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Research Article

Spatiotemporal Trends and Purpose Based Dynamics of Sheep and Goat Populations in Ethiopia

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Abstract:

Small ruminants, particularly sheep and goats, play a vital role in Ethiopia's agricultural economy and rural livelihoods. Despite their importance, comprehensive evidence on long-term spatiotemporal population trends and purpose-based dynamics remains limited. This study analyzed the spatiotemporal trends, regional distribution and sex and purpose-based dynamics of sheep and goat populations in Ethiopia from 2004 to 2022 using secondary data obtained from the Central Statistical Agency (CSA). Non-parametric Mann–Kendall trend tests and Sen's slope estimators were applied to assess the magnitude and significance of population changes over time. The results revealed a sustained and statistically significant increase in both sheep and goat populations at the national level, with goats exhibiting a faster growth rate than sheep. Strong positive trends were observed across most regions, particularly in pastoral and agro-pastoral areas such as Afar and Somali, while Benishangul-Gumuz showed non-significant trends for sheep. Purpose-based analysis indicated that population growth was largely driven by breeding females, while males were predominantly associated with meat production. Goat populations showed especially strong increases in breeding and milk oriented female categories, reflecting their adaptability and growing economic relevance. Overall, the findings highlight significant regional disparities and functional differentiation in small ruminant production systems. These insights provide valuable evidence for designing targeted breeding programs, improving market integration, strengthening animal health services and enhancing the resilience and productivity of Ethiopia's small ruminant sector

Key words: sheep; goat; population trends; purpose-based dynamics; Ethiopia; small ruminants

Introduction

Small ruminants, specifically sheep and goats are integral to Ethiopia's agricultural system, providing meat, milk, wool, hides and serving as financial assets for rural households (FAO, 2020; CSA, 2021). Ethiopia harbors one of the largest small ruminant populations globally, with an estimated 42.9 million sheep and 52.5 million goats, representing about 10% of Africa's and 4% of the world's small ruminant livestock (Frontiers Media, 2022; EthJBD, 2022). These populations are largely maintained under traditional mixed crop–livestock and pastoral/agro-pastoral systems, which dominate Ethiopian livestock production landscapes (CSA, 2008–2021; Diribi & Getiso, 2022), with sheep and goats contributing significantly to food security, income generation, and resilience against climate variability (Tefera et al., 2022; Alemayehu et al., 2021).

Sheep are primarily reared for meat, wool, and breeding, while goats are valued for meat, milk, and genetic improvement of flocks, often adapting better to arid and semi-arid regions compared to other livestock (Gebremedhin et al., 2020; Belay et al., 2022). The economic contributions of small ruminants are substantial. They supply a significant proportion of domestic meat consumption sheep account for approximately 25% of national meat output and contribute to cash income and export earnings through live animals and related products (Agri & Food Security, 2018; Frontiers Media, 2022). At the same time, small ruminants provide nearly 2% of Ethiopia's annual GDP through their stock value and production outputs (Frontiers Media, 2022). Their relatively low input requirements, quick reproductive cycles and adaptability to diverse and often harsh agro-ecological conditions make

them attractive assets for resource-poor farmers and pastoralists (Scientia Ricerca, 2025; EthJBD, 2022).

Despite their economic and social importance, the spatial and temporal distribution of these livestock remains uneven across Ethiopian regions, influenced by agro-ecological factors, market access, high juvenile mortality rates, low offtake and commercialization, poor genetic potential, inadequate feeding and health services, and limited access to markets and modern management technologies pastoral and mixed farming systems, and traditional husbandry practices (Desta et al., 2019; Solomon et al., 2021). Previous studies have highlighted an overall increase in small ruminant populations, yet there is limited comprehensive analysis that integrates both spatiotemporal trends and purpose-based dynamics, particularly considering sex-specific contributions to population growth and production objectives (Abebe et al., 2021; Wondimu et al., 2022).

Understanding the growth patterns of sheep and goat populations and their primary production purposes is critical for optimizing breeding programs, market development, and sustainable resource utilization. For instance, breeding females play a pivotal role in population expansion, whereas males are more frequently sold for meat, reflecting traditional management strategies and market-driven utilizati∫n (FAO, 2018; CSA, 2021). Insights into these dynamics enable targeted interventions in veterinary services, extension support, and rangeland management, ultimately enhancing productivity, resilience, and livelihoods across rural Ethiopia (Getachew et al., 2020; Teshome et al., 2022). Recent trends in livestock populations suggest significant regional disparities and shifts in purpose-based utilization, influenced by climatic variability, policy initiatives, and commercialization of small ruminant production (Kebede et al., 2021; Hailu et al., 2020).

Despite this recognized importance, gaps remain in understanding how population trends vary across regions, purposes (such as meat, milk, breeding, and others), and between sexes. Such nuanced analysis is essential for designing context-appropriate livestock development strategies that enhance productivity, market integration, resilience to climate variability, and the contribution of small ruminants to national development goals. Consequently, this study aims to fill the knowledge gap by providing a comprehensive analysis of spatiotemporal trends and purpose-based dynamics of sheep and goat populations in Ethiopia from 2004 to 2022, offering comprehensive insights for researchers, policymakers, and livestock development stakeholders with the objective of to analyze the spatiotemporal trends and purpose-based dynamics of sheep and goat populations in Ethiopia

Source of data

Information on the number of Ethiopian sheep and goats (Shoat) populations and distribution by region was obtained from the CSA (http://www.csa.gov.et/) annual report series, the agricultural sample survey (CSA, 2024-2022). The annual Livestock Sample Survey covered the rural agricultural population in all the regions of the country except the non-sedentary population of Addis Ababa.

Methodology

Data on annual sheep and goat population growth and Purpose in Ethiopia for the period of 2004 to 2022 were collected from the Central Statistical Agency (CSA). Trend tests were carried out using the non-parametric Mann-Kendall's trend test by R, which is less sensitive to outliers and tests for a trend in a time series without specifying whether the trend is linear or non-linear (Partal and Kahya, 2006; Yenigun *et al.*, 2008; Hadgu *et al.*, 2013). The trends in small ruminant production and purpose and sex-based dataset were analyzed using Kendall R packages of R-4.3.3 version. This package has useful functions for data visualization and analysis. The Mann-Kendall trend test and p-value at 95 % Confidence Interval (CI) on population growth purpose and sex-based data for annual time series from 2004 to 2022 was performed/computed using R Studio and R Programming software. The Mann-Kendall test is a frequently utilized non-parametric test for annual time series data to determine the trend (Chisang et al., 2024; Butler and Vance, 2022; Akinbile et al., 2015). The annual trend and its statistical significance were calculated using the trend R package (McLeod, 2005; Pohlert, 2016). The Sen's slope function in trend R package was used to calculate the slope of the trend (increase/decrease per year) while the MK test function (Mann-Kendall test) was used to verify if the trend is statistically significant or if it is the result of the variability within the population growth and Purpose and sex based (Mangiafico, 2016)20. More information on trend analysis is provided by Akinbile et al. (2015), Butler and Vance (2022) and Mcleod (2005). The equation (5), (6), (7) and (8) were used to compute the Mann Kendall's test statistic, the sign function, the variance of S and ZMK (approximates the standard normal distribution) respectively. The Mann-Kendall's test statistic is given as:

$$S = \sum_{i=1}^{N-1} * \sum_{j=i+1}^{N} sgn\left(x_j - x_i\right) \text{equation} \quad (5)$$

Where S is Mann-Kendall's test statistics; x_i and x_j are the sequential data values of the time series in the years *i* and *j* (*j* >*i);* and *N* is the length of the time series. A positive *S* value indicates an increasing trend, and a negative value indicates a decreasing trend in the data series. The sign function is given as

(6)

$$sgn\left(x_j - x_x\right) = \begin{cases} +1 \; if & \left(x_j - x_i\right) > 0 \\ 0 \; if & = 0 \\ -1 \; if & < 1 \end{cases} \text{equation}$$

The variance of *S* for the situation where there may be ties (i.e., equal values) in the *x* values is:

$$\text{var}(S) = \frac{1}{18}\left[N(N-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)\right] \text{equation} \quad (7)$$

Where *m* is the number of tied groups in the data set and t_i is the number of data points in the i^{th} tied group. For n larger than 10, Z_{MK} approximates the standard normal distribution (Partal and Kahya, 2006; Yenigun*et al*., 2008) and is computed as follows:

$$\begin{cases} \frac{S-1}{\sqrt{var(S)}} & if S > 0 \\ 0 & if \; S = 0 \\ \frac{S+1}{\sqrt{var(S)}} & if \; S < 0 \end{cases} \quad \text{Equation (8)}$$

The presence of a significant trend is evaluated using the Z_{MK} value. The null hypothesis Ho should be accepted in a two-sided trend test if Z MK Z1- $\alpha/2$ at a given level of significance. The critical value of ZMK in the standard normal table is Z1- $\alpha/2$.

National Trends of Small Ruminant Populations

Trend of Small ruminant (Shoat) Population in Ethiopia was presented in table 1**.** The trend analysis of small ruminant populations in Ethiopia from 2006 to 2022 indicates a sustained increase in both sheep and goat numbers, highlighting the growing importance of these species in the

national livestock sector. Sheep populations increased steadily from approximately 20 million in 2006 to a peak of over 42 million by 2021, followed by a slight decline in 2022. Similarly, goat populations exhibited a more marked growth trajectory, rising from about 16 million in 2006 to over 52 million in 2021 before decreasing marginally in 2022. Throughout the period, goats consistently outnumbered sheep from around 2014 onward, suggesting a shift in production preference or adaptive advantage. The faster growth rate observed in goats may be attributed to their higher tolerance to feed scarcity, drought, and harsh environmental conditions, which are increasingly prevalent in many parts of Ethiopia. Goats' browsing behavior and greater reproductive efficiency likely contribute to their rapid population expansion compared to sheep. The steady rise in both populations between 2006 and 2019 reflects increased demand for small ruminants due to population growth, urbanization, and export market expansion, particularly for live animals and meat. The sharp increase observed between 2019 and 2021 may also be associated with improved livestock development programs, disease control efforts, and favorable market incentives during that period. The slight decline in both sheep and goat populations in 2022 could be linked to external stressors such as recurrent droughts, feed shortages, conflict-related disruptions, or disease outbreaks, which negatively affect livestock survival and productivity. This fluctuation underscores the vulnerability of small ruminant production systems to climatic and socio-economic shocks.

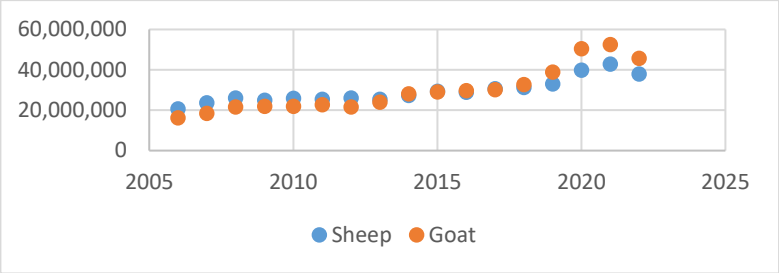

Table 1: Trends of Small ruminant (shoat) Population in Ethiopia from 2006-2022

Spatiotemporal Distribution of Sheep Population by Region

The distribution of sheep populations across Ethiopian regions from 2004 to 2022 is presented in Table 2. The regional distribution of sheep in Ethiopia from 2004 to 2022 showed pronounced spatial and temporal variation. Oromia and Amhara consistently accounted for the largest share of the national sheep population throughout the study period. In Oromia, sheep numbers increased from 6.0 million heads in 2004 to 9.8 million in 2019**,** before slightly declining to 9.3 million in 2022, while Amhara rose from 6.1 million to a peak of 11.1 million in 2018, remaining high at 10.3 million in 2022. Pastoral regions exhibited substantial growth, particularly Somali**,** where sheep numbers expanded sharply from 0.5 million in 2004 to over 11.0 million in 2021, and Afar, which increased from 0.2 million to 4.5 million in 2021, highlighting the importance of sheep in pastoral and agro-pastoral systems. The SNNP region showed moderate but steady growth, ranging from 3.0 to 5.2 million, reflecting mixed crop–livestock production systems. In contrast, Benishangul-Gumuz**,** Sidama**,** Harari and Dire Dawa consistently recorded relatively low sheep populations. Overall, these patterns emphasize the dominant role of mixed and pastoral production systems in shaping regional sheep distribution in Ethiopia.

Year	Tigray	Afar	Amhara	Oromia	Somale	Benishangul-Gumuz	Sidama	SNNP	Gambella	Harari	Dire Dawa
2004	653	239	6,116	5,970	460	58	315	3,008	NA	4	52
2005	726	2,090	6,391	6,905	463	66	316	3,270	NA	3	46
2006	814	157	7,531	8,085	594	69	390	3,403	NA	5	54
2007	973	248	8,236	9,265	715	89	453	4,030	NA	4	49
2008	1,388	353	9,470	9,402	1,306	85	430	4,000	48	5	60
2009	1,377	403	8,988	9,098	1,163	84	457	3,839	18	4	43
2010	1,150	604	8,597	9,453	1,067	89	437	4,935	26	5	55
2011	1,255	990	8,680	8,815	1,054	106	378	4,497	40	6	66
2012	1,388	353	8,228	8,619	1,135	98	433	3,866	51	5	56
2013	1,382	916	8,825	8,749	1,282	93	430	4,118	50	6	68
2014	1,482	1,475	8,518	9,494	1,421	84	436	4,749	45	8	73
2015	1,817	1,666	10,024	9,716	1,296	105	455	4,580	35	6	87
2016	1,638	1,732	9,797	9,487	1,308	98	531	4,704	44	9	75
2017	2,042	1,729	10,736	9,866	1,022	100	520	5,087	44	7	64
2018	2,473	2,082	11,086	9,394	1,361	160	NA	4,640	35	7	64
2019	2,283	4,475	9,651	9,776	1,361	144	NA	5,214	41	6	70
2020	2,098	4,040	10,386	9,260	9,188	72	476	4,736	44	4	65
2021	2,098	4,476	10,392	9,752	11,013	61	468	4,562	28	5	59
2022	NA	3,626	10,267	9,295	10,557	34	470	3,675	34	5	50

NA=Not available

Table 2: Distribution of total sheep Population by Region in Ethiopia (2004–2022, in Thousands)

Spatiotemporal Distribution of Goat Population by Region

The distribution of goat populations across Ethiopian regions from 2004 to 2022 is presented in Table 3. Oromia consistently accounted for the largest share, increasing from 4.1 million heads in 2004 to 9.1 million in 2019, before declining to **7.**6 million in 2022**,** while Amhara followed a similar trend, rising from 4.0 million to **7.**8 million in 2018 and recording 6.8 million in 2022**.** Marked growth was observed in pastoral regions, particularly Somali, where goat numbers increased from 0.6 million to over 17.0 million in 2020 and remained high (16.5 million in 2022**),** and Afar, which expanded from 0.4 million to nearly 10.0 million in 2019**.** SNNP showed steady growth **(**2.3–5.9 million**),** whereas Benishangul-Gumuz**,** Sidama**,** Harari**,** and Dire Dawa maintained comparatively low populations. These trends highlight the increasing importance of goats in pastoral and mixed production systems.

Year	Oromia	Amhara	Tigray	Afar	Somale	Benishangul-Gumuz	Sidama	SNNP	Gambella	Harari	Dire Dawa
2004	4,081	3,969	2,035	438	607	219	175	2,318	NA	26	132
2005	4,849	4,102	2,090	484	651	245	177	2,290	NA	27	119
2006	5,384	4,856	2,400	411	669	314	193	2,054	NA	33	124
2007	5,787	5,141	2,752	628	1,062	339	196	2,539	NA	34	137
2008	7,686	5,469	3,005	600	1,703	372	153	2,625	55	41	155
2009	7,440	6,022	3,108	801	1,375	322	229	2,627	32	36	122
2010	7,346	4,878	2,621	961	1,509	336	235	4,057	38	41	173
2011	7,531	5,176	3,049	1,775	1,411	446	299	3,087	84	45	181
2012	7,227	5,189	3,005	600	1,365	454	253	3,506	80	42	161
2013	7,555	5,103	3,191	1,936	1,639	412	236	3,912	84	51	179
2014	8,151	5,292	4,000	2,984	2,033	417	265	4,954	90	58	184
2015	7,850	6,065	4,255	3,149	1,904	441	267	5,093	89	58	210
2016	8,378	6,086	3,948	3,301	1,836	449	301	5,343	94	68	203
2017	8,130	6,439	4,584	3,461	1,520	431	339	5,258	99	73	206
2018	8,591	7,767	4,301	3,265	2,826	603	337	4,958	107	70	249
2019	9,083	6,806	4,233	9,975	2,826	524	325	5,116	133	81	186
2020	7,527	6,883	4,839	8,531	17,002	404	323	4,820	134	104	259
2021	8,426	7,045	4,839	8,843	16,465	446	309	5,519	135	110	326
2022	7,555	6,808	NA	7,628	16,506	342	486	5,944	117	105	225

Table 3: Number of Goats Population by Region in Ethiopia (2004–2022, in Thousands)

NA=Not available

Regional Trend Analysis of Sheep Population

The trend analysis indicates that Ethiopia's sheep population has generally increased over time, with statistically significant growth observed in most regions. Using the Mann–Kendall test at a significance level of $\alpha = 0.05$, the results show that in Oromia, the sheep population (in millions) showed a significant ($p = 0.005$), with Sen's slope indicating an average increase of about 75,632 sheep over the study period (2004-2022). In Amhara region, In the Amhara and the sheep population showed a significant ($P = 0.000$) increasing trend by Sen's slope of 205,574, with the largest growth rate among all regions, suggesting rapid expansion of sheep production for 2004-2024.

Similarly, for the years of 2004-2024 in Tigray and Somale regions sheep population showed highly significant increasing trends ($p = 0.000$ for both), with strong positive Kendall's τ values and Sen's slope estimates of 85,358 and 84,900 sheep, respectively. In Sidama also exhibited a significant upward trend ($p = 0.001$), although the magnitude of increase was relatively smaller (Sen's slope = 7,196), while in SNNP sheep population showed a significant increase ($p = 0.006$) with a Sen's slope of 88,983 sheep. In the smaller administrative regions, Harar ($p = 0.021$) and Dire Dawa ($p = 0.042$) both demonstrated statistically significant increasing trends, though with modest growth rates. In Afar sheep population showed a highly significant increasing ($p = 0.000$), with a large Sen's slope of 184,785, consistent with its pastoral production system where sheep are a key livelihood asset. In contrast, in Benishangul-Gumuz sheep population showed a statistically non-significant trend ($p = 0.21$), indicating that changes in sheep population there may be irregular or influenced by localized factors. Overall, the results reveal that nine out of ten regions show significant positive trends, confirming that sheep populations in Ethiopia are increasing over time. This national-level increase may be attributed to rising demand for small ruminants, the adaptability of sheep to diverse agro-ecological zones, improved animal health and extension services and increased farmer awareness, trends that are consistent with reports by the Central Statistical Agency (CSA) and supported by livestock development research in Ethiopia.

Variable	Zmk	MK Statistic (S)	Kendall's τ	p-value	Alpha (α)	Sens's slope	Trend
Oromia	2.79	81	0.47	0.005	0.05	75632	Increase
Amhara	3.85	111	0.65	0.000	0.05	205574	Increase
Tigray	4.69	135	0.79	0.000	0.05	85358	Increase
Somale	4.24	122	0.72	0.000	0.05	84900	Increase
Benishangul-Gumuz	1.26	37	0.22	0.21	0.05	1861	Increase

Sidama	3.29	95	0.56	0.001	0.05	7196	Increase
SNNP	2.73	79	0.46	0.006	0.05	88983	Increase
Harar	2.31	67	0.39	0.021	0.05	167	Increase
Dire Daw	2.03	59	0.35	0.042	0.05	1042	Increase
Afar	4.31	124	0.73	0.000	0.05	184785	Increase

Regional Trend Analysis of Goat Population

The trend analysis shows (table 5) that Ethiopia's goat population has increased significantly over time**,** with all regions exhibiting statistically significant upward trends at the 5% significance level ($\alpha = 0.05$). In Oromia**,** goat population is highly significant increasing trend ($p = 0.000$), with a strong positive Kendall's τ (0.64) and a Sen's slope of 178,505, implying a substantial rise in goat numbers over the period (2004-2022). In Amhara region also experienced a highly significant increase ($p = 0.000$), supported by a very strong Kendall's τ (0.77) and a Sen's slope of 161,989, reflecting rapid growth in goat population. Similarly, in Tigray region goat population showed a highly significant upward trend ($p = 0.000$), with one of the strongest associations ($\tau = 0.83$) and a Sen's slope of 165,798, indicating consistent and pronounced growth. In Somale region, the goat population increased significantly as well ($p = 0.000$), with a strong positive trend ($\tau = 0.77$) and a Sen's slope of 156,228, which aligns with the region's pastoral livelihood system where goats play a central role.

In Benishangul-Gumuz**,** although the magnitude of increase was relatively smaller compared to major regions, the trend was still statistically significant ($p = 0.003 < 0.05$), with a moderate positive Kendall's τ (0.51) and a Sen's slope of 12,609, indicating steady growth. In Sidama also exhibited a highly significant increasing trend ($p = 0.000$), with a strong Kendall's τ (0.78), though the Sen's slope **(**10,449**)** suggests a more modest rate of increase. In SNNP goat population showed the strongest and most substantial increases ($p = 0.000$), with a Kendall's τ of 0.79 and a large Sen's slope of 214,953, highlighting its importance as a major goat-producing region. Also, in Harar and Dire Dawa region**,** goat population showed highly significant increasing trends ($p = 0.000$ for both), with very strong Kendall's τ values (0.94 and 0.79, respectively), although the absolute magnitude of increase was comparatively low due to their smaller geographic size. In Afar region goat population exhibited a highly significant and robust upward trend ($p = 0.000$), with a strong Kendall's τ (0.83) and the largest Sen's slope of 336,624, underscoring the importance of goats in the pastoral production system of the region.

Overall, the results clearly indicate that goat populations have increased significantly across all regions of Ethiopia**,** demonstrating a strong national-level upward trend. This widespread growth may be attributed to the adaptability of goats to diverse and harsh agro-ecological conditions, increasing market demand for goat meat and live animals, improved animal health and extension services, and the resilience of goat production systems, particularly in arid and semi-arid areas. The consistent significance across regions confirms that goat production is expanding throughout the country and continues to play a crucial role in Ethiopia's livestock sector and rural livelihoods

Variable	Zmk	MK Statistic	Kendall's τ	p-value	Alpha (α)	Sens's slope	Trend
Oromia	3.78	109	0.64	0.000	0.05	178505	Increase
Amhara	4.55	131	0.77	0.000	0.05	161989	Increase
Tigray	4.9	141	0.83	0.000	0.05	165798	Increase
Somale	4.59	132	0.77	0.000	0.05	156228	Increase
Benishangul-Gumuz	3.01	87	0.51	0.003	0.05	12609	Increase
Sidama	4.62	133	0.78	0.000	0.05	10449	Increase
SNNP	4.69	135	0.79	0.000	0.05	214953	Increase
Harar	5.59	161	0.94	0.000	0.05	4383	Increase
Dire Daw	4.69	135	0.79	0.000	0.05	7631	Increase
Afar	4.94	142	0.83	0.000	0.05	336624	Increase

Purpose and Sex Based Trends of Sheep Population

The trend analysis **of** sheep population by purpose and sex in Ethiopia tells clear differences in growth patterns between male and female sheep uses, based on the Mann–Kendall test at a significance level of $\alpha = 0.05$. For male sheep, all major purposes show statistically significant increasing trends. Male sheep kept for mutton/meat showed a highly significant upward trend ($p = 0.000$), with a strong Kendall's τ (0.75) and a Sen's slope of 33,254, indicating a substantial increase over time, likely driven by growing domestic and export demand for meat. Similarly, male sheep used for wool production show a significant increasing trend ($p = 0.001$), though with a comparatively smaller Sen's slope (819.2**),** reflecting limited but consistent growth in wool-oriented management. The strongest increase among males is observed in breeding purposes**,** where the trend is highly significant ($p = 0.000$), supported by a very strong Kendall's τ (0.79) and a large Sen's slope (65,317.5), suggesting increased emphasis on genetic improvement and flock expansion. Male sheep categorized under other purposes also demonstrate a significant increasing trend ($p = 0.000$), with moderate growth, indicating diversified uses over time. For female sheep, the trends vary by purpose. Female sheep kept for mutton/meat show a statistically significant increasing trend ($p = 0.007$), although the magnitude of increase is relatively small (Sen's slope = 2,366.5), reflecting the traditional preference to retain females for reproduction rather than slaughter. In contrast, female sheep used for wool production show no statistically significant trend ($p = 0.967 > 0.05$), with a near-zero Kendall's τ (0.01), indicating that wool production from female sheep has remained largely stable over time without systematic growth. Female sheep used for breeding purposes exhibit a highly significant and very strong increasing trend ($p = 0.001$), with a large Kendall's τ (0.72) and an exceptionally high Sen's slope **(**457,310.5**)**, underscoring the central role of females in flock reproduction and population growth. Additionally, female sheep categorized under other purposes show a significant increasing trend ($p = 0.002$), with moderate growth, suggesting expanding multifunctional use.

Overall, these results indicate that sheep population growth in Ethiopia is strongly driven by breeding purposes**,** particularly among females, while male sheep contribute more to meat and diversified uses**.** This pattern aligns well with traditional small ruminant production systems in Ethiopia, where females are predominantly retained for reproduction and herd replacement, and males are more frequently marketed for meat. Similar findings have been reported by the Central Statistical Agency

(CSA) and livestock sector studies, which highlight that increasing demand for small ruminant products, improved breeding practices, and enhanced extension and animal health services have contributed to the expansion and functional differentiation of sheep populations in Ethiopia (CSA, 2021; FAO, 2019). The use of Mann–Kendall and Sen's slope methods for such livestock trend analyses is widely supported in agricultural research due to their robustness and suitability for non-normally distributed time-series data (Hirsch et al., 1982; Kendall, 1975).

	Variable	Zmk	MK Statistic (S)	Kendall's τ	p-value	Alpha (α)	Sens's slope	Trend
Male	Mutton/Meat	4.48	129	0.75	.0.00	0.05	33254	Increase
	Wool	3.13	77	0.57	0.001	0.05	819.2	Increase
	Breeding	4.69	135	0.79	0.000	0.05	65317	Increase
	Others purposes	3.64	105	0.61	0.000	0.05	3044	Increase
Female	Mutton/Meat	2.68	66	0.49	0.007	0.05	2366	Increase
	Wool	0.04	2	0.01	0.967	0.05	50.1	Increase
	Breeding	3.99	98	0.72	0.001	0.05	457310	Increase
	Others purposes	3.09	76	0.56	0.002	0.05	3529	Increase

Table 6: Mann-Kendall Trend Analysis and Sen's Slope of Sheep Products by Sex and Purpose

Purpose and Sex Based Trends of Goat Population

The analysis of goat population trends by purpose and sex in Ethiopia revealed an overall increasing pattern, although the magnitude and statistical significance varied across categories based on the Mann–Kendall test (α = 0.05). All male goat categories exhibited highly significant upward trends. Male goats used for meat production showed a strong increase (p = 0.000), with a high Kendall's τ (0.69) and a Sen's slope of 32,333.8, indicating a substantial rise in market-oriented offtake. Similarly, male goats kept for breeding purposes demonstrated a very strong and highly significant trend (p = 0.000; τ = 0.88), with a Sen's slope of 100,653.4, suggesting increasing emphasis on herd expansion and genetic improvement. Male goats classified under other purposes also showed a significant upward trend, although with a smaller growth rate, reflecting gradual diversification in goat utilization over time.

Female goat population trends showed greater variation by production purpose. Female goats used for meat production did not exhibit a statistically significant trend (p = 0.649), despite a positive Sen's slope, which is consistent with management practices that prioritize retaining females for reproduction rather than slaughter. In contrast, female goats kept for milk production exhibited a highly significant increasing trend (p = 0.000; τ = 0.82), with a Sen's slope of 123,305, highlighting the growing importance of goat milk for household nutrition and income generation, particularly in arid and semi-arid areas. The strongest increase was observed among breeding females (p = 0.000; τ = 0.94), with a very large Sen's slope (568,197.4), underscoring their central role in herd reproduction and overall population growth. Collectively, these findings indicate that goat population expansion in Ethiopia is primarily driven by breeding and milk-oriented females, while males contribute mainly to meat production, a pattern consistent with traditional goat production systems and the functional specialization observed in small ruminant management. The robustness of the Mann–Kendall test and Sen's slope estimator further supports the reliability of these trends for livestock time-series analysis.

Goats	Variable	Zmk	MK Statistic (S)	Kendall's τ	p-value	Alpha (α)	Sens's slope	Trend
Male	Meat	4.13	119	0.69	0.000	0.05	32333	Increase
	Breeding	5.25	151	0.88	0.000	0.05	100653	Increase
	Others purposes	4.34	125	0.73	0.000	0.05	4746	Increase
Female	Meat	0.46	14	0.08	0.649	0.05	807.1	Increase
	Milk	4.89	141	0.82	0.000	0.05	123305	Increase
	Breeding	5.59	161	0.94	0.000	0.05	568197	Increase
	Others purposes	2.59	75	0.44	0.010	0.05	2191.6	Increase

Table 7: Mann-Kendall Trend Analysis and Sen's Slope of goats Products by Sex and Purpose

Conclusion

This study provides a comprehensive assessment of spatiotemporal trends and purpose-based dynamics of sheep and goat populations in Ethiopia from 2004 to 2022. The findings clearly demonstrate that small ruminant populations have increased significantly over time, with goats showing a more pronounced growth trajectory than sheep. The expansion is widespread across regions, although the magnitude and significance of trends vary spatially, reflecting differences in agro-ecological conditions, production systems, and livelihood strategies. Pastoral and agro-pastoral regions such as Afar and Somali exhibited particularly strong growth, underscoring the critical role of sheep and goats in arid and semi-arid environments. Purpose and sex-based analyses revealed that population growth is primarily driven by breeding females, while males contribute mainly to meat production. In goats, the strong upward trends in female breeding and milk purposes highlight the increasing importance of goat milk for household nutrition and income generation. Conversely, relatively weaker or non-significant trends in some female meat and wool categories reflect traditional management practices that prioritize reproductive functions. Overall, the results confirm that Ethiopia's small ruminant sector is expanding but remains highly heterogeneous across regions and production objectives. While this growth presents opportunities for improving food security, income, and export earnings, it also underscores the need for context-specific development strategies

that address regional constraints, climate vulnerability, and productivity gaps. The application of robust non-parametric trend analysis strengthens the reliability of these conclusions and provides an empirical basis for informed livestock policy and planning.

Recommendation

Based on these findings, it is recommended that region-specific breeding programs be enhanced, extension and veterinary services be strengthened, and market linkages for meat, milk, and live animals be developed. Additionally, diversification into secondary products such as wool and milk, support for women farmers, and integration with sustainable rangeland management are critical for optimizing productivity, ensuring environmental sustainability, and enhancing the contribution of small ruminants to Ethiopia's food security and rural economy.

Conflict of interest

The authors declare that they have no conflict of interest.

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