SUBJECT II
SUSTAINING LIVELIHOODS: THE ROLE OF LIVESTOCK, POULTRY
AND FISHERIES IN RURAL ECONOMY

Assessing Sustainability of Livestock Sector in India

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ABSTRACT

The paper evaluates the sustainability of livestock production across 28 states and 9 Union Territories during the periods covered by the 2012 and 2019 livestock censuses. The study uses a three-pillar economic, ecological, and social sustainability model to develop the Sustainable Livestock Production Index (SLPI). The results indicate an overall improvement in sustainability across India, although ecological sustainability has declined in some hilly regions, primarily due to environmental degradation and reduced forest cover. The study also reveals a reduction in the cattle population and disparities in veterinary institutions in regions known for milk production, which has negatively impacted economic sustainability. The research highlights the need for region-specific strategies to address these issues, providing policymakers with a valuable tool to create action plans that improve sustainability in the livestock sector. The findings underscore the importance of balancing economic growth with ecological conservation to ensure the sector's long-term sustainability, particularly in India's growing livestock population and evolving agricultural practices.

Keywords: Sustainable Livestock Production, Sustainability Index, Livestock census, sustainability

JEL codes: Q11, Q13, Q16, Q18

I

INTRODUCTION

India is an agrarian nation where a significant portion of the population relies on agriculture for their livelihood. India has the world's largest livestock population, i.e., 536.76 million, and India's share of the world's total cattle, buffalo, goat, and sheep is 13.80, 54.38, 13.42, and 5.99 per cent, respectively. Livestock production and agriculture are mutually interdependent and essential for ensuring the country's food security. The livestock sector is a vital livelihood activity for a large rural population. As per the Situation Assessment Survey (NSSO 77th round), small and marginal farmers hold nearly 72 per cent of the total bovines (NSO, 2019). It supplies inputs for agriculture, enhances household health and nutrition, offers supplemental income, and creates employment opportunities, making it both a supplementary and complementary enterprise (GoI, 2023).

According to the periodic labour force survey conducted from July 2022 to June 2023, an estimated 5.34 per cent of workers in usual status (principal status+ subsidiary status) were engaged in animal production, while 3.63 per cent were involved in mixed farming (NSSO, 2023). Between 2014-15 and 2020-21, the livestock sector achieved a compound annual growth rate (CAGR) of 7.9 per cent (at constant

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prices). Its share of total agriculture GVA (at constant prices) rose from 24.3 per cent in 2014 to 30.1 per cent in 2021 (GoI, 2023)

The livestock sector's contribution to the total agriculture value of output increased from 14 per cent in the TE 1992-93 to 33 per cent in the TE 2018-19 (Gulati and Juneja, 2022). This shift indicates a growing economic significance of livestock rearing, reflecting its transition towards a more market-oriented activity. This trend raises serious doubts about sustainable livestock production by increasing productivity and using resources more efficiently. With increased livestock production, negative consequences include sustainability of production and productivity, climate change, and degradation of natural resources. For further development of the livestock sector, it is necessary to focus more on animal productivity.

The concept of sustainability emerged from the Brundtland Report. Sustainable development is described as development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs." This definition was broadened at the 1992 Earth Summit and was fully established at the Johannesburg Conference in 2002, emphasizing the three pillars of sustainability: social, environmental, and economic (Moldan *et al.,* 2012).

Sustainability indicators and composite indices have become increasingly popular (Singh *et al.,* 2012). This study sought to evaluate the sustainability of the livestock sector through the Sustainable Livestock Sector Index (SLSI), which integrates the economic, ecological, and social dimensions of livestock production in line with the three pillars of sustainability.

II

METHODOLOGY

The study encompasses 28 states and 9 Union Territories of India, divided into seven distinct zones as outlined below:

Name of zones	States and Union Territories
Northern zone	Haryana, Himachal Pradesh, Punjab, and Rajasthan
North-eastern zone	Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland Tripura and Sikkim
Central zone	Chhattisgarh, Madhya Pradesh, Uttarakhand and Uttar Pradesh
Eastern zone	Bihar, Jharkhand, Odisha, and West Bengal
Western zone	Goa, Gujarat, and Maharashtra
Southern zone	Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, and Telangana
Union Territory	Chandigarh, Delhi, Jammu and Kashmir, Ladakh, Dadra and Nagar Haveli, Daman and Diu, Puducherry, Andaman and Nicobar Islands and Lakshadweep

Selected indicators were defined and discussed under each of the three pillars of sustainability—Economic, Ecological, and Social—for all Indian States. Defining and discussing these indicators became essential for thoroughly understanding each pillar. However, due to limited data availability and challenges in quantification, the

indicators discussed were carefully chosen. The study incorporated data from two livestock censuses: the 19th in 2012 and the 20th in 2019.

2.1 Economic Sustainability

Livestock population, livestock production, per capita availability of livestock products, veterinary institution, productive livestock, and value of output were considered for estimating the economic sustainability of livestock production. The livestock population data included cattle, buffalo, sheep, and goats. For livestock production, the study considered milk, meat, and wool production. Additionally, the per capita availability of livestock products was calculated using population data. Veterinary institutions encompassed veterinary hospitals, dispensaries, and aid centres nationwide. The value of output covered the worth of straw and stalks, as well as green and dry fodder. All these parameters indicate the economic viability of livestock production and its positive influence on economic sustainability.

2.2 Social Sustainability

Rural population and female literacy were considered to estimate the social sustainability of livestock production. Given the interdependence between livestock and agriculture, livestock farming is predominantly concentrated in rural areas. This is why the rural population is considered a key indicator of social sustainability. Additionally, women play a crucial role in the care, management, processing, and marketing of livestock products, making female literacy a vital indicator.

2.3 Ecological Sustainability

Livestock density and forest cover were considered for estimating the ecological sustainability of livestock production. Forest cover, which provides grazing land, is included in the index. However, high livestock population density can result in the overuse of common property resources, negatively affecting ecological sustainability.

2.4 Index Development

Methodology for index development was adopted from several studies carried out in the past (Iyengar and Sudarshan, 1982; Chand *et al.*, 2011; Chand and Sirohi, 2012; Subash and Kaur, 2017). The Sustainable Livestock Production Index (SLPI) was constructed using eight indicators. The SLPI can be considered a broader application of the relative method employed in formulating the Human Development Index by UNDP.

$$I_{ijk} = \frac{X_{ijk} - Min\ X_{ijk}}{Max\ X_{ijk} - Min\ X_{ijk}} \text{ for a positive association with SLPI} \qquad \dots (1)$$

$$I_{ijk} = \frac{Max\ X_{ijk} - X_{ijk}}{Max\ X_{ijk} - Min\ X_{ijk}} \text{ for a negative association with SLPI} \qquad \dots (2)$$

Where, X_{ijk} is the value of ith variable representing j^{th} component of SLPI of kth State

The calculated I_{ijk} for each component (eight in our study) was used to calculate the Economic Efficiency index (EEI), Social Equity Index (SEI), and Ecological Security Index (ESI) as the simple mean of respective indices:

$$EEI = \frac{\sum_{i-1}^{4} I_{ijk}}{4} \qquad \dots (3)$$

$$SEI = \frac{\sum_{i-1}^{2} I_{ijk}}{2} \qquad \dots (4)$$

$$ESI = \frac{\sum_{i-1}^{2} I_{ijk}}{2} \qquad \dots (5)$$

The SLPI for the state and the zone was calculated as a weighted mean of the indices obtained from the above equation, i.e.,

$$SLPI_k = \frac{W_1 EEI_k + W_2 ESI_k + W_3 SEI_k}{3} \qquad \dots (6)$$

Where 'W' denotes the weight assigned to the respective component of the SLPI and is calculated as the ratio of the inverse of the proportional contribution of EEI, SEI, and ESI to the sum of all the three inverse proportions.

2.5 Categorisation of the Sustainability Indices

A simple ranking of the sustainability score could give a spatial comparison to understand the extent of sustainability categorization into different levels of sustainability using probability distribution (Iyengar and Sudarshan, 1982). One such distribution that is widely used is beta distribution. The probability density function of this distribution is given by:

$$f(z) = \frac{z^{a-1}(1-z)^{b-1}}{\beta(,b)} \qquad \dots (7)$$

Where $0<z<1$ and a, b>0. β (a, b) is beta function defined by

$$\beta(a,b) = \int_0^1 x^{a-1}(1-x)^{b-1} dx \qquad \dots (8)$$

Then distribution was divided into linear intervals (0,z1), (z1,z2),(z2,z3), (z3,z4) and (z4,1). These intervals have been used in this study to characterise the various level of sustainability as given below:

1	Least sustainable	if	$0 < X_{ijk} < z1$
2	Low sustainable	if	$z1 < X_{ijk} < z2$
3	Medium sustain	if	$z2 < X_{ijk} < z3$
4	High sustainable	if	$z3 < X_{ijk} < z4$
5	Higher sustainable	if	$z4 < X_{ijk} < 1$

Where, X_{ijk} is estimated ESI, EEI, SEI, and SLPI values

TABLE 1. DEFINITION OF DIFFERENT DIMENSIONS OF SUSTAINABILITY INDICES

Sustainability (1)	Indicators (2)	Definition (3)	Functional Relationship (4)	Source (5)
1.0 Economic	Livestock Population	Total Population of Cattle, Buffaloes, Sheep and Goats	Positive	19th and 20th Livestock Census
	Livestock Production	Total Milk Production (Cattle, Buffaloes, Goat), Meat Production (Goar and Sheep), Wool Production (Sheep)	Positive	Basic Animal Husbandry Statistics-2012, 2019
	Productive Livestock	Total In Milch Animals (Exotic and Indigenous Cattle, Buffaloes)	Positive	19th and 20th Livestock Census
	Veterinary Institutions	Total number of Veterinary Hospitals, Dispensaries, Aid Centres	Positive	Annual Reports-2012, 2019, DAH&D.
	Value of Output	Total Value of Grass, Fodder, Straw and Stalks	Positive	State-wide value of output from agriculture, NSO-2022
2.0 Social	Per Capita Availability	Per capita availability of Milk, Wool and Meat	Positive	Census of India, 2011 & Report of Technical Group on Population Projections,2020
	Rural Population	Rural Population in total population	Positive	
	Female Literacy	Percentage of literate female	Positive	Census of India, 2011 & NSO 75th Round, 2020.
3.0 Ecological	Livestock Density	Per square km Livestock population (Cattle, Buffaloes, Sheep and Goats)	Negative	State of Forest Report-2013, 2019
	Forest Cover	Square km forest area to the total geographical area	Positive	

III

RESULTS AND DISCUSSION

3.1 Livestock Production Sustainability Across Different Zones of India

The values of the Sustainable Livestock Production Index (SLPI), along with its three dimensions (Economic, Ecological, and Social) for different zones of the country, are presented in Table 2. Economic sustainability has decreased since 2012, with the mean index value dropping from 0.287 to 0.269 between the two census periods. The coefficient of variation (C.V.) increased from 44.37 per cent in 2012 to

45.23 per cent in 2019, indicating greater interregional variation. The highest economic sustainability was observed in the northern zone, while the lowest was in the northeastern zone.

TABLE 2. SUSTAINABILITY OF LIVESTOCK SECTOR IN DIFFERENT ZONES OF INDIA

Zone	EEI		ESI		SSI		SLPI	
	2012	2019	2012	2019	2012	2019	2012	2019
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. North	0.468	0.449	0.317	0.434	0.536	0.652	0.317	0.495
2. North-eastern	0.028	0.029	0.539	0.585	0.63	0.58	0.064	0.079
3. Eastern	0.236	0.227	0.267	0.396	0.515	0.643	0.297	0.354
4. Central	0.362	0.356	0.558	0.644	0.489	0.632	0.323	0.505
5. Western	0.309	0.296	0.509	0.435	0.467	0.51	0.318	0.393
6. Southern	0.351	0.306	0.478	0.574	0.49	0.492	0.326	0.426
7. UTs	0.256	0.221	0.629	0.662	0.31	0.293	0.288	0.318
Mean	0.287	0.269	0.471	0.533	0.491	0.543	0.276	0.367
C.V. (%)	44.37	45.23	25.88	18.97	18.10	21.71	31.71	36.41

Ecological sustainability improved in all zones, with the mean value rising from 0.471 in 2012 to 0.533 in 2019. The C.V. value indicates less interregional variation compared to the economic sustainability index. Similarly, social sustainability showed improvement in almost all regions, with the mean index value increasing from 0.491 in 2012 to 0.543 in 2019.

The SLPI values for all zones exhibited greater variation in 2019 compared to 2012, with the coefficient of variation (C.V.) increasing to 36.41 per cent in 2019 from 31.71 per cent in 2012. The mean SLPI value for all zones also rose from 0.276 in 2012 to 0.367 in 2019. In 2012, the southern zone had the highest sustainability in livestock production, but by 2019, the northern zone had surpassed the southern zone, driven by social and ecological sustainability improvements.

3.2 Indices Values of Different Dimensions for Economic Sustainability Index

The Economic Sustainability Index (EEI) comprises six distinct dimensions, and the indices values for all these dimensions for all the Indian states and seven zones that encompass these states are presented in Table 3. The index values of livestock population for the North, North-eastern zones, and Union Territories (U.T.) decreased between two livestock censuses, with the decline particularly notable in the North zone of India. Livestock populations have demonstrated improvement across all other zones, with a noteworthy increase observed in the Eastern zone (rising from 0.370 to 0.420 in 2019). Livestock production results varied across the regions. The North, North-eastern, and Eastern zones have maintained their production levels, while the Western, Union Territory, and Southern zones have experienced a significant decline between 2012 and 2019. The Central zone stands out as the sole region in the country to have achieved an increase in livestock production during this period.

TABLE 3: INDEX VALUES OF ECONOMIC SUSTAINABILITY INDEX (EEI) AND ITS DIMENSIONS FOR DIFFERENT STATES OF INDIA

Name of Zone and States	Livestock Population		Livestock Production		Per Capita Availability		Veterinary Institution		Productive Livestock		Value of Output		EEI	
	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019
A. North Zone	0.295	0.276	0.446	0.446	0.936	0.920	0.600	0.538	0.221	0.213	0.313	0.302	0.468	0.449
1. Haryana	0.143	0.102	0.311	0.338	0.833	0.906	0.519	0.357	0.153	0.122	0.225	0.199	0.364	0.337
2. H.P.	0.070	0.064	0.099	0.078	0.991	0.830	0.594	0.433	0.057	0.053	0.025	0.022	0.306	0.247
3. Punjab	0.119	0.103	0.373	0.366	0.918	0.946	0.547	0.361	0.175	0.162	0.276	0.266	0.401	0.367
4. Rajasthan	0.850	0.835	1.000	1.000	1.000	1.000	0.741	1.000	0.499	0.512	0.727	0.721	0.803	0.845
B. North-eastern Zone	0.041	0.036	0.006	0.005	0.056	0.063	0.040	0.040	0.019	0.021	0.007	0.008	0.028	0.029
1. Arunachal P.	0.011	0.007	0.001	0.002	0.048	0.118	0.059	0.054	0.004	0.002	0.003	0.003	0.021	0.031
2. Assam	0.259	0.236	0.029	0.024	0.069	0.000	0.103	0.146	0.121	0.143	0.039	0.039	0.093	0.098
3. Manipur	0.005	0.004	0.003	0.002	0.035	0.021	0.023	0.015	0.004	0.002	0.002	0.003	0.012	0.008
4. Meghalaya	0.020	0.021	0.003	0.002	0.043	0.028	0.016	0.021	0.011	0.008	0.004	0.004	0.016	0.014
5. Mizoram	0.000	0.000	0.000	0.000	0.000	0.011	0.013	0.008	0.000	0.000	0.000	0.000	0.002	0.003
6. Nagaland	0.005	0.001	0.004	0.001	0.135	0.032	0.016	0.011	0.003	0.002	0.006	0.006	0.028	0.009
7. Sikkim	0.003	0.003	0.001	0.001	0.135	0.221	0.008	0.007	0.002	0.002	0.000	0.000	0.025	0.039
8. Tripura	0.023	0.016	0.004	0.005	0.045	0.072	0.082	0.058	0.009	0.010	0.004	0.004	0.028	0.028
C. Eastern Zone	0.370	0.420	0.153	0.154	0.095	0.098	0.511	0.345	0.180	0.231	0.111	0.111	0.236	0.227
1. Bihar	0.479	0.535	0.261	0.290	0.122	0.139	0.433	0.339	0.297	0.407	0.179	0.168	0.298	0.313
2. Jharkhand	0.254	0.330	0.066	0.067	0.087	0.087	0.156	0.104	0.100	0.132	0.047	0.048	0.118	0.128
3. Odisha	0.304	0.266	0.066	0.066	0.054	0.061	0.679	0.514	0.114	0.116	0.063	0.061	0.213	0.181
4. West Bengal	0.442	0.547	0.221	0.198	0.116	0.105	0.734	0.422	0.207	0.271	0.154	0.167	0.316	0.285
D. Central Zone	0.456	0.472	0.341	0.364	0.261	0.282	0.454	0.350	0.383	0.394	0.276	0.274	0.362	0.356
1. Chhattisgarh	0.217	0.227	0.046	0.046	0.071	0.075	0.187	0.188	0.083	0.083	0.055	0.053	0.110	0.112
2. M.P.	0.538	0.599	0.331	0.457	0.271	0.396	0.474	0.337	0.394	0.439	0.376	0.373	0.397	0.433
3. U.P.	1.000	1.000	0.922	0.893	0.275	0.265	0.191	0.133	1.000	1.000	0.647	0.645	0.673	0.656
4. Uttarakhand	0.070	0.064	0.067	0.061	0.427	0.392	0.962	0.741	0.056	0.054	0.025	0.023	0.268	0.222
E. Western Zone	0.293	0.295	0.283	0.278	0.249	0.239	0.383	0.276	0.233	0.248	0.414	0.440	0.309	0.296
1. Goa	0.001	0.001	0.002	0.001	0.063	0.034	0.000	0.000	0.001	0.001	0.001	0.000	0.011	0.006
2. Gujarat	0.402	0.397	0.463	0.456	0.496	0.490	0.224	0.219	0.376	0.388	0.241	0.319	0.367	0.378
3. Maharashtra	0.478	0.487	0.385	0.378	0.189	0.194	0.926	0.610	0.324	0.355	1.000	1.000	0.550	0.504
F. Southern Zone	0.403	0.453	0.384	0.329	0.358	0.303	0.657	0.453	0.206	0.201	0.097	0.096	0.351	0.306
1. Andhra Pradesh	0.829	0.984	0.665	0.709	0.511	0.590	1.000	0.681	0.362	0.335	0.177	0.174	0.591	0.579
2. Karnataka	0.407	0.424	0.494	0.287	0.528	0.298	0.781	0.529	0.237	0.224	0.141	0.128	0.431	0.315
3. Kerala	0.039	0.041	0.113	0.077	0.187	0.121	0.211	0.139	0.030	0.032	0.015	0.015	0.099	0.071

Per capita availability depends on both production levels and the human population. In the North zone, the decline in per capita availability was due to a reduction in productive livestock and an increase in the human population in the region over the two periods (GoI, 2020). In contrast, the North-eastern, Eastern, and Central zones experienced increased per capita availability of livestock products alongside increased production. Conversely, the Western, Union Territory, and Southern zones observed a decrease in per capita availability. The veterinary institutions focused on livestock health exhibited inter-regional disparities in infrastructure development, resulting in decreased indices values, apart from the North-eastern zone. The number of productive livestock (milch cattle and buffaloes) has increased in every zone except for the North and Southern zones, which is also evident in the production performance of these regions. The value of output, which included green, dry, straw, and stalks, has decreased in modest amounts in all the zones, barring eastern and U.T.

The economic sustainability index for all regions declined between the two livestock census periods, except for the North-eastern zone. In the North zone, the decline was attributed to decreases in indices values of veterinary institutions, the value of output, livestock population, and productive livestock, which resulted in reduced per capita availability. In the Eastern and Central zones, the decline was primarily due to a reduction in the index values of veterinary institutions. The Western and Southern zones experienced a substantial decline in economic sustainability mainly due to a decrease in indices values of veterinary institutes, production, and production, which also led to the decrease in the availability of livestock products.

The Western and Southern zones experienced a substantial decline in economic sustainability largely due to decreased indices values of veterinary institutions and productive livestock, which also affected livestock production. Economic sustainability in Union Territories declined due to decreased livestock population levels and production, leading to reduced per capita availability.

3.3 Indices Values of Different Dimensions for Social Sustainability Index

The Social Sustainability Index (SSI) comprises two dimensions: the proportion of the rural population relative to the total population and female literacy. The indices of these dimensions, which range from 0 to 1 for all states and zones, are presented in Table 4.

The index values for the rural population increased in the Eastern, Central, Western, and Northern zones between the two census periods. In contrast, for the North-eastern and Southern zones, it decreased. This interregional variation primarily contributed to the rise in index values for some regions. Female literacy is crucial because many women are involved in livestock rearing, and their literacy levels influence their decision-making regarding adopting advanced livestock production methods.

TABLE 4. INDEX VALUE OF SOCIAL SUSTAINABILITY INDEX (SSI) AND ITS DIMENSIONS FOR DIFFERENT STATES OF INDIA

Name of State/Zone	Rural Population		Female Literacy		SSI	
	2012	2019	2012	2019	2012	2019
A. North Zone	0.711	0.722	0.361	0.582	0.536	0.652
1. Haryana	0.572	0.566	0.355	0.590	0.463	0.578
2. H.P.	1.000	1.000	0.601	0.751	0.800	0.875
3. Punjab	0.527	0.556	0.473	0.675	0.500	0.616
4. Rajasthan	0.745	0.767	0.015	0.312	0.380	0.540
B. North-eastern Zone	0.702	0.670	0.557	0.490	0.630	0.580
1. Arunachal P.	0.778	0.786	0.153	0.000	0.465	0.393
2. Assam	0.930	0.929	0.365	0.733	0.647	0.831
3. Manipur	0.670	0.689	0.515	0.382	0.592	0.536
4. Meghalaya	0.828	0.849	0.527	0.395	0.677	0.622
5. Mizoram	0.275	0.355	0.931	0.821	0.603	0.588
6. Nagaland	0.676	0.561	0.606	0.478	0.641	0.520
7. Sikkim	0.739	0.550	0.594	0.465	0.666	0.507
8. Tripura	0.722	0.639	0.769	0.649	0.745	0.644
C. Eastern Zone	0.812	0.817	0.218	0.469	0.515	0.643
1. Bihar	0.979	0.974	0.000	0.343	0.489	0.659
2. Jharkhand	0.759	0.776	0.096	0.431	0.427	0.603
3. Odisha	0.885	0.884	0.308	0.509	0.597	0.697
4. West Bengal	0.624	0.634	0.468	0.592	0.546	0.613
D. Central Zone	0.728	0.739	0.250	0.525	0.489	0.632
1. Chhattisgarh	0.773	0.770	0.214	0.509	0.493	0.640
2. M.P.	0.697	0.730	0.190	0.416	0.443	0.573
3. U.P.	0.789	0.805	0.140	0.397	0.465	0.601
4. Uttarakhand	0.652	0.650	0.456	0.777	0.554	0.713
E. Western Zone	0.312	0.338	0.622	0.682	0.467	0.510
1. Goa	0.102	0.100	0.818	0.701	0.460	0.401
2. Gujarat	0.439	0.463	0.448	0.642	0.444	0.552
3. Maharashtra	0.394	0.453	0.601	0.704	0.497	0.578
F. Southern Zone	0.445	0.414	0.534	0.570	0.490	0.492
1. Andhra Pradesh	0.584	0.571	0.187	0.120	0.386	0.345
2. Karnataka	0.507	0.525	0.409	0.507	0.458	0.516
3. Kerala	0.351	0.172	1.000	1.000	0.676	0.586
4. Tamil Nadu	0.339	0.387	0.539	0.655	0.439	0.521
G. UTs	0.000	0.000	0.620	0.586	0.310	0.293

The Northern, Eastern, and Central zones have seen remarkable improvements in literacy since 2012, while the Southern and Western zones have experienced more modest improvements. On the other hand, the literacy index values have decreased for the North-eastern zones and Union Territories between the two census periods. The Social Sustainability Index for all regions has increased compared to 2012, except for the North-eastern zones and Union Territories, where it has decreased. The decline in sustainability in these areas was attributed to a decline in the female literacy index values.

3.4 Indices Values of Different Dimensions for Ecological Sustainability Index

The Ecological Sustainability Index (ESI) encompasses the Livestock population density and the proportion of forest area to the total geographical area. The index values for both dimensions are shown in Table 5. Livestock population density negatively correlates with ecological sustainability, as a higher livestock density on the

same land area leads to resource depletion. For all zones except the Central zone, the index value of livestock population density increased, indicating a decrease in density per square kilometre. Forest cover, which provides common grazing areas, saw a modest increase in index value across all regions except the North-eastern zone, where it decreased from 0.263 in 2012 to 0.260 in 2019. The ecological sustainability of livestock production has increased across all zones since the last livestock census. The North zone saw the highest level of improvement, with its ESI rising from 0.317 in 2012 to 0.434 in 2019. The Western zone was the only region that experienced a decline in ecological sustainability, attributed to increased livestock population density between the two census periods.

TABLE 5. INDEX VALUES OF ECOLOGICAL SUSTAINABILITY INDEX (SSI) AND ITS DIMENSIONS FOR DIFFERENT STATES OF INDIA

Name of State/Zone	Population density		Forest cover		ESI	
	2012	2019	2012	2019	2012	2019
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. North Zone	0.544	0.771	0.091	0.096	0.317	0.434
1. Haryana	0.366	0.733	0.000	0.000	0.183	0.367
2. H.P.	0.755	0.869	0.172	0.182	0.463	0.525
3. Punjab	0.537	0.764	0.002	0.003	0.270	0.384
4. Rajasthan	0.517	0.719	0.190	0.198	0.354	0.459
B. North-eastern Zone	0.815	0.910	0.263	0.260	0.539	0.585
1. Arunachal P.	0.981	0.995	0.865	0.858	0.923	0.926
2. Assam	0.353	0.651	0.343	0.352	0.348	0.502
3. Manipur	0.955	0.981	0.203	0.201	0.579	0.591
4. Meghalaya	0.823	0.891	0.206	0.204	0.514	0.548
5. Mizoram	1.000	1.000	0.230	0.216	0.615	0.608
6. Nagaland	0.943	0.992	0.154	0.143	0.548	0.568
7. Sikkim	0.902	0.946	0.023	0.023	0.462	0.484
8. Tripura	0.566	0.821	0.084	0.081	0.325	0.451
C. Eastern Zone	0.255	0.486	0.280	0.307	0.267	0.396
1. Bihar	0.000	0.338	0.069	0.075	0.034	0.207
2. Jharkhand	0.376	0.518	0.281	0.290	0.329	0.404
3. Odisha	0.621	0.804	0.622	0.659	0.621	0.732
4. West Bengal	0.021	0.282	0.150	0.202	0.085	0.242
D. Central Zone	0.572	0.742	0.545	0.546	0.558	0.644
1. Chhattisgarh	0.690	0.808	0.711	0.712	0.700	0.760
2. M.P.	0.663	0.777	1.000	1.000	0.831	0.889
3. U.P.	0.187	0.518	0.167	0.174	0.177	0.346
4. Uttarakhand	0.748	0.863	0.301	0.299	0.524	0.581
E. Western Zone	0.743	0.593	0.274	0.277	0.509	0.435
1. Goa	0.927	0.960	0.008	0.008	0.468	0.484
2. Gujarat	0.602	0.000	0.171	0.175	0.387	0.087
3. Maharashtra	0.701	0.820	0.644	0.648	0.673	0.734
F. Southern Zone	0.575	0.722	0.380	0.426	0.478	0.574
1. Andhra Pradesh	0.411	0.586	0.572	0.634	0.491	0.610
2. Karnataka	0.588	0.745	0.455	0.487	0.521	0.616
3. Kerala	0.805	0.880	0.206	0.258	0.506	0.569
4. Tamil Nadu	0.498	0.679	0.289	0.326	0.393	0.503
G. UTs	0.888	0.939	0.370	0.386	0.629	0.662

3.5 Classification of Sustainability Index Values

The sustainability index values were classified into five categories using beta distribution, as presented in Table 6. The economic sustainability of livestock

production remained in the least, low, and medium categories during both census periods. The only notable change was in the southern zone, where it dropped from low in 2012 to least in 2019, indicating a decrease in sustainability.

TABLE 6. CATEGORISATION CLASSES FOR SUSTAINABILITY INDICES

Sustainability Level	EEI	ESI	SSI	SLPI
(1)	(2)	(3)	(4)	(5)
1. Least	0 - 0.312	0 - 0.447	0 - 0.046	0 - 0.108
2. Low	0.312 - 0.438	0.447 - 0.523	0.046 - 0.129	0.108 - 0.196
3. Medium	0.438 - 0.553	0.523 - 0.588	0.129 - 0.250	0.196 - 0.294
4. High	0.553 - 0.681	0.588 - 0.661	0.250 - 0.434	0.294 - 0.426
5. Higher	0.681 - 1.000	0.661 - 1.000	0.434 - 1.000	0.426 - 1.000

Ecological sustainability for all zones was categorized as least, low, or medium, except for the Union Territories, which had a high level of sustainability. The status of ecological sustainability changed for several regions in 2019: the central zone increased to high, the western zone decreased to least, the southern zone moved to medium, and the Union Territories improved to higher. This indicates a decline in ecological sustainability in the western zone. Social sustainability was higher across all zones, except for the Union Territories, where it was high. This condition remained unchanged during the 2019 livestock census.

The Sustainable Livestock Production Index (SLPI) has been categorized for all zones. It was classified as "Least" for the north-eastern zone and "High" for the eastern and western zones during both census periods (Table 7). The northern zone saw an improvement in their SLPI from "High" to "Higher" between the two census periods. Similarly, the central and southern zones improved from "High" in 2012 to "Higher" in 2019. The Union Territories had a "Medium" SLPI level in 2012, which improved to "High" in 2019. This indicates that almost all regions of India were sustainable in their livestock production when assessed with the included indicators. The north-eastern zone's low level of sustainability was due to low economic sustainability, which carries more weight in the SLPI index.

TABLE 7. SUSTAINABILITY LEVEL OF LIVESTOCK SECTOR IN DIFFERENT ZONES OF INDIA

Zone	EEI	ESI	SSI	SLPI
(1)	(2)	(3)	(4)	(5)
		2012		
1. North	Medium	Least	Higher	High
2. North-eastern	Least	Medium	Higher	Least
3. Eastern	Least	Least	Higher	High
4. Central	Low	Medium	Higher	High
5. Western	Least	Low	Higher	High
6. Southern	Low	Low	Higher	High
7. UTs	Least	High	High	Medium
		2019		
1. North	Medium	Least	Higher	Higher
2. North-eastern	Least	Medium	Higher	Least
3. Eastern	Least	Least	Higher	High
4. Central	Low	High	Higher	Higher
5. Western	Least	Least	Higher	High
6. Southern	Least	Medium	Higher	Higher
7. UT	Least	Higher	High	High

IV

CONCLUSIONS

The findings reveal that the sustainability level of livestock production has increased across all zones of India over the years, based on the three-pillar sustainability model. This progress is mainly due to economic and social sustainability improvements across nearly all states and Union Territories. However, a significant concern for policymakers is the decline in ecological sustainability in many states, primarily due to the reduction in forest cover. This problem is particularly pronounced in the north-eastern and hilly regions of North India, where north-eastern states have lost nearly 18 per cent of their forest cover between 2012 and 2019. This concerning trend requires immediate attention from all stakeholders, as ecological degradation has larger repercussions beyond just livestock sustainability.

The overall results are encouraging, but a closer examination raises several concerns. Despite the high overall sustainability in regions such as the western, eastern, southern, and central zones, their economic sustainability has decreased. This decline may be attributed to a decrease in some states' cattle population, insufficient livestock production improvements, and underdeveloped veterinary infrastructure. Addressing these issues could enhance overall sustainability, boost income from livestock rearing, and alleviate farmers' standard of living.

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