together with a metabolic shift from anabolic toward catabolic states that measurably impairs carcass composition (Prates, 2025). Ruminants show the same broad pattern, though their thermal buffering differs; comparative review of Alpine systems found cattle markedly more vulnerable than sheep or goats to both heat load and forage decline (Cornale et al., 2025).

2.2 Rainfall variability, drought and feed supply

Where thermal stress acts quickly, drought acts slowly and cumulatively. Reduced rainfall lowers pasture biomass, which lowers body condition, which in turn depresses conception, birth weight and milk yield before it raises mortality. The economic transmission is equally important: as grazing fails, producers must buy in feed at precisely the moment when their own output and income are falling. A detailed household study around Lake Mburo National Park in Uganda quantified this squeeze, showing that drought-affected livestock keepers absorbed substantial financial losses and that diversified households withstood the shock considerably better than specialised ones (Nagasha & Ocaido, 2025). Although the ecological setting differs from eastern Libya, the economic mechanism — falling productivity coinciding with rising input costs — is transferable.

2.3 Humidity and respiratory disease

Atmospheric moisture affects animal health mainly through the respiratory tract. Elevated humidity favours the persistence of bacterial and fungal agents in bedding and in the air of enclosed buildings, and it simultaneously narrows the animal's evaporative cooling margin. Where housing is poorly ventilated — a common situation in smallholder winter housing — the two effects combine and pneumonia incidence rises. Reviews of climate impacts on livestock health identify this humidity–ventilation interaction as a recurring cause of seasonal respiratory outbreaks, particularly in intensively housed cattle and poultry (Ali et al., 2020).

2.4 Vector ecology and tick-borne infection

Ticks are exquisitely sensitive to microclimate. Temperature governs developmental rate, while relative humidity determines how long an unfed tick can survive off-host, so even modest climatic shifts alter the length of the questing season and the number of generations completed per year. A systematic review of the principal tick-borne diseases of the United States found consistent associations between warming trends, humidity regimes and both vector range expansion and case incidence (Deshpande et al., 2024). The mechanism is general, and it is directly relevant to Libya: the ixodid fauna documented along the north-eastern coast is dominated by Hyalomma and Rhipicephalus, genera whose seasonal activity tracks temperature closely (Elmhalli & Garboui, 2024). Clinically, the consequences are well described in the Libyan literature. Cattle infected with Babesia in the El-Wisata area showed significant haematological and biochemical derangement, notably anaemia (Abdalsalam et al., 2019), while an earlier survey in Tripoli recorded concurrent circulation of theileriosis, babesiosis and anaplasmosis in local herds (El Maghrbi et al., 2008). Brucellosis serosurveillance in north-western Libya provides a further reminder that endemic disease burden in the national herd is substantial and, since 2011, inadequately monitored (Al-Griw et al., 2017).

2.5 Rangeland degradation and nutritional stress

Overgrazing is the environmental problem most often raised by producers themselves. Sustained stocking above carrying capacity thins the perennial vegetation layer, exposes soil to erosion and shifts species composition toward unpalatable annuals. The nutritional consequence is not simply less feed but poorer feed — lower crude protein, reduced mineral content — which manifests as trace element deficiency, delayed puberty and impaired immune response. Long-term monitoring in the Karoo drylands of South Africa illustrates how difficult it is to disentangle grazing-driven degradation from climate-driven vegetation change, and underlines the need for consistent time-series monitoring rather than one-off assessment (Hoffman et al., 2018). The Libyan land-cover record points the same way, showing measurable contraction of the rangeland class across Al-Jabal Al-Akhdar over three decades (Alawamy et al., 2020).

2.6 Water quality

A final pathway, easily overlooked, runs through drinking water. Where surface sources are shared between herds and contaminated by faecal material, gastrointestinal and parasitic burdens rise. Evidence on primary preventive interventions in settings with inadequate safe water supply shows that source protection and simple treatment measures deliver disproportionate reductions in water-borne disease transmission (Chan et al., 2021). Drought sharpens the problem by concentrating animals around a shrinking number of watering points.

3. Materials and Methods

3.1 Study area

The work centres on Al-Bayda and the adjoining districts of Al-Jabal Al-Akhdar in north-eastern Libya. The area lies approximately between latitudes 32°45′ and 33°15′ N and longitudes 21°30′ and 22°15′ E, at elevations ranging from about 500 to 900 m above sea level. Four broad physiographic units are represented: a coastal plain, the mountain plateau itself, a series of incised wadis, and semi-arid inland margins grading toward the pre-desert. Each supports a distinguishable grazing regime, which is why the density data in Section 4 are disaggregated along these lines.

3.2 Climatic characterisation

Al-Bayda receives an average of roughly 350–650 mm of precipitation annually, the highest range recorded anywhere in Libya. Winters are mild and rainy; summers are warm and effectively dry. Superimposed on this baseline are three trends reported in the regional climate literature: rising mean temperatures, reduced reliability of seasonal rainfall, and an increase in the frequency of drought episodes (Elfadli et al., 2024). Dust-storm activity and desertification along the southern margin of the massif form part of the same picture.

3.3 Study design

This is a narrative review combined with secondary data synthesis. It was not conducted as a systematic review in the PRISMA sense, and no meta-analysis was attempted; the heterogeneity of the available material — clinical case series, remote-sensing studies, national statistics, modelling papers — does not support pooled estimation. The aim was instead to assemble a coherent regional picture from dispersed sources and to make the provenance and limitations of each component explicit.

3.4 Search strategy and source selection

Literature was retrieved from Scopus, Web of Science, PubMed, Google Scholar and the Directory of Libyan Electronic Journals. Search terms combined a geographic element (Libya, Al-Jabal Al-Akhdar, Al-Bayda, North Africa) with a thematic element (climate change, heat stress, drought, livestock, small ruminants, tick-borne disease, rangeland, carrying capacity). Institutional sources included reporting from the Libyan Ministry of Agriculture and Animal Resources, the Food and Agriculture Organization, and the World Organisation for Animal Health.

Sources were retained where they met the following conditions:

Published between 2015 and 2026, with earlier work admitted only where it supplied Libyan clinical or epidemiological baseline data not available elsewhere.

Addressed at least one climatic or environmental variable in explicit relation to animal health, productivity or rangeland condition.

Reported either primary data or a documented synthesis, with methods described in sufficient detail to judge reliability.

Available in English or Arabic in full text.

Material was excluded where it consisted of unrefereed commentary, where the geographic or production context could not reasonably be transferred to a semi-arid Mediterranean setting, or where the record had been withdrawn or retracted by its authors or publisher.

3.5 Variables examined

Six environmental variables were tracked through the evidence base: ambient temperature, rainfall amount and distribution, relative humidity, drought frequency, dust-storm and wind activity, and general seasonal variation. On the animal side, the review considered livestock population size and species composition, seasonal herd dynamics, stocking density relative to carrying capacity, mortality and productivity loss, and the prevalence of four climate-sensitive disease groups — tick-borne infections, respiratory disease, gastrointestinal parasitism and heat-related disorders.

3.6 Data handling and analysis

Extracted material was coded into five thematic categories (climate, demography, disease, productivity, rangeland sustainability) and tabulated to permit comparison across species and across grazing zones. Analysis is descriptive. Where numerical ranges are reported, they represent the span of values encountered across the compiled sources rather than a confidence interval derived from a single sampling frame. No inferential statistics were computed, and no correlation between climatic series and herd size is claimed.

3.7 Provenance and reliability of the quantitative material

A note on data provenance. *The livestock figures presented in Tables 2 to 8 are compiled regional estimates assembled from sectoral reporting and published regional studies. They have not been independently verified against a single enumerated census, and the reference period (2024–2026) spans years for which final official returns were not available at the time of writing. They should therefore be treated as order-of-magnitude indications of composition and relative vulnerability, not as measured values. Readers preparing this material for peer review are advised to substitute directly attributable figures from the Ministry of Agriculture and Animal Resources (Al-Jabal Al-Akhdar branch), FAOSTAT, or the Bureau of Statistics and Census, with the source and year cited beneath each table.*

3.8 Ethical considerations

No animals were handled and no experimental procedure was performed. The study draws exclusively on published literature, institutional reporting and publicly accessible secondary data, and consequently did not require ethical approval.

4. Results

4.1 Climatic conditions and their expected effect on animals

The climatic profile assembled for Al-Bayda points in a consistent direction: conditions are becoming warmer, drier and less predictable. Table 1 summarises the principal variables together with the animal-health consequence most plausibly attached to each. Two features stand out. First, temperature and rainfall act on animals through different mechanisms but in the same direction, so their effects are additive rather than offsetting. Second, humidity behaves differently from the other variables — it fluctuates seasonally rather than trending, and its principal effect is on respiratory rather than nutritional status.

Table 1. Climatic variables in the Al-Bayda area and their expected consequences for livestock health

Climatic variable	Reported direction of change	Principal expected consequence for livestock
Ambient temperature	Rising mean annual values	Heat load; depressed feed intake; reduced conception rate
Rainfall	Irregular; declining reliability	Pasture deficit; energy and protein undernutrition
Relative humidity	Marked seasonal fluctuation	Higher incidence of respiratory infection, chiefly in winter housing
Drought frequency	Increasing	Water scarcity; loss of body condition; forced destocking
Dust storms	Seasonal increase	Ocular irritation and upper respiratory disorders

Sources: synthesised from Elfadli et al. (2024), Lacetera (2019), Ali et al. (2020) and Prates (2025). Directions of change refer to trends reported for the northern Libyan coastal belt; they are not derived from a station-level time series analysed in this study.

4.2 Livestock composition

Compiled estimates place the regional inventory at approximately 940,500 head. Small ruminants account for 83.5% of that total — a proportion that reflects deliberate adaptation rather than accident, since sheep and goats tolerate sparse, seasonally variable forage far better than cattle do. Cattle represent 8.3% of the inventory despite contributing disproportionately to milk output, a mismatch explained by their water and feed requirements. Camels remain a minor component at 2.3%, concentrated toward the drier inland margin.

Table 2. Compiled estimates of livestock composition, Al-Bayda region (reference period 2024–2026)

Species	Estimated population	Share of total (%)	Primary production role
Sheep	520,000 head	55.3	Meat and wool
Goats	265,000 head	28.2	Meat and milk
Cattle	78,000 head	8.3	Milk and meat
Poultry	56,000 birds	5.9	Meat and eggs
Camels	21,500 head	2.3	Meat and transport
Total	940,500	100.0	—

Compiled regional estimates; see Section 3.7 regarding provenance. Percentages are calculated from the compiled totals and may not sum exactly owing to rounding.

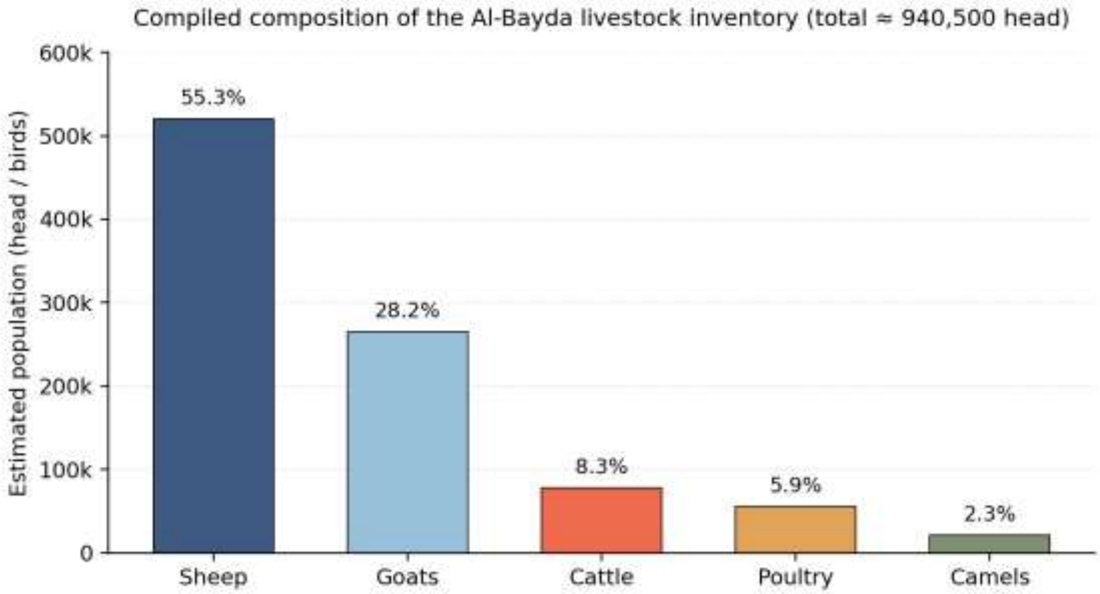

Figure 1. Composition of the compiled Al-Bayda livestock inventory. Small ruminants together account for 83.5% of recorded animals.

4.3 Distribution across grazing zones

Stocking density is far from uniform across the region (Table 3). The wadi systems carry the heaviest loads — 200–280 sheep per square kilometre — because seasonal water and sheltered vegetation concentrate animals there. The mountain plateau follows. Semi-arid inland margins carry roughly a quarter of the wadi density, which is consistent with their sparser cover. This distribution has an uncomfortable implication: the zones offering the best forage are also the zones under the greatest grazing pressure, and they are precisely where degradation would first become visible during an extended dry period.

Table 3. Livestock density across the principal grazing zones of the Al-Bayda region

Grazing zone	Sheep (head/km²)	Goats (head/km²)	Cattle (head/km²)	Observed vegetation status
Wadi systems	200–280	120–180	30–50	Seasonal grazing resource; high pressure
Mountain plateau	180–240	100–150	25–40	Highest pasture quality
Coastal plain	120–160	80–110	20–35	Moderate vegetation cover
Semi-arid inland margin	60–90	40–70	10–20	Limited vegetation

Ranges denote the span of values reported across compiled sources; they are not confidence intervals. Zones are ordered by descending sheep density.

4.4 Seasonal dynamics

Herd size is not static through the year (Table 4, Figure 2). Numbers peak in spring, when forage is at its most abundant and lambing has concluded, then fall through summer. The summer contraction is substantial: sheep decline by roughly 13% from the spring peak, cattle by 12.5%. Autumn brings partial recovery. Three processes plausibly contribute — mortality under heat and feed stress, distress sales as feed costs climb, and transhumant movement out of the district — but the compiled data do not permit their relative contributions to be separated. That separation would require animal-level movement records, which are not currently collected in the region.

Table 4. Seasonal variation in ruminant herd size, Al-Bayda region

Season	Sheep	Goats	Cattle	Dominant environmental driver
Winter	520,000	260,000	78,000	Stable grazing; respiratory disease risk
Spring	540,000	270,000	80,000	Peak forage availability; breeding season
Summer	470,000	240,000	70,000	Heat load and feed scarcity
Autumn	500,000	255,000	75,000	Gradual pasture and herd recovery

Compiled estimates; see Section 3.7. Figures are rounded to the nearest 5,000 head in the underlying sources.

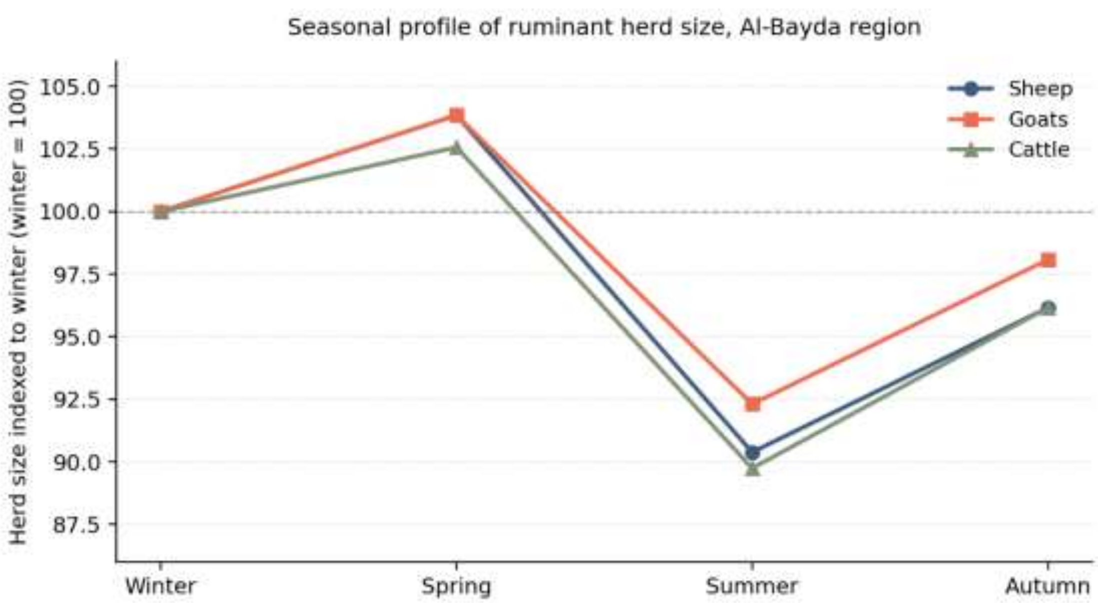

Figure 2. Seasonal profile of ruminant herd size indexed to the winter baseline. The summer trough is evident in all three species, and is deepest in sheep.

4.5 Reported losses

Table 5 sets out annual loss ranges attributed to the four principal causes. Drought and the feed shortage that follows it dominate every column, accounting for 10–15% of sheep, 8–12% of goats and 12–18% of cattle. Across all four causes cattle sustain the highest losses, which confirms from the loss side what Table 2 implies from the composition side: the species least represented in the regional herd is also the least suited to it.

Table 5. Estimated annual livestock losses attributed to climatic and disease factors (% of herd)

Cause of loss	Sheep (%)	Goats (%)	Cattle (%)	Principal economic consequence
Drought and feed shortage	10–15	8–12	12–18	Largest single source of production loss
Heat stress	6–9	5–8	8–12	Depressed growth, milk yield and fertility
Tick-borne disease	4–7	3–5	6–10	Treatment cost and direct mortality
Respiratory disease	3–6	2–4	5–8	Seasonal outbreaks, chiefly in winter

Ranges compiled from regional reporting; causes are not mutually exclusive and percentages should not be summed.

4.6 Climate-sensitive disease pattern

Disease occurrence follows the seasons closely (Table 6). Tick-borne infections cluster in the warm months, when Hyalomma and Rhipicephalus activity peaks; respiratory disease is a winter problem tied to housing and humidity; gastrointestinal parasitism rises in autumn as animals return to pasture carrying accumulated contamination. Heat-stress syndrome is, unsurprisingly, confined to summer and falls most heavily on poultry and cattle.

Table 6. Climate-associated livestock diseases reported for the Al-Bayda region

Condition	Vector or source	Peak season	Species most affected
Babesiosis	Ixodid ticks	Summer	Cattle
Theileriosis	Ixodid ticks	Spring–summer	Cattle and sheep
Anaplasmosis	Ixodid ticks	Warm season	Ruminants generally
Respiratory infection	Housing and humidity	Winter	Poultry and cattle
Gastrointestinal parasitism	Pasture contamination	Autumn	Sheep and goats
Heat-stress syndrome	High thermal load	Summer	Poultry and cattle

Compiled from Elmhalli and Garboui (2024), Abdalsalam et al. (2019), El Maghrbi et al. (2008) and Deshpande et al. (2024).

4.7 Carrying capacity under varying rainfall

Rangeland capacity responds sharply to rainfall (Table 7). A wet year supports 18–22 livestock units per square kilometre; a severe drought year supports 5–7. That is a reduction of roughly two-thirds. Since herd size cannot contract at the same speed, the gap is absorbed as overgrazing — which is the mechanism by which a single bad season leaves a degradation signature that persists for several subsequent years.

Table 7. Rangeland carrying capacity under differing rainfall conditions

Rainfall condition	Carrying capacity (LU/km²)	Resulting grazing pressure	Expected outcome
High-rainfall year	18–22	Balanced	Stable production; vegetation maintained
Normal year	14–18	Moderate	Slight environmental stress
Drought year	8–12	High	Overgrazing risk; condition loss
Severe drought	5–7	Critical	Forced destocking; pasture degradation

LU = livestock unit. Values are indicative ranges compiled from regional rangeland assessments and require local validation against measured biomass data.

4.8 Production performance by species

Table 8 completes the picture by setting productivity against vulnerability. Cattle out-produce every other species on both growth and milk yield, and they also carry the highest mortality. Camels present the inverse profile — modest output, lowest mortality at 4–7%. Sheep and goats occupy the middle ground, and it is that combination of acceptable output with genuine resilience which explains their dominance in the regional herd. Any adaptation strategy for the region has to work with this trade-off rather than against it.

Table 8. Production performance indicators for the principal livestock species

Species	Annual weight gain (kg)	Milk yield (L/yr)	Fertility rate (%)	Mortality rate (%)
Cattle	120–180	900–1,500	75–88	7–12
Camels	80–130	500–800	65–78	4–7
Sheep	18–25	—	70–85	6–10
Goats	15–22	120–180	68–82	5–9

Compiled ranges; species ordered by descending weight gain. Sheep milk yield is not separately recorded in the available regional reporting.

5. Discussion

5.1 Interpreting the seasonal signal

The clearest finding to emerge from the compiled data is the depth of the summer contraction in herd size. A fall of 12–13% between spring and summer is not a minor fluctuation; it represents the annual point at which climatic pressure exceeds the system's buffering capacity. The physiological literature offers a coherent explanation. Sustained thermal load depresses feed intake at exactly the moment when maintenance energy requirements are elevated, and the resulting negative energy balance suppresses both reproductive function and immune competence (Lacetera, 2019). Global modelling of thermoregulatory response reaches the same conclusion from a different direction, projecting substantially widened physiological responses in ruminants under mid-century scenarios (Silveira et al., 2026).

What the present data cannot do is apportion the summer decline between mortality, distress sale and transhumance. This matters for policy, because the three call for entirely different responses — veterinary intervention, market support, and movement infrastructure respectively. Resolving it would require animal-level tracking that does not presently exist in the region.

5.2 Why cattle carry the highest burden

Cattle appear at the unfavourable end of almost every table in Section 4: highest losses under each of the four causes examined, highest mortality, and the largest proportional summer decline after sheep. This is consistent with comparative work on Alpine systems, where cattle were found markedly more sensitive than small ruminants to both heat load and forage decline (Cornale et al., 2025). The explanation is largely a matter of scale and metabolism: a lactating cow generates more metabolic heat and requires more water per unit of body mass than a ewe, and in a system where both heat and water are becoming limiting, that is a structural disadvantage.

The policy implication is not that cattle should be abandoned — they supply the bulk of regional milk — but that cattle production in Al-Jabal Al-Akhdar requires environmental modification (shade, ventilation, reliable water) to a degree that small ruminant production does not. Treating all species with a single management template will systematically under-serve the most vulnerable one.

5.3 Vector-borne disease as a climate-mediated constraint

Tick-borne infection is the second recurring theme. The seasonal clustering shown in Table 6 aligns with what is known about ixodid biology, and the Libyan vector data support the inference: Hyalomma and Rhipicephalus dominate the north-eastern coastal fauna, and both are temperature-responsive genera (Elmhalli & Garboui, 2024). The clinical consequence in Libyan cattle is documented — significant anaemia and biochemical disturbance in Babesia-infected animals (Abdalsalam et al., 2019), alongside concurrent theileriosis and anaplasmosis recorded in the Tripoli region (El Maghrbi et al., 2008). Evidence from the United States, while drawn from an entirely different disease system, confirms the underlying principle that warming and humidity shifts extend both the questing season and the geographic range of tick vectors (Deshpande et al., 2024).

Two caveats deserve emphasis. First, the Tripoli data (El Maghrbi et al., 2008) describe a different region and are now more than fifteen years old; they establish that these pathogens circulate in Libya, not that current prevalence in Al-Jabal Al-Akhdar matches those figures. Second, the North American evidence base cannot be read as a prediction for Libya. It establishes mechanism, not magnitude. Locally generated prevalence data remain the missing element, and the absence of a functioning national surveillance system since 2011 — a gap already visible in brucellosis serosurveillance (Al-Griw et al., 2017) — is the reason.

5.4 Rangeland pressure and the carrying-capacity gap

The carrying-capacity data in Table 7 describe a system with very little slack. When capacity falls from roughly 20 to roughly 6 livestock units per square kilometre in a severe drought year, and herd size does not fall correspondingly, the deficit is met by grazing the resource itself. Land-cover analysis for Al-Jabal Al-Akhdar has already recorded contraction of the rangeland class across recent decades (Alawamy et al., 2020), and work on pastoral land-use intensity in the same region attributes measurable grazing damage to stocking pressure (Abdalrahman et al., 2023). Experience in the South African Karoo suggests that separating grazing-driven degradation from climate-driven vegetation change requires sustained monitoring rather than periodic survey (Hoffman et al., 2018) — a methodological lesson that applies directly here.

Broader regional analysis reinforces the point. Assessment of climate impacts on agriculture across the SADC countries found that rangeland-dependent systems are among the least able to absorb rainfall variability, precisely because their productive capital is the vegetation itself (Semosa, 2025). The same structural vulnerability characterises Al-Jabal Al-Akhdar.

5.5 Comparison with the wider literature

Placed against the international evidence, the Al-Bayda picture is neither unusual nor reassuring. Heat stress, feed insecurity, and shifting disease distribution were found to be the three main climate impacts on livestock globally in the scoping review by Anuta et al. (2025), and all three are included in the current synthesis. Work on the Bangladesh livestock sector describes an almost identical triad of heat stress, oxidative damage and immune suppression operating in a very different agro-ecology (Ali et al., 2020). What distinguishes the Libyan case is not the nature of the pressures but the weakness of the institutional buffer: surveillance is intermittent, extension capacity is limited, and there is no operational early-warning link between meteorological services and veterinary authorities.

5.6 Limitations

Several constraints qualify these findings and should be stated plainly.

The study generated no primary data. Every quantitative value reported here is secondary, and a portion is estimated rather than enumerated.

Table values are compiled ranges without documented sampling frames. They indicate magnitude and relative order; they do not support statistical inference.

No formal correlation between meteorological series and herd or disease outcomes was computed, so all causal language in this paper should be read as mechanistic reasoning supported by the literature, not as a demonstrated association in these data.

Several supporting studies originate outside North Africa — Uganda, the United States, South Africa, the Alps, Bangladesh. They are cited for mechanism, and their quantitative results are not transferred to the Libyan context.

The 2024–2026 reference period includes years for which final official returns were unavailable at the time of writing.

Grey literature and unpublished ministerial records that may hold relevant data could not be accessed systematically.

These limitations point toward the obvious next step. A field study combining a station-level temperature–humidity index series for Al-Bayda with monthly herd records and seasonal parasitological sampling would convert the descriptive account offered here into a testable quantitative relationship. That is the study the region needs.

6. Conclusions and Recommendations

6.1 Conclusions

Environmental and climatic conditions exert a measurable and largely negative influence on animal health and productivity in Al-Bayda. Heat load, drought-driven feed deficits, humidity fluctuation and rangeland degradation act together rather than separately, and their combined effect is visible in a seasonal herd contraction of 12–13% between spring and summer. Cattle bear the heaviest burden across every indicator examined; small ruminants dominate the regional herd precisely because they tolerate these conditions better. Tick-borne disease represents the principal climate-mediated infectious constraint, with a seasonal signature that follows vector activity closely. Rangeland carrying capacity contracts by roughly two-thirds under severe drought, and because herd size adjusts more slowly, the shortfall is absorbed as degradation of the resource itself.

These conclusions rest on secondary and partly estimated data, and are advanced as a structured regional assessment rather than as validated measurement. Their value lies in identifying where intervention and where measurement is most urgently required.

6.2 Recommendations

Four priorities follow from the evidence assembled here.

Establish climate-linked veterinary surveillance. Routine monitoring of tick burden and haemoprotozoan prevalence, reported by locality and by season and linked to meteorological data from the Al-Bayda station, would allow acaricide application and vaccination to be timed against actual vector activity rather than against the calendar.

Manage grazing against measured capacity. Rotational grazing, rangeland restoration in the wadi systems where pressure is highest, and stocking rates set against seasonally assessed biomass would reduce the degradation that follows each drought year. This requires a functioning biomass assessment capability, which at present does not exist at district level.

Modify the thermal environment for the most exposed classes. Shade provision, improved ventilation in winter housing, and reliable clean water are low-technology measures with well-documented returns, and they matter most for dairy cattle and poultry. Attention to ventilation carries the additional benefit of reducing the winter respiratory burden.

Build the evidence base. The single most useful investment would be a longitudinal dataset: a temperature–humidity index series for Al-Bayda alongside monthly herd inventories and seasonal disease sampling. Without it, adaptation planning for the region will continue to rely on estimates of the kind presented in this paper.

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