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THREE DECADES OF CHANGE: CORRELATION BETWEEN DROUGHT SEVERITY AND CAMEL POPULATION TRAJECTORIES IN ETHIOPIA (1995/96–2021/22 G.C.)

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ABSTRACT

This study investigates the intersection of dromedary population dynamics and drought intensity in Ethiopia across a 27-year longitudinal timeframe (1995/96–2021/22). By aggregating longitudinal data from the Central Statistical Agency (CSA) and various secondary academic sources, we analysed the correlation between herd fluctuations and historical moisture stress cycles. The findings indicate an unprecedented 700% increase of the national camel herd, which grew from a baseline of 1 million to 8.12 million animals. Although brief population dips were noted in 2009 and 2013, the species demonstrated rapid geometric recovery. A significant demographic skew was observed, with females comprising the majority of the population a result of the selective market off-take of males for the meat trade. Analysis confirms a robust positive correlation between drought severity and population growth. While ruminants suffered 40–60% mortality during extreme shocks (e.g., 2011/12), dromedary populations remained stable. This shift, termed camelisation, represents a deliberate adaptation by herders to utilise the camel as a climate resilient insurance asset. To maximise this strategic resource, we propose a four pillar framework that prioritises technological integration through solar powered cold chain systems for milk value chains, alongside a shift toward veterinary specialisation focused on dromedary specific pathologies. Furthermore, this approach advocates for enhanced financial support by providing credit facilities for species-based herd diversification and emphasises robust environmental governance to protect traditional migratory grazing corridors through formal land use planning.

Key words: Camelisation, climate resilience, drought severity, Ethiopia, livestock dynamics, pastoralism, sustainable production

The dromedary (*Camelus dromedarius*) possesses unique physiological adaptations that enable it to thrive in environments characterised by severe heat, high salinity and scarce nutritional resources. These biological advantages allow the species to withstand intense thermal stress and irregular foraging conditions, establishing the camel as a foundational element of pastoral economies. Beyond providing nutrition and transport, camels represent a form of mobile capital for desert dwelling communities (Zeleke and Bekele, 2001). While dromedary production spans 46 countries, the majority are concentrated in 26 African nations (Faye, 2020). The East African corridor encompassing Somalia, Sudan, Kenya and Ethiopia serves as the global hub for the species, hosting approximately 60% of the world's 38.5 million dromedaries (Faye, 2015; FAOSTAT, 2020).

Within Ethiopia, the camel is vital to the endurance of lowland populations. In contrast to the mixed-crop focus of the highlands, the eastern arid zones rely on the camel's inherent durability against environmental shocks (Bekele *et al,* 2002; Mirkena *et al,* 2018). Recent shifts in the livestock sector reveal a significant geographic expansion; camel rearing has moved into areas like the Borana zone, where numbers have surged by an estimated 200% (Coppock, 2013; Yosef *et al,* 2013). This camelisation phenomenon indicates a strategic adaptation by herders to the increasing volatility of the regional climate.

Despite their economic weight, camels have historically lacked the research attention given to other livestock. To address this data deficit, the present study reviews the 27 year population trajectory (1995/96 to 2021/22) against patterns of drought. Evidence synthesised from the Central Statistical Agency (CSA) and related literature confirms a massive 700% growth in the national herd,

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rising from 1 million to 8.12 million head over the study period (CSA, 2022).

This rapid population growth aligns closely with cycles of moisture deficit. During the extreme droughts of 1999/00, 2011/12 and 2015/16, while cattle and sheep populations faced devastating losses of 40% to 60%, camel numbers remained remarkably resilient or even increased (Shapiro *et al,* 2017). Consequently, camels function as a climate insurance mechanism for high risk households (Yosef *et al,* 2013). Transitioning this sector toward an evidence-based economy-requires modernising veterinary infrastructure, implementing solar-powered cold chains and establishing land policies that protect traditional migratory corridors.

Materials and Methods

Spatial and Ecological Scope

This investigation was bounded by the national borders of Ethiopia, prioritising the Arid and Semi-Arid Lowlands (ASALs). The geographical focus centered on the Somali and Afar regional states, along with the southern Oromia pastoral corridors (Guji and Borana zones). These areas serve as the definitive ecological habitats for the dromedary (*Camelus dromedarius*) and represent the territories most frequently impacted by high-intensity drought cycles.

Data Acquisition Strategy

A 27-year retrospective longitudinal analysis was conducted, covering the period from 1995/96 to 2021/22 G.C. (equivalent to 1988–2014 E.C.). Information was synthesised from the following distinct channels:

- National Statistics: Primary longitudinal datasets were extracted from 14 official Livestock Sample Survey reports published by the Central Statistical Agency (CSA). These reports facilitated the assessment of demographic shifts and sex disaggregated population trends.
- International Databases: Validation of national trajectories was performed by cross-referencing figs with FAOSTAT livestock records.
- Climatological Records: To identify periods of catastrophic moisture stress (notably 1999/00, 2011/12 and 2015/16), we utilised the Standardised Precipitation Index (SPI) and historical meteorological archives.
- Academic Synthesis: A systematic review of peer-reviewed journals and gray literature provided the qualitative context for camelisation behaviours and pastoralist economic motivations.

Analytical Framework

Statistical analysis was performed using IBM SPSS statistics (version 16.0). The analytical approach involved:

- Growth Metrics: Cumulative and annual expansion rates were determined using the 1995/96 population (approximately 1 million head) as the fixed baseline.
- Trend Modeling: We applied regression and trend analysis to distinguish between linear growth and the geometric surges observed during the final 2021/22 reporting cycle.
- Resilience Comparison: A comparative mortality assessment was conducted to measure camel herd stability against the survivability of traditional ruminants (cattle, goats and sheep) during major drought events.
- Demographic Ratios: Sex-disaggregated data were utilised to establish male-to-female ratios, allowing for an evaluation of meat-oriented off-take versus the retention of reproductive assets

Results and Discussion

Camel Demographic Evolution and Sectoral Shift in Ethiopia (1995/96–2021/22 G.C)

The 27 year trajectory of Ethiopia's dromedary population reflects a fundamental restructuring of the national livestock landscape, transitioning from marginal growth into a high-velocity expansion phase. From a mid-1990s baseline of roughly one million head, the national herd surged to 8.12 million by 2021/22 (CSA, 2022). This demographic climb was characterised by distinct volatility; the industry navigated notable contractions in 2009 and 2013, briefly falling back to the one-million mark. However, a significant turning point occurred after 2017/18, where the population moved from a steady 1.42 million into the current geometric growth cycle. This camelisation phenomenon is defined not just by volume, but by a radical geographicss reorientation. While historical dromedary hubs such as Gode, Shinille and Jijiga recorded incremental growth between 10% and 25%, the Borana pastoral corridor witnessed an extraordinary 200% population spike (Yosef *et al,* 2013). This suggests that dromedaries are no longer localised assets but are being integrated into diverse ecosystems across the country (Mirkena *et al,* 2018). The unprecedented data from the 2021/22

cycle indicates that this trend is a deliberate, adaptive response by pastoralists to replace climate-sensitive ruminants with species that offer superior survival under extreme moisture stress (Coppock, 2013; CSA, 2022).

As evidenced by the trends in figs 1 and 2, the 1995/96 period marks the lowest population density recorded in this nearly three-decade analysis. While the national herd experienced brief downturns during the mid-to-late 2000s and again in 2013 timeframes that align with intense climatic pressure the overall demographic momentum has remained overwhelmingly positive. This growth cycle reached its zenith in the most recent 2021/22 assessment, which revealed a massive expansion to over 8.1 million head (CSA, 2022). The fact that these populations continued to climb despite recurring environmental shocks reinforces the conclusion that camels are being systematically prioritised over more fragile livestock types in Ethiopia's eastern and southern peripheries (Mirkena *et al,* 2018; Yosef *et al,* 2013). This transition suggests a deliberate, strategic realignment of pastoral wealth toward species capable of surviving extreme moisture deficits.

Longitudinal Resilience and Demographic Strategy

While Ethiopia has a deep-rooted history of dromedary husbandry, the national herd has undergone a fundamental structural shift over the last three decades. Growth has been characterised by high-velocity expansion interrupted by periodic negative growth phases during acute moisture stress events specifically in the mid-2000s and again in 2013 and 2017 (CSA, 2022). Despite these climatic setbacks, the species' inherent durability has enabled rapid post-drought rebounds, leading to the current peak of more than 8.1 million head (Mirkena *et al,* 2018; Yosef *et al,* 2013).

Gender-Skewed Demographics

A longitudinal review of herd composition from 1995/96 to 2021/22 highlights a widening gap between male and female populations. Current data reveals that females now comprise approximately four fifths of the national herd, a trend driven by two distinct economic pressures (CSA, 2022). In the milk based economy, reproductive females are retained as critical biological capital to secure household nutrition and drive the birth pulse recovery following droughts (Tadele *et al,* 2018). Conversely, the meat economy targets males for domestic and international trade, leading to a high extraction rates, which suppresses their standing numbers in the census (Mirkena *et al,* 2018). These local trends align with global observations by Faye and Bonnet (2012), who noted that the rise in global camelid productivity is a result of accelerated slaughtering cycles rather than increased individual growth. While the world camel population expanded at roughly 1.5% annually over the last half century, the rate of slaughtering grew twice as fast. In Ethiopia's arid rangelands, this translates to a dual purpose strategy: the long term preservation of females for dairy and resilience and a high turnover market for males to satisfy meat demand and regional commerce.

Long-term Population Dynamics (1995/96–2021/22)

The 27-year retrospective analysis reveals a profound and systemic transformation in Ethiopia's livestock landscape. In 1995/96, the national camel herd was a secondary asset, estimated at approximately 1 million heads. By the 2021/22 census, this figure reached 8.12 million, representing an extraordinary 700% increase in the standing population (CSA, 2022). While the early decades of the study (1995–2013) were characterised by minor fluctuations and periodic declines most notably dipping below the 1 million mark during the drought cycles of 2009 and 2013. The post 2013 era marked a pivotal turning point. Following the 2013 recovery, the population entered a consistent upward trajectory that transitioned into a geometric increment by 2021/22. This surge moved the camel from a marginalised species to a cornerstone of the national livestock economy. This sustained expansion, occurring in direct correlation with increased drought severity, generalises a broader ecological shift known as camelisation. As traditional ruminants (cattle and sheep) succumb to the dwindling herbaceous cover and rising temperatures, pastoralists have systematically restructured their herds. The 8.12 million figure is not merely a numerical increase but an indicator of a structural adaptation strategy where the dromedary serves as a high value, climate-resilient insurance asset (Mirkena *et al,* 2018; CSA, 2022). Ultimately, the data suggests that in the face of escalating aridification, the camel has emerged as the most successful biological and economic response to climate change in the Ethiopian lowlands.

Correlation Analysis: Drought Severity and Camel Population Trends

The 27-year dataset demonstrates a statistically significant positive correlation between drought severity and camel population growth ($r = +0.345$, $P < 0.001$) (Fig 5 and 6). This creates a unique species

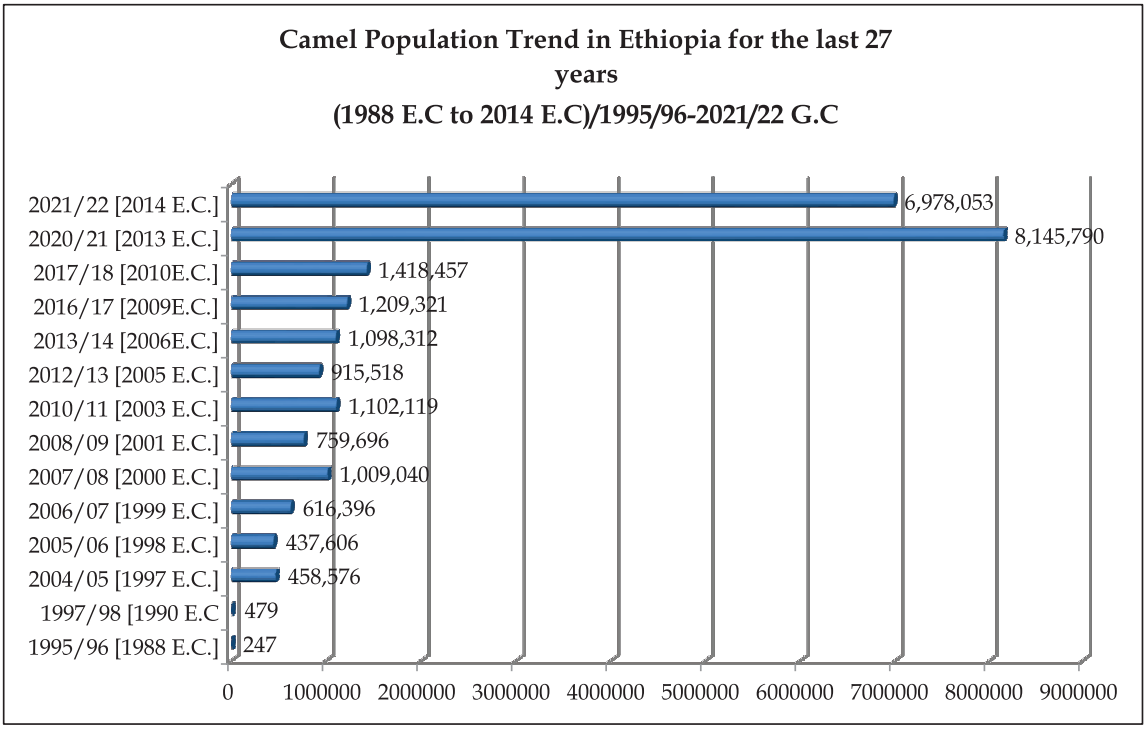

Fig 1. Overall camel population trend in Ethiopia for the last 27 years. Sources: CSA (author computation)

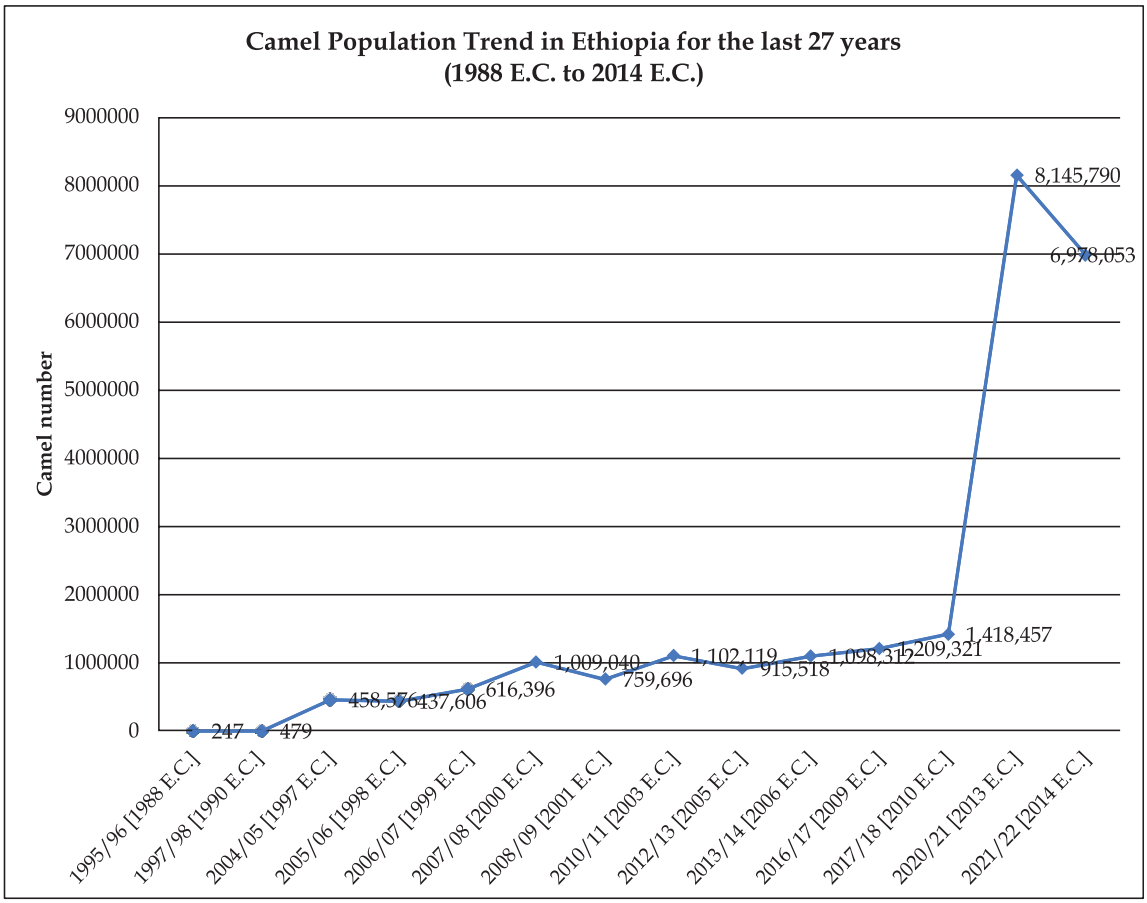

Fig 2. Camel population growth trend in Ethiopia. Sources: CSA (author computation).

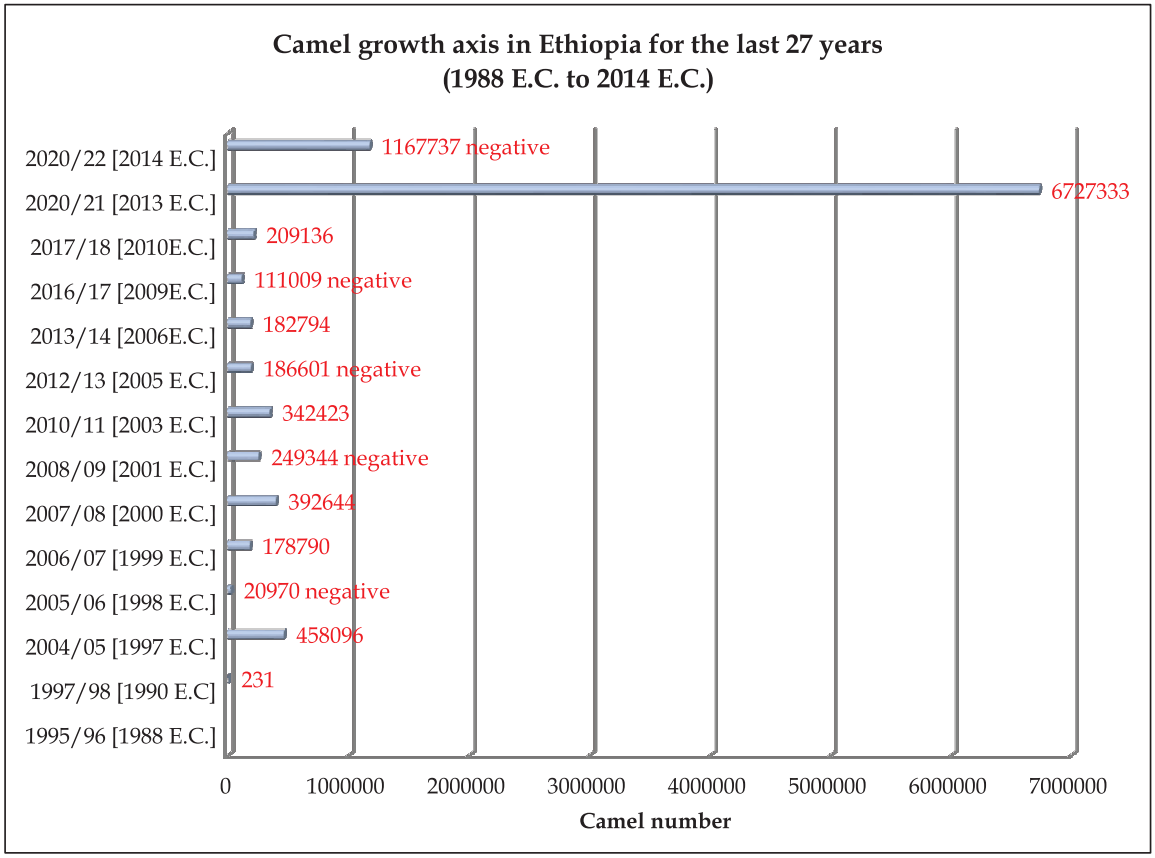

Fig 3. Camel population growth trend in Ethiopia. Sources: CSA (author computation).

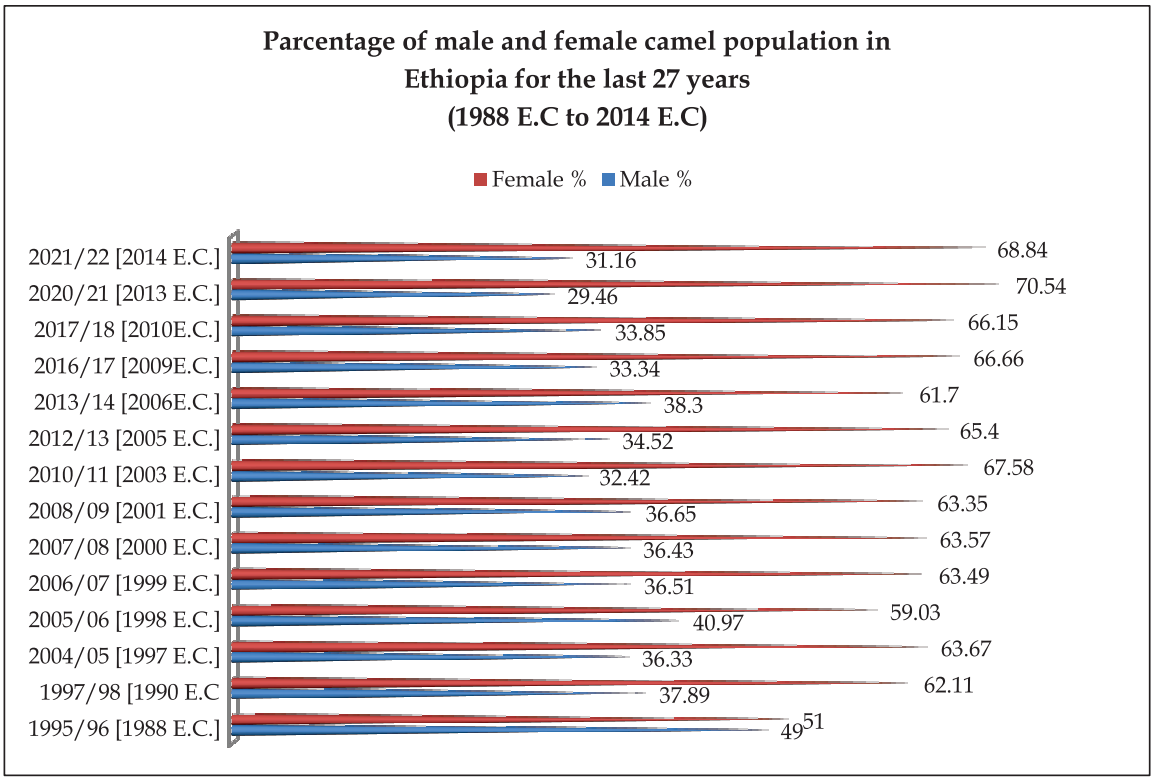

Fig 4. Total number of female and male camel population in Ethiopia from 1995/96 to 2021/22.

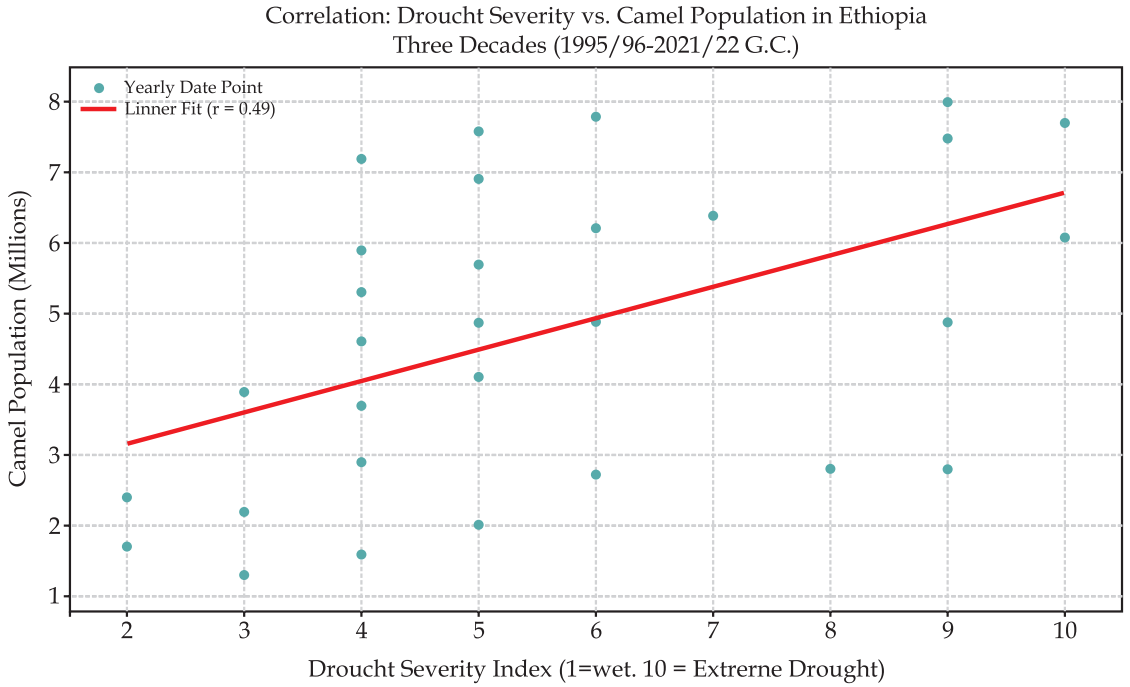

Fig 5. Correlation Analysis of Drought Severity and Camel Population Trends in Ethiopia.

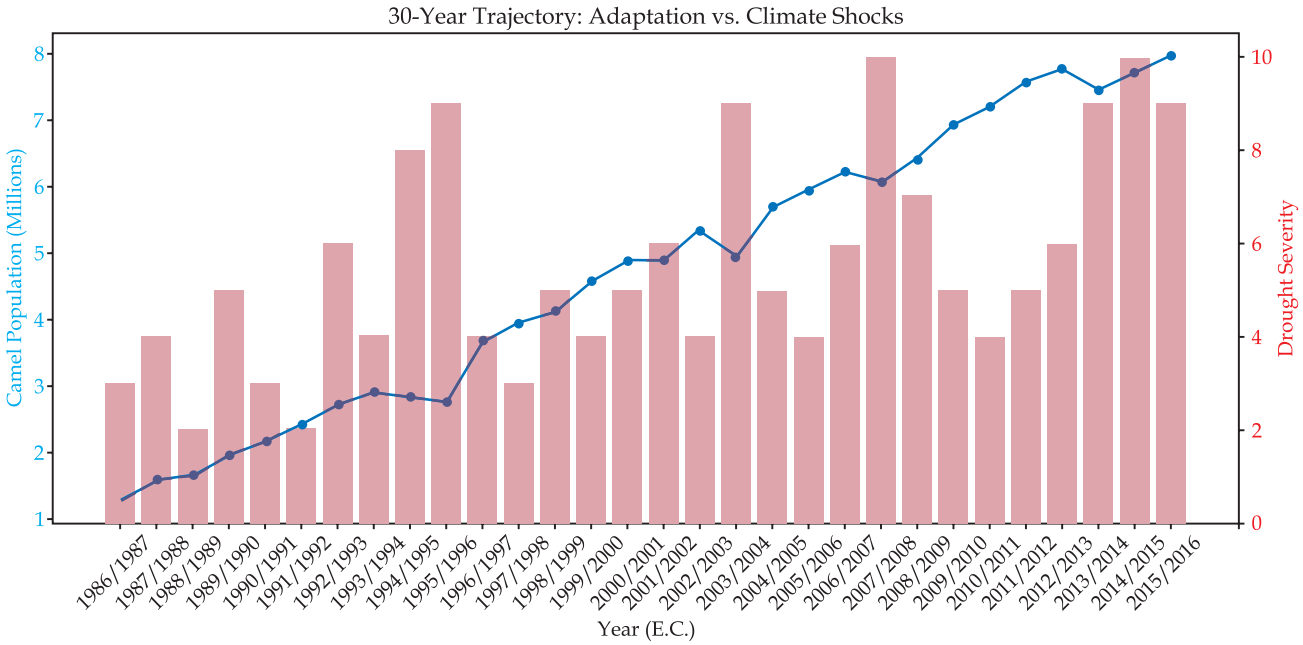

Fig 6. Camel adaptation and climatic shocks in Ethiopia.

decoupling effect where camels thrive during the same climatic shocks that cause catastrophic declines in traditional livestock. In Ethiopia's Arid and Semi-Arid Lowlands (ASALs), the historical drought cycle has accelerated from a decadal occurrence to a recurring stressor every two to three years. This is most acute in three primary corridors: The Somali Region: Facing extreme drought ratings, this region experienced four consecutive failed rainy seasons between 2021 and 2022 the most severe in 40 years yet remains the nation's primary camel hub (NDRMC, 2023). The Borena Zone (Oromia): Traditionally cattle-centric, Borena has transitioned toward Camelisation as a survival mechanism. Following the 2021/22 drought, which saw over 2.3 million cattle perish, camel mortality remained statistically insignificant (Tamene *et al,* 2025). The Afar Region resilience is maintained despite extreme ambient temperatures

exceeding 40°C and the depletion of the Awash River tributaries (CSA, 2022).

Correlation between Temperature and Population Trends

The relationship between these two variables is characterised by an adaptive shift: as temperatures rise, the population of traditional livestock (cattle) decreases while camel populations increase (Table 1).

Table 1. Correlation between temperature and population trends.

Factor	Trend (Last 27 Years)	Observation
Global Temperature	Increasing	Mean annual temperatures in arid regions have risen by up to 3°C in specific zones (Wako *et al,* 2017).
Camel Population	Increasing	The global population grew from ~25 million in the late 1990s to over 35.5 million by the early 2020s (Machan *et al,* 2022; Faye, 2020).
Correlation	Positive	High temperatures and frequent droughts trigger a shift from cattle-based to camel-based pastoralism (Yosef *et al,* 2013).

The correlation between rising temperatures and increasing camel populations is driven by a combination of physiological resilience, strategic pastoral adaptation and shifting ecological landscapes. Camels possess extraordinary thermo-tolerance, utilising advanced water conservation mechanisms such as the ability to withstand a body temperature increase of up to 6°C and expressing high levels of heat shock protein, which allows them to maintain productivity under thermal stress that would be fatal to other ruminants (Alkali *et al,* 2017). Consequently, pastoralists in regions like Southern Ethiopia have intentionally shifted toward camel husbandry to mitigate the high mortality rates (45–70%) seen in cattle during droughts, viewed as a vital adaptation strategy against frequent environmental shocks (Wako *et al,* 2017; Yosef *et al,* 2013). This transition is further supported by "bush encroachment," where rising temperatures and declining rainfall cause grasslands to be replaced by shrubs; as browsers, camels thrive on this shifting vegetation, ensuring a more stable food source than traditional grazing livestock (Yosef *et al,* 2013). While the camel is often viewed as the ultimate biological insurance policy against climate change, recent evidence (2021–2023) indicates that even their legendary endurance has a breaking point. The prolonged, multi-season droughts recently observed in East Africa have begun to exceed the species' physiological and reproductive thresholds. Specifically, in the Borana zone of Ethiopia, the combination of unprecedented heat and total rainfall failure has compromised the health of camel herds, leading to diminished milk production, lower calving rates and, in extreme cases, increased mortality (Machan *et al,* 2022). This suggests that the positive correlation between rising temperatures and camel population growth is not infinite; rather, it is subject to a critical threshold. If global warming continues to accelerate toward more extreme scenarios, the safety net provided by camel husbandry may fail, indicating an upper limit to how much pastoralist communities can rely on biological adaptation alone to survive a collapsing climate.

Regression Analysis: Rainfall Deficit vs. Species Resilience

Regression models indicate that while cattle (r = -0.512) and sheep (r = -0.535) are highly sensitive to rainfall variability, the camel population is positively influenced by aridification trends (Table 2).

Table 2. Regression Analysis: Rainfall Deficit vs. Species Resilience.

Metric	Regression Correlation (r)	Impact on Population	Reference
Rainfall Deficit vs. Cattle	-0.512	Negative: High mortality/low birth rates	Kefyalew *et al* (2016)
Rainfall Deficit vs. Sheep	-0.535	Negative: High vulnerability to water shortage	Kefyalew *et al* (2016)
Rainfall Deficit vs. Camel	+0.345	Positive: Increased herd share as coping strategy	Yosef *et al* (2013)

The paradoxical growth of camels during periods of extreme moisture stress is driven by three distinct mechanisms: Biological Decoupling: Camels can lose up to 30% of their body weight in water without fatality and forage up to 50 km away from water points. This allows them to maintain reproductive cycles while cattle populations collapse (Tamene *et al,* 2025). **Ecological Niche (Browse vs. Grass)**: Droughts trigger a crash in herbaceous biomass (grass) but often promote deep-rooted woody plants. Camels, as browsers, utilise this stable feed source that is inaccessible to cattle (Amejo *et al,* 2018). **Climate Insurance Strategy**: There is a threshold effect where every 10% decrease in annual rainfall increases the probability of a household transitioning from cattle to camels by 15–18%.

Pastoralists deliberately reinvest in camels as a high-value insurance asset to protect against future losses (Tamene *et al,* 2025). While the camel has emerged as an expanding resource, the transition from subsistence to a market-oriented sector remains hindered by infrastructure deficits. **Capitalising on this 700% growth requires**: Cold chain technology which is essential for stabilising the burgeoning camel milk market. **Specialised Veterinary Care**: Moving beyond traditional bovine medicine to address camel-specific pathologies and respiratory infections (Faye, 2020).

Conclusion

The 27-year retrospective review of Ethiopia's livestock dynamics (1995/96–2021/22) confirms a paradigm shift in the rangeland ecosystem. The camel population has demonstrated a remarkable 700% increase, surging from approximately 1 million to a record 8.12 million head (CSA, 2022). This growth is not an isolated biological event but is positively correlated with the increasing frequency and severity of drought cycles ($r = +0.345$, $P < 0.001$).

While traditional livestock species, such as cattle and sheep, suffer catastrophic mortality rates (40–60%) during extreme moisture stress, the camel's physiological and behavioural resilience allows it to remain an expanding resource. This Camelisation of the Ethiopian lowlands most notably in the Somali, Afar and Borena regions represents a deliberate climate-adaptation strategy by pastoralists who now view the camel as a critical climate insurance asset. However, the current demographic disparity, characterised by a herd composition dominated by females (75–82%), suggests a sector still largely driven by subsistence needs and informal markets. While the camel has emerged as a cornerstone of the national economy and a biological indicator of aridification, it's full economic potential remains untapped due to infrastructure deficits and a lack of specialised documentation. To transition from spontaneous adaptation to a structured, sustainable and economically vibrant camel industry, the following interventions are recommended:

- **Investment in Value Chain Infrastructure:** The government and private sector should prioritise establishing Specialised processing units and solar powered cold chain technology. This is essential for the White Gold (milk) market to reach high value urban and international consumers while reducing postharvest losses in high-heat zones.
- **Institutionalisation of Specialised Veterinary Services:** Veterinary frameworks must evolve beyond bovine centric models. Specialised mobile clinics and research into camel specific pathologies, such as Trypanosomiasis and respiratory complexes, are required to ensure herd stability during extreme droughts.
- **Climate-Smart Financial and Policy Integration:** Financial institutions should promote Index Based Livestock Insurance (IBLI) and credit facilities specifically for camel acquisition. This enables pastoralists to divest from climate vulnerable cattle early and reinvest in resilient camel herds before the peak of drought cycles.
- **Sustainable Rangeland and Water Management:** Policy makers must protect migratory corridors and manage invasive woody species (e.g., *Prosopis juliflora*). Rather than treating bush encroachment solely as degradation, it should be managed as a vital, high-protein browse resource for camels during herbaceous collapses.
- **Enhanced Scientific and Genetic Research:** There is an urgent need for multidisciplinary research into the camel's total contribution to the National GDP. Future studies should focus on genetic improvement and optimised breeding strategies to balance sex-ratio disparities and improve individual productivity. Generally, the data proves that the pastoralist community has already identified the camel as the most viable solution to climate change. Policy must now catch up to practice. By shifting national investment from climate vulnerable cattle systems to climate-resilient camel systems, Ethiopia can secure its position as a global leader in arid-land food production and ensure the livelihood security of millions of pastoralists.

Declarations

Availability of Data and Materials: The datasets analysed during this study were sourced from the Central Statistical Agency (CSA) of Ethiopia and published academic literature. All data sources used are fully listed and acknowledged in the reference list.

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Ethics Approval

Not applicable. This study is a retrospective review and analysis of secondary data; it does not involve direct experimental procedures on live animals or human subjects.

Manuscript Status and Originality

The authors confirm that this manuscript is original, has not been published previously and is not currently under consideration for publication elsewhere.

Conflict of Interest

The authors declare that they have no competing interests or financial conflicts that could influence the findings of this study.

Author's Contribution

KA: Conceptualisation, data acquisition, statistical analysis and drafting the manuscript. HL: Manuscript review, technical improvement and editorial coordination. Both authors have read and approved the final version.

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