Indian Journal of Agricultural Economics 80: 1 (2025): 59-90
DOI:10.63040/25827510.2025.01.003

Leveraging the Livestock Sector to Sustain Livelihoods in Rural India*

B.S. Chandel[1]

ABSTRACT

This paper explores the critical role of the livestock sector in sustaining livelihoods in rural India and emphasizes the need for sustainable livestock production. Livestock farming, which engages over 64% of agricultural households—predominantly small and marginal farmers—contributes significantly to household income, nutritional security, and poverty reduction. In 2022-23, livestock accounted for 30.23% of gross value added (GVA) in India's agriculture and allied sectors, highlighting its economic significance. However, environmental degradation, methane emissions, and inadequate animal welfare pose sustainability concerns. The paper introduces a four-dimensional framework to assess the sustainability of the livestock sector, focusing on livelihood security, meeting nutritional demands, environmental immunity, and animal welfare. Analysis reveals that growth in milk production, a key indicator of livestock productivity, has been driven more by population increase than yield improvements, raising questions about long-term sustainability. Additionally, resource use efficiency remains suboptimal, with labour being overutilized and essential inputs like veterinary care underused. Spatial analysis identifies cropping intensity and livestock income share as significant factors influencing livestock farming adoption across states. The paper also underscores the importance of livestock support services, such as veterinary care and technical knowledge dissemination, in enhancing productivity and profitability. Animal welfare and indigenous breed conservation are crucial for societal acceptability and environmental sustainability. The paper recommends strategies to enhance livestock productivity, reduce environmental impact through methane mitigation, improve resource use efficiency, and strengthen support services. A sustainable livestock sector, driven by higher productivity and responsible practices, is essential for ensuring sustainable livelihoods and addressing future agricultural challenges in India.

Keywords: Sustainable livestock production, rural livelihoods, environmental impact, animal welfare, resource-use efficiency

JEL codes: Q12, Q13, Q16, Q57, O13

I

INTRODUCTION

Targeting livelihoods implies orienting development strategies to have an ultimate impact on people. While development strategies are concerned with creating assets, the livelihood approaches aim to generate regular income from the assets. Chambers and Conway (1991) defined livelihood as the capabilities, assets (including material and social resources), and activities required for living. The five core concepts/ principles identified by DFID (1999) to characterize the livelihoods approach are that it is people-centred, holistic, dynamic, building on strengths, macro- micro links, and sustainability. The concept of sustainability is built into livelihoods. A livelihood is sustainable when it can cope with and recover from stress and shocks and

*Keynote Address delivered at the 84th Annual Conference of the Indian Society of Agricultural Economics (Mumbai) organized by the Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA & RI), Karaikal, Puducherry during November 11-13, 2024.

[1]Former Principal Scientist & Head of the Division, Dairy Economics, Statistics and Management Division, ICAR-National Dairy Research Institute, Karnal, Haryana – 132 001.

simultaneously maintain or enhance its capabilities and assets both now and in the future without undermining the natural resource base (Chambers and Conway, 1991).

The question of sustainable livelihood is more confronted by the resource-poor and poverty-ridden households. The Rangarajan Committee estimated that 29.5 per cent of the population in India was below the poverty line in 2011-12 (GoI, 2014). Using a multi-dimensional approach, there were 14.96 per cent incidences of poverty and 44.39 per cent intensity of poverty in 2019-21, which has reduced by 9.89 and 2.75 points, respectively, from 2015-16 (NITI Aayog, 2023). According to the report, the incidence of poverty is higher in rural areas (19.28%) than in urban areas (5.27%). Most poor households in rural areas are small and marginal farmers practicing animal husbandry and drawing a larger portion of their income from livestock, poultry and fisheries.

In India, 64.62 per cent of agricultural households (60.16 million) were engaged in farming of animals in 2018-19. Out of which, 63.05 per cent were small and marginal farmers (NSO, 2021b), which means that the remaining agricultural households (medium, semi-medium and large) engaged in farming of animals, either in principal status or subsidiary status, were only 1.57 per cent. Not only are the larger proportion of small and marginal farmers engaged in farming of animals, but they also draw a larger share of income from animals. In the country, the overall share of net income from farming of animals was 15.48 per cent (Rs 1582 per month per household) in the total monthly income of an average agricultural household (Rs 10218) in 2018-19, while the same was 15.72 per cent in case of small and marginal households. In fifteen years, the net income from farming of animals of an average agricultural household has registered a seven-time increase in absolute value in real terms (base year 2011=100) from 2002-03 to 2018-19.

The contribution of livestock to economic development is more pronounced at the national level. The share of livestock in the agricultural gross domestic product (GDP) is nearly 50 per cent in high-income countries. In contrast, the same averages ~25% for low- and middle-income countries (Baltenweck *et al.*, 2020). In India, livestock alone contributed 30.23 per cent to gross value added (GVA) from the agriculture and allied sector in 2022-23 at current prices (DAHD, 2024). If a 7.25 per cent contribution from fishery and aquaculture is added, the total share of the livestock sector becomes 37.48 per cent in the GVA of agriculture and allied sectors.

It is evident that animal husbandry, which includes livestock, poultry, and fishery, occupies an important place in the Indian economy and the livelihoods of the rural people. Thus, the sustainability of the livestock sector will ensure the sustainability of the livelihoods. The relationship between the sustainable livestock sector and sustainable livelihoods is cause and effect, not vice-versa. The sustainability of livelihoods of other functionaries engaged in backward and forward linkages also depends to a larger extent on a continuous better performance of the livestock sector.

Four to seventeen jobs can be created and sustained in small-scale dairying for every 100 litres of milk collected, processed and marketed (Bennett *et al.*, 2006).

II

ROLE OF ANIMAL HUSBANDRY IN SUSTAINING THE LIVELIHOOD: A REVIEW

The role of animal husbandry in the sustenance of livelihoods and poverty alleviation, especially that of small and marginal farmers, has been investigated and established in its lengths and breadths by several studies in the past. The contributions of livestock farming are very well documented in (1) increasing income and employment, (2) improving the nutritional security of households that own bovines, backyard poultry, and fishery, and (3) reducing poverty. In addition, there is a gender aspect of livestock, as two-thirds of the poor livestock keepers are women (Staal *et al.*, 2009). The women meet two-thirds of the labour requirement (Deoghare, 1997; Birthal and Taneja, 2006; Jumrani and Birthal, 2015) and have been empowered by livestock production. According to Thirunavukkarasu & Christy (2002), women spend almost five hours daily on various dairy activities. Livestock farming is a regular source of income, especially for poor farmers, and it also earns employment for otherwise unemployed family labour (Sidhu & Bhullar, 2004; Varathan *et al.*, 2013). The incidence of poverty was found to be much less among households owning livestock (Ojha, 2007; Birthal and Negi, 2012; Bijla *et al.*, 2023). Many studies in India and abroad corroborated the higher milk consumption and other nutritional intake by livestock owner households (Bhagowalia *et al.*, 2012; Pradyumna *et al.*, 2021). The results from these studies establish that livestock plays a positive role in sustaining the livelihoods of rural people. Thus, there seems to be less need to re-investigate the same. What is required is to foster a sustainable livestock sector. Currently, the Indian livestock sector is at a lower level of sustainability. Keeping this in view, this paper investigates the sustainability dimensions of the Indian livestock sector, its present situation, and the way forward.

III

SUSTAINABLE LIVESTOCK PRODUCTION: CONCEPTS AND ISSUES

To meet the increasing demand for animal food, livestock production is inflicting stress on both man-made and natural resources. It has high environmental and societal externalities. Livestock farming contributes substantially to greenhouse gas emissions and related global warming (Steinfeld *et al.* 2006). In a country like India, with a lack of animal health and discarding strategies, zoonotic diseases and stray cattle are becoming a major problem day by day. Livestock farming is confronting the issues of livelihoods, food security, and environmental impact in the long run and on a sustainable basis. Consequently, there is a strong social demand for sustainable livestock systems (Lebacq *et al.*, 2013). A trade-off between these antagonistic outcomes of the livestock sector leads to sustainability. The sustainable transformation of livestock production systems, both large and small, has been considered critical by

FAO (2023a) for enhancing livestock's contribution to food security, nutrition, poverty reduction, sustainable livelihoods, and the realization of the 2030 Agenda.

It is difficult to have a single definition/ criterion for sustainable livestock production because of the multifunctionality of the sector (Rangnekar, 2006). From the supply side, sustainable livestock production encompasses practices that aim to meet the needs of raising animals for food while minimizing adverse environmental impact (FAO, 2023b). On the demand side, it may be defined as managing animals in a way that continuously meets current demands and future expectations. Rademaker *et al.* (2017) have grouped definitions of sustainable agriculture into two broad paradigms- resource availability and functional integrity. The resource availability paradigm explains sustainability in terms of rates of production and depletion of resources and emphasizes conservation, regeneration and substitution for increasingly scarce resources. On the other hand, functional integrity is a dynamic system model comprising ecological and social reproduction processes, and sustainability is defined in terms of vulnerability and anthropogenic stress. The functional integrity paradigm is better for understanding the importance of biodiversity, the problem of spatial and temporal scale, and the relationship between society and ecology.

Due to the diverse livestock utility, numerous criteria have been used to determine the sustainability of the sector. The sustainable livestock sector is often connected to (1) enhance production not at the expense of humans and animals (Perry *et al.*, 2018; Varijakshapanicker *et al.*, 2019), (2) animal welfare (Buller *et al.*, 2018; Scherer *et al.*, 2018), and (3) the carrying capacity (Gao *et al.*, 2021). At the same time, confusion has been expressed about whether different desired goals—e.g., farm profitability, reduction of greenhouse gas emissions, and public health—can be achieved by using sustainability as a (master-)criterion (Hansen 1996; Korthals 2001).

To measure the sustainability of the livestock sector, the composite index has been used underlying the Human Development Index proposed by UNDP (1990). However, the number of dimensions and indicators in each dimension used in measuring composite sustainability index varies across the literature. Major indicators used to measure the sustainability of the livestock sector fall into the categories of environmental, economic, and socio-cultural (Battaglini *et al.*, 2014; Márquez-Romero *et al.*, 2016; Otta *et al.*, 2016; Peña *et al.*, 2018; Sarandón & Flores, 2009). The Organization of Economic Cooperation and Development (OECD) introduced the Pressure-State-Response (PSR) model for addressing the problem of systematic identification of indicators and is considered a widely accepted model for measuring sustainability (Woodhouse *et al.*, 2000; Suresh *et al.*, 2022).

Based on the literature review, we may consider a four-dimensional scale to monitor the sustainability of the Indian livestock sector (Figure 1). These four dimensions may be (1) Meeting increasing/ changing demand and nutritional security,

(2) Animal welfare and Societal acceptability, (3) Livelihood security and (4) Environmental immunity. These criteria can be further elaborated as given below:

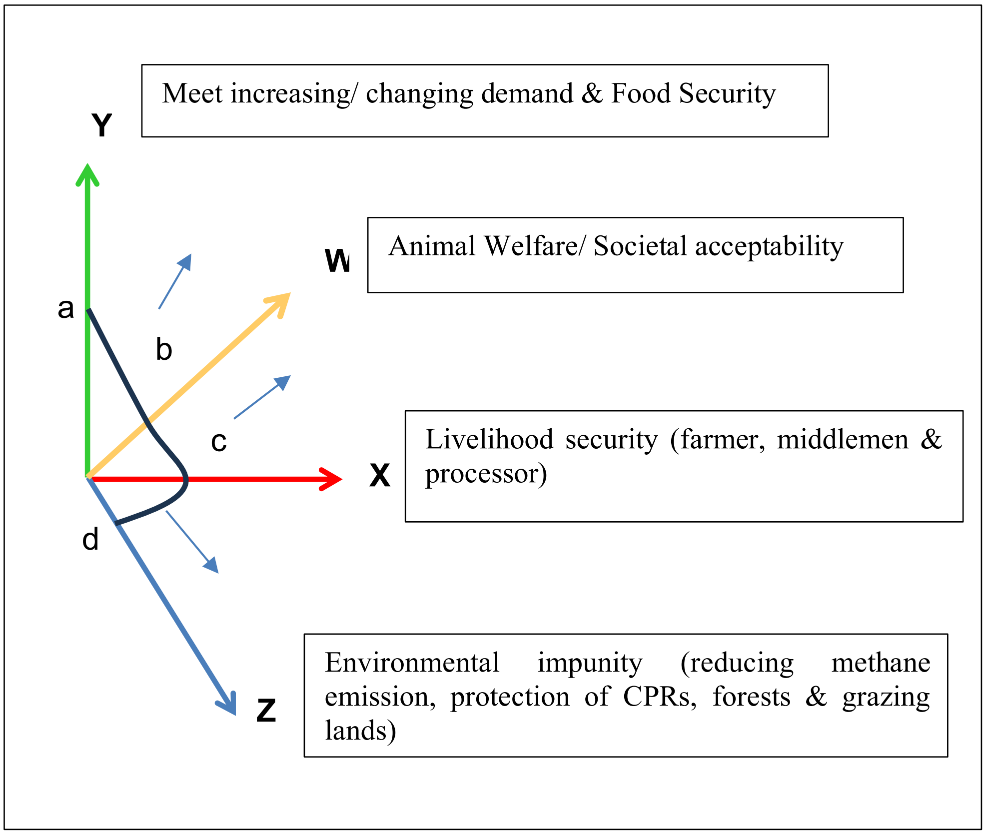

Figure 1. Four-dimensional Scale of Sustainable Livestock Sector

Livelihood security (X-axis): A sustainable livestock sector ensures the livelihood security of all stakeholders, i.e. farmers, middlemen and processors, on a long-term basis and in the changing economic environment. A profitable livestock production based on resource use, marketing, and processing efficiencies can only sustain livelihood security and poverty alleviation for the poor segment of society as livestock is reared the most by them. The share of dairying in family income of smallholder dairy farmers ranges from 22 to 39 per cent (Kashish *et al.*, 2017). Milk marketing is the major source of income for milk vendors (middlemen), who market about 36 per cent of the marketed surplus. Many small processors earn income by processing milk in creameries.

Meeting increased/ changing demand and nutritional Security (Y-axis): India is in the transition phase of increased demand for livestock products because of growth in per capita income, urbanization and shift in consumption pattern (Dastagiri, 2004, Gandhi

& Zhou, 2010). The livestock sector in India has been geared to meet the changed and increasing demand for livestock products like milk, meat, egg, fish, etc. In the last twenty-five years, the annual growth rate in milk production in India has been 4.71 per cent, which is higher than the growth in human population and has also increased per capita availability. Despite large-scale commercialization and splendid growth in egg production, the per capita availability (103 eggs) of egg is still lower than the recommended level (180 egg per capita). There is a greater challenge to increasing livestock production based on productivity to instill sustainability. In addition, the quality aspect is integral to the nutritional security of the population, especially when taking animal-sourced food. The important economic considerations in meeting demand on a sustainable basis are availability, acceptability and affordability.

Environmental Immunity (Z-axis): Imbalanced livestock production harms the environment, including air, land, soil, water, and biodiversity. In the Indian context, lowering methane emissions from the livestock sector is a major environmental challenge because of the sizeable unproductive livestock population. As per recent estimates, total livestock in India emits 12.74 million metric tons of methane per year, which is about 38-54 per cent of the total methane emission in the economy in carbon dioxide equivalent terms (Samal *et al.*, 2024; MOEFCC, 2023). Most of this population thrives on grazing biomass produced on common lands and forests, destroying biodiversity and slowing the rejuvenation process of plantation and the soil. The adverse effects of intensive livestock production on land and water are well recognized. Under Indian conditions, the area under cultivated fodder in stagnant at 5 to 6 per cent for the last twenty-five years, excluding the irrigated areas (Kelley and Parthasarathy Rao, 1994; Parthasarathy Rao and Hall, 2003) and the livestock is counted for comparatively lesser indirect consumptive water use, primarily because of the reason that the livestock in the country is mainly fed crop residues counting for 61 per cent on dry matter basis (Parthasarathy Rao and Bhowmick, 2001). A large amount of green fodder is also drawn from weeds, bunds and plant leaves. Keeping in mind the magnitude of the environmental impact of livestock, strategies to reduce adverse environmental effects need to be followed to make livestock production a sustainable option for the country and the farmers alike.

Animal Welfare and Societal Acceptability (W-axis)**:** With the commercialization of livestock production, animals are being treated as machines, ignoring their need for clean air & water, adequate space & feed, and survival after productive life. The discarding of unproductive animals and calve fallouts into a large population of stray animals causing massive environmental and crop losses besides creating public nuisance resulting in accidents and loss of precious human lives. These externalities are something not socially acceptable. For the sustainability of the livestock sector, these environmental and societal externalities (stray animals, human and crop losses, etc.) need to be accounted for and charged to maximize production and profit. Animal welfare is a ramification of societal acceptability, a broader concept than better animal health and curing diseases and infections. An estimated 60 per cent of the known infectious diseases and up to 75 per cent of new or emerging infectious diseases among human beings have a zoonotic origin (Anonymous, 2023). There is a growing initiative for 'One Health"; a unifying approach to balance and optimize the health of people, animals and ecosystems (WHO, 2024).

On a four-dimensional scale (Figure 1), any movement from left to right increases the sustainability of the livestock sector. Adjudged on these scales, the Indian livestock sector is presently at a lower level of sustainability, as determined subjectively by the curve 'abcd'. On the demand and supply dimension, the sector can increase production and add value to meet the growing demand for livestock products to some extent and commands a higher position (a) on the y-axis. Yet, the enhanced livestock production is more population-based and less productivity-based. The position of point 'b' on the w-axis shows lower concerns about animal welfare and societal acceptability. The point 'c' on the x-axis exhibits the level of livelihood security of the stakeholder because farming of animals is a source of livelihood for 60.16 million agricultural households and contributes 15.69 per cent of the monthly income of the small and marginal farmers. The real net income from farming animals has registered a compound growth rate of about 13 per cent annually from 2002-03 to 2018-19. Nevertheless, the profitability of livestock production is at stake and based on lower resource use efficiency. The lesser environmental impunity of the Indian livestock sector is reflected by point 'c' on the z-axis because of the large livestock population feeding on CPRs, causing massive methane emissions and degradation of grazing land. Any improvement away from the origin of these four fronts will enhance the sustainability of the livestock sector. The farther the sustainability curve (abcd) from the origin on this four-dimensional scale, the more sustainable is the livestock sector.

The model provides a basis for working on four dimensions to attain a higher level of sustainability. The following sections of this paper analyze the present situation of the Indian livestock sector and delineate the ways and means to enhance the sustainability of the livestock sector and the livelihoods in the rural economy.

IV

SPATIAL FACTORS DETERMINING OPTING FOR FARMING OF ANIMALS

The spatiotemporal changes taking place in the farming of animals are to be kept in mind while planning for its sustainable development. Over time, the number of agricultural households engaged in farming animals has increased from 57.89 per cent in 2002-03 (NSS,59th round) to 64.62 per cent in 2018-19 (NSS, 77th round). The point worth noting is that the proportion of households engaged in farming animals has increased in recent years in those states where it was lesser earlier (Figure 2). From the figure, it can be observed that states like Punjab, Rajasthan, Gujarat, Haryana, UP, etc., with a larger proportion of farmers engaged in farming of animal during 2002-03, have experienced either a decrease or negligible change in subsequent years, i.e. 2012-13 and 2018-19.

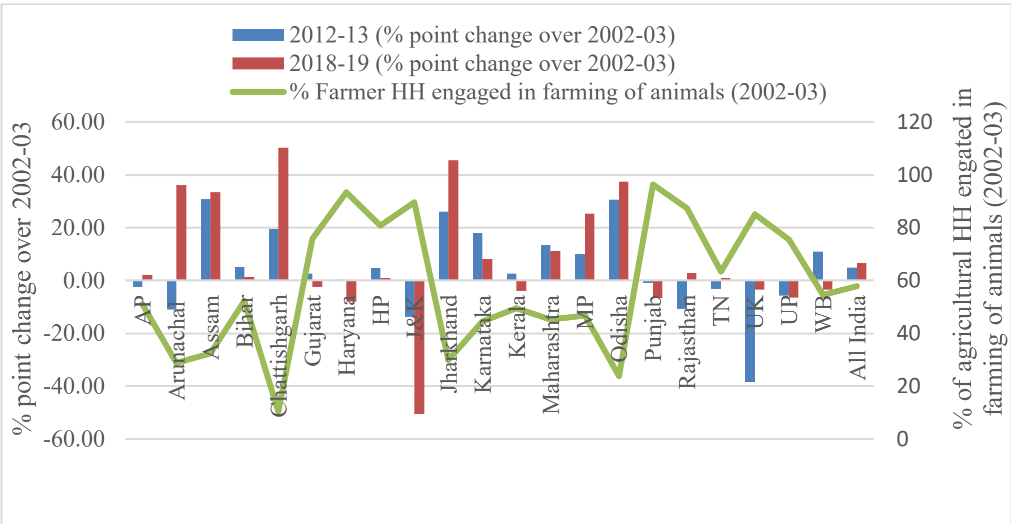

Figure 2. State-wise percentage point change in the proportion of agricultural households engaged in farming of animals over 2002-03 (NSS, 59th round)

To determine the spatial factors (state factor) responsible for this change, a Grouped Logit (Glogit) model was applied to estimate the probability of agricultural households adopting farming of animals in a state. The model was estimated using weighted least-squares regression (WLS) of the following form (Gujarati *et al.*, 2015) to overcome the problem of heteroscedastic disturbance term of simple logit model:

$\sqrt{w_i}L_i = \beta_0\sqrt{w_i} + \sum \beta_j \sqrt{w_i}X_{ij} + v_i$; where 'i' are the states varies from 1-21 and 'j' are the spatial factors varies from 1-5. The v_i is the transformed error term $v_i = \sqrt{w_i}u_i$, which is homoscedastic in properties. To calculate logit ($L_i = Ln(\hat{P}_i/(1-\hat{P}_i)$), the probability ($\hat{P}_i = {}^{n_i}/_{N_i}$) of agricultural households opting for farming of animals in i^th^ state was computed where n_i is the number of agricultural households engaged in farming of animals andN_i is the total agricultural households in a state. The WLS was run on state-wise panel data for 2012-13 (NSO, 2014) and 2018-19 (NSO, 2021b). Many spatial factors were tried, but the following five factors contributed significantly to determining the probability of households opting to farm animals in a state. These factors are (1) a percentage share of net income from farming animals in total monthly income per agricultural household (LVSINC); (2) the proportion of indebted agricultural households in a state (INAHH); (3) number of animals served per veterinary institute (No. of animals/vet inst.) as proxy of infrastructural development in the state (LVSVT); (4) proportion of operational holding < 2 hectares (in percentage); a factor representing poor farmers (MSAHH), and (5) the factor representing state's agricultural development was the Cropping intensity (CI) in percentage. The results of maximum likelihood regression with random effect are given in Table 1, along with states having a high marginal effect of the respective spatial factor.

TABLE 1. FACTORS DETERMINING THE PROBABILITY OF AGRICULTURAL HOUSEHOLDS ADOPTING FARMING OF ANIMALS IN A STATE

Factor	Coefficient	High marginal effect/ Rate of change in probability
Share of net income from farming of animals in total income (%) (LVSINC)	0.01861* (0.01026)	(≥ 0.0045) AP, TN, OD, KA, KE, CH, BH
Proportion of indebted agricultural households (%) (X2) (INAHH)	-0.00877** (0.00442)	(≥ -0.0022) AP, BH, CH, KA, KE,OD,TN
Animals served per veterinary institute (No./vet inst.) (LVSVT)	-0.00002 (0.00001)	(≥ -4.0* 10^{-6}) AP, BH, CH, KA, KE, OD, TN
Proportion of operational holding < 2 ha (%) (MSAHH)	-0.02354*** (0.00566)	(≥ -0.0055) AP, BH, CH, JH, KA, KE, MA, OD,TN, UP, WB
Cropping intensity (%) (CI)	0.00939*** (0.00325)	(≥ 0.0022) AP, AS, BH, CH, JK, JH, KA, KE, MA, OD, TN, UP, WB
Constant	1.56596* (0.81803)	
Log-likelihood	-212.01	
Wald chi2	106.12	

Figures in parentheses are standard errors. *, ** and *** represent significance at 10, 5 and 1 per cent probability levels, respectively.

State Symbols: AP (Andhra Pradesh), AS (Assam), BH (Bihar), CH (Chhattisgarh), JK (Jammu & Kashmir), JH (Jharkhand), KA (Karnataka), KE (Kerala), MA (Maharashtra), OD (Odisha), TN (Tamil Nadu), UP (Utter Pradesh), WB (West Bengal).

The table shows that four out of five factors significantly determine the probability of an agricultural household opting for farming animals. The two variables having significant coefficients with negative signs were the proportionate of indebted agricultural households (INAHH) and the proportion of operational holding < 2 hectare (MSAHH). The coefficient of INAHH implies that with a one per cent reduction in indebted agricultural households, the weighted odds in favor of owning farming animals go up by 0.88 per cent ($(e^{0.00877} - 1) * 100$). Empirically, indebtedness is also low among households that own livestock. It may be noted that about 50 per cent of the agricultural households were in debt, with an average amount of Rs 74121 per agricultural household in 2018-19 (NSO, 2021a). A high proportion of marginal and small farmers (MSAHH) in a state negatively affects the probability of agricultural households being involved in the farming of animals. MSAHH was a proxy variable for the proportion of poor farmers in a state. The results contradicted the theoretical expectations that farmers taking animal husbandry is directly proportionate to the poor farmers. The share of net income from farming animals (LVSINC) and the cropping intensity (CI) positively affect animal farming by agricultural households. The factors reveal that higher income from livestock and intensive crop cultivation in a state encourage farmers to venture into farming animals. One per cent raise in cropping intensity increases weighted odds in favor of owning farming of animals by 0.009 points. The LVSVT variable was non-significant, but the sign (negative) was as expected, which means increasing the number of veterinary institutes/ infrastructures to the present livestock population will reduce the number of animals to be served by one veterinary institute and, in turn, is likely to encourage agricultural households to opt for farming of animals.

The analysis reveals that the sustainability of a state's livestock sector depends on the magnitude of its crop diversity and share of livestock income. Livestock farming is encouraged by the lower indebtedness of agricultural households. Schemes like the Kisan Credit Card (KCC) are likely to have a positive effect on the farming of animals. The high marginal effect shows the states where identified spatial factors must be strengthened to make livestock farming a livelihood-sustaining proposition.

V

SOURCES OF CHANGE IN THE MILK PRODUCTION

In sustainable livestock production, productivity is a major consideration, which is substantially low in India. The average egg production per layer per year is 21 per cent lower (238 eggs/ layer) in India compared to the United States. The average milk yield per cow in India is two-thirds (4.87 kg/day) of the world average (7.2 kg) (Chand, 2023). The change in production derived from change in productivity improves economic efficiency, an important marker for long-term sustenance.

The contribution of yield and animal population to the total change in milk production can be analyzed by estimating growth rates of yield, population and production or by decomposing the change in average production using Hazell (1982) approach. The former method splits the compound annual growth rate (CAGR) of milk production into the growth rate of yield and the growth rate of the in-milk population of different bovine species in the country as a whole using the following sequence of equations.

Milk Production (PR_t) = Yield (Y_t) * In-milk population (P_t) …….. (1)

Taking natural log both sides of the equation (1)

Ln PR_t = Ln Y_t + Ln P_t ….. (2)

Taking differentiating the equation (2) w.r.t. time

$$\frac{d\ LnPR_t}{dt} = \frac{d\ LnY_t}{dt} + \frac{d\ LnP_t}{dt} \quad \ldots\ldots\ldots.. (3)$$

$\dot{PR}_t = \dot{Y}_t + \dot{P}_t$; where $\dot{PR}_t$, $\dot{Y}_t$ and $\dot{P}_t$ are the CARGs of the milk production, yield and in-milk population.

The method shows the contribution of yield and in-milk population to annual growth in milk production.

According to Hazell (1982) approach, the four components of change in average production are:

$$\Delta E(\overline{PR}) = \bar{P}_b(\Delta\bar{Y}) + \bar{Y}_b(\Delta\bar{P}) + (\Delta\bar{P})(\Delta\bar{Y}) + \Delta Cov.(PY) \text{ ……….(4)}$$

On dividing both sides by $\Delta E(\overline{PR})$, we get

$$1 = \bar{P}_b(\Delta\bar{Y})/\Delta E(\overline{PR}) + \bar{Y}_b(\Delta\bar{P})/\Delta E(\overline{PR}) + (\Delta\bar{P})(\Delta\bar{Y})/\Delta E(\overline{PR}) + \Delta Cov.(PY)/\Delta E(\overline{PR}) \text{ (5)}$$

1 = Yield effect + Population effect + Interaction effect of yield and population + change in covariance of yield and population

Both the analyses were applied on triennial moving average (TE) data of PR_t, Y_t and P_t from TE 2002-03 to TE 2021-22 recorded from various issues of Basic Animal Husbandry Statistics of the Government of India (GoI).

Table 2 shows the contribution of productivity in milk production growth using both approaches. It can be observed from the table that the total milk production in the country grew at a CAGR of 5.35 per cent from TE 2002-03 to TE 2021-22. In this growth, the contribution of yield is higher (52.52 per cent) than the contribution of the in-milk population (47.48 per cent). The productivity growth has been mainly driven by the higher growth in productivity of non-descriptive/ indigenous cows, which grew at the CAGR of 2.97 per cent and contributed to its growth of milk production (indigenous cow) by 71.39 per cent. On the contrary, the growth of milk production from exotic/ crossbred (CB) cows was the highest (7.97 per cent), which was mainly driven by the growth in its population. The population growth contributed 82.81 per cent of the growth in milk production from CB cows. The share of yield in growth was only 17.19 per cent. In the case of buffalo, the contribution of the population was higher, i.e. 54.09 per cent in the total growth of its milk production (4.16%). The results from the decomposition analysis were not different from those of the growth rate analysis. According to decomposition, there is no significant difference between the yield effect (38.92%) and population effect (37.84%) on the overall change in milk production in the country during the period under study. The changes in interaction effect, which occurred because of simultaneous changes in average yield and average population, accounted for about 23.17 per cent of the country’s change in milk production in the last twenty years. Overall, the change in covariance of yield and population was minimal and accounted for 0.07 per cent of the change in milk production.

TABLE 2. CONTRIBUTION OF PRODUCTIVITY IN THE GROWTH OF MILK PRODUCTION; TE 2002-03 TO TE 2021-22 (per cent)

Components	Symbols	Bovine species			
		Non-descriptive/ Indigenous cow	Exotic/ Crossbred cow	Buffalo	Total
		Compound Annual Growth Rate (CAGR)			
Total Milk production	PR	4.16	7.97	4.16	5.35
Milk Yield per animal	Y	2.97 (71.39)	1.37 (17.19)	1.91 (45.91)	2.81 (52.52)
In-milk Population	P	1.44 (34.61)	6.60 (82.81)	2.25 (54.09)	2.54 (47.48)
		Decomposition Analysis			
Yield effect	$\bar{P}_b(\Delta\bar{Y})/\Delta E(\overline{PR})$	57.49	8.72	37.85	38.92
Population effect	$\bar{Y}_b(\Delta\bar{P})/\Delta E(\overline{PR})$	25.24	70.40	43.31	37.84
Interaction effect	$(\Delta\bar{P})(\Delta\bar{Y})/\Delta E(\overline{PR})$	17.19	20.73	18.86	23.17
Change in covariance	$\Delta Cov.(PY)/\Delta E(\overline{PR})$	0.08	0.15	-0.02	0.07
Contribution to total change in production		18.35	39.98	41.67	100.00

Note: The figures in parenthesis are percentages of the total milk production growth rate.

The results in Table 2 reveal that CB cows and buffaloes have contributed about 82 per cent to the total change in milk production during the last twenty years. Still, it was largely drawn from the increase in their population in-milk. The CB cow contributed about 40 per cent to the change in total milk production. The population effect was as high as 70.40 per cent. The results indicate a larger impact of the population in the growth of milk production, except for Indigenous cattle. The results hint at unsustainable growth in milk production in the country, and the way forward is to focus on an increase in productivity, especially that of the CB herd and emphasize conservation and upgradation of indigenous herds in the country for long-term sustainability.

The state-wise decomposition of the change in milk production into four components is given in Table 3. For the convenience of interpretation, the states are arranged in descending order based on their contribution to the total change in milk production in the country. The results show that the states contributing the most to the change in milk production in the country have a higher population effect than the yield effect. On the other hand, the states that count on a lesser share of the country's total change in milk production have a higher yield effect than the population effect.

TABLE 3. STATE-WISE DECOMPOSITION OF CHANGE IN MILK PRODUCTION INTO FOUR COMPONENTS; TE 2002-03 to TE 2021-22 (per cent)

State	Yield effect	Population effect	Interaction effect	Change in covariance effect	Contribution to total change in milk production
Rajasthan	31.51	34.99	33.55	-0.04	16.79
Uttar Pradesh	18.30	66.61	15.22	-0.14	13.70
Andhra Pradesh	48.89	23.17	28.23	-0.28	11.94
Madhya Pradesh	30.89	38.53	30.54	0.04	9.90
Gujarat	31.49	43.48	25.02	0.00	8.10
Bihar	17.93	49.31	32.97	-0.21	7.09
Maharashtra	67.23	17.54	14.86	0.36	5.85
Haryana	47.51	32.02	20.63	-0.17	5.31
Karnataka	64.02	19.48	16.08	0.43	4.76
Punjab	74.65	17.00	8.99	-0.63	4.50
Tamil Nadu	62.82	23.23	13.88	0.06	3.69
West Bengal	61.61	26.19	11.92	0.28	2.05
Odisha	89.52	4.54	6.53	-0.59	1.18
Chhattisgarh	-30.05	62.27	-11.85	79.63	0.76
Himachal Pradesh	56.58	26.91	16.48	0.03	0.63
Uttarakhand	64.97	24.31	10.81	-0.09	0.58
Assam	86.78	9.37	3.27	0.59	0.22

Source: author's calculation based on data from various Basic Animal Husbandry Statistics (BAHS) reports.

The results in this section underline more contribution of yield than population in milk production in future. The available feed, breeding and management strategies to increase milk productivity may be targeted in states that contributed more to the county's milk production.

VI

LIVESTOCK INCOME ANALYSIS AND RESOURCE USE EFFICIENCY

Yet another and very important aspect of sustainable livestock production is the income from the livestock sector and the efficiency of inputs used. This section analyzes the trends in livestock receipts (total income) and expenses per agricultural household engaged in farming animals. The data has been taken from different Situation Assessment Survey (SAS) reports of NSSO (59^{th}, 70^{th} and 77^{th} rounds).

The total income from livestock per agricultural household engaged in farming animals was Rs 3704 per month in 2018-19, which increased by 42.24 per cent from Rs 2604 per month in 2012-13. Figure 3 shows the percentage share of major livestock products in total receipts. The major products included in the analysis are milk, eggs, fish, live animals/ livestock, and other livestock products. The share of wool was negligible and has also reduced over time, so receipts from wool were added to live animals for calculation purposes, bearing in mind that the primary sources of wool are the sheep, goat and rabbit, and these animals also sold live for meat purposes. The other livestock products include skin, hide, bones, manure, etc.

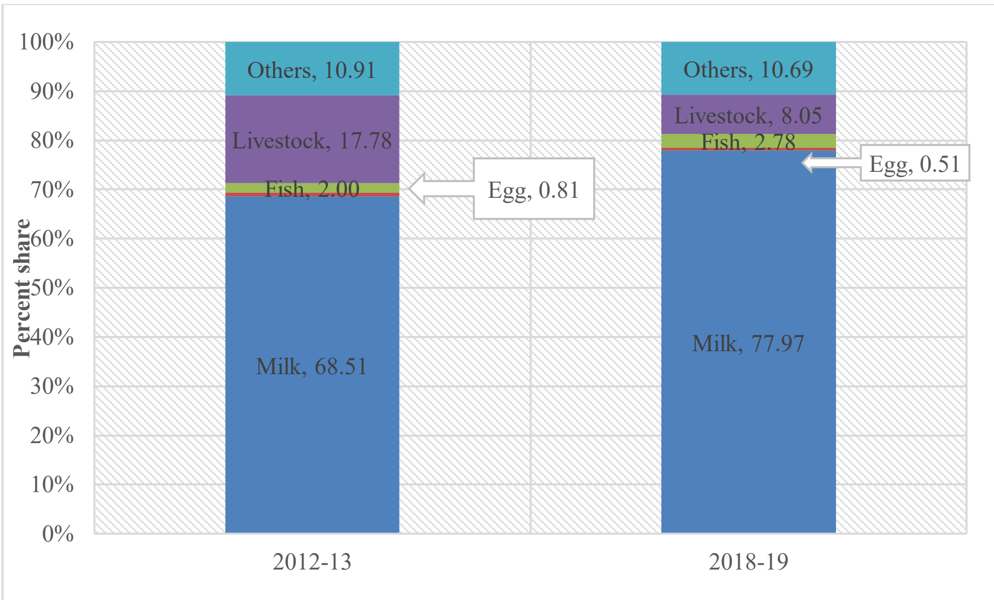

Figure 3. Percentage share of major livestock products in total receipts per household

Milk and fish are the products whose percentage share in total receipts has increased significantly. The milk share increased by 11.46 percentage points in six years from 68.51 per cent in 2012-13. Likewise, the share of fish in total receipts increased from two per cent to almost three per cent (2.78%) during the same period. The share of remaining products has decreased both in absolute and percentage terms. The share of income from other livestock products (skin, hide, bone and manure) has also marginally declined. The decrease in the share of eggs (poultry) in total income is a testimonial of shifting poultry from backyard to commercial production.

6.1 Trends in Real Income and Expenses

Figure 4 shows the state-wise CAGRs of monthly total income and paid-out expenses from livestock per agricultural household engaged in farming animals over time (2002-03 to 2018-19). Before estimating the growth rates, the current values of the income and expenses were deflated using the gross domestic product (GDP) deflator to estimate real income and expenses at the base price (2011=100) (World Bank).

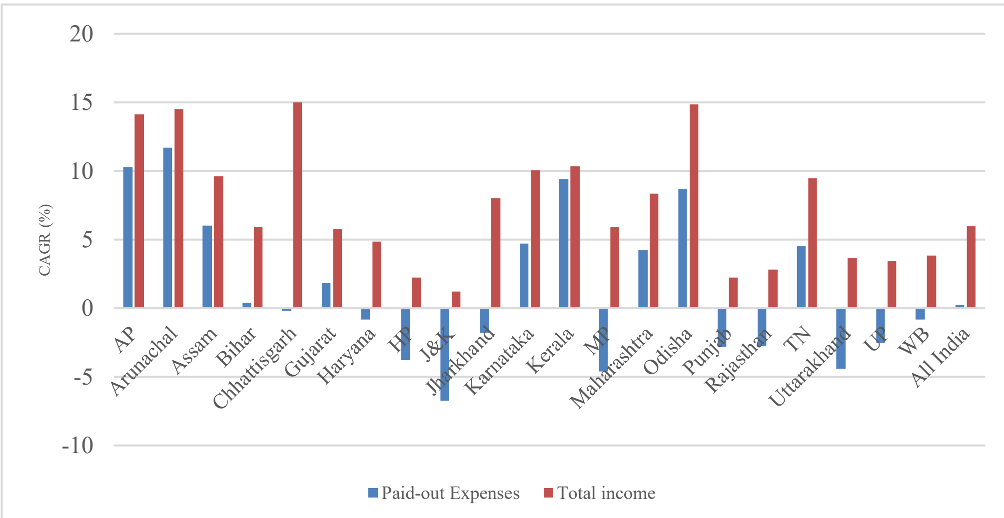

Figure 4: State-wise compound annual growth rates (CAGR) of real total income and paid-out expenses (2011=100) from 2002-03 to 2018-19.

Note: The name of some of the states has been deliberately kept either short or abbreviated to save space

It can be observed from the figure that monthly total income from farming animals in real terms (2011=100) has increased in all states with an overall growth rate of 5.98 per cent in the country. The overall growth in monthly paid-out expenses is less than one (0.26%), resulting in a 16.23 per cent CAGR of net income (Total income – paid-out expenses) from livestock per household in real terms. However, the situation is not the same in different states. The growth in total income from farming animals was about 15 per cent per annum in Andhra Pradesh (AP), Arunachal Pradesh, Chhattisgarh and Odisha. During the last seventeen years, the states which registered lower growth rates (CAGR > 5%) in total income per household from farming animals were Himachal Pradesh (HP), Jammu & Kashmir (J&K), Punjab, Rajasthan, Uttarakhand, Uttar Pradesh (UP) and West Bengal (WB). Among the later states, a large number were those with better-developed livestock systems in place even before the study period. According to the 59th survey round of NSO (2005), the total income per month from livestock was the highest among states, namely Gujarat (Rs 1141), J&K (Rs 1117) and Rajasthan (Rs 1109). The trend indicates the growing importance of livestock in non-traditional states with lower livestock activities before 2002-03.

The growth of paid-out expenses in livestock activities was negative in some major states, namely HP, J&K, Jharkhand, MP, Punjab, Rajasthan, Uttarakhand and UP. The highest decline (CAGR -6.75%) in the real value of paid-out expenses was in J&K, followed by MP (-4.62%), Punjab (-2.79%) and Rajasthan (-2.75%). The paid-out expenses include the cost of animal 'seed', animal feed, veterinary charges, labour charges and other costs. The other expenses comprise interest on loans utilized for farming animals, lease rent for land used for farming animals, cost of livestock insurance and other pity expenses. The decline in paid-out expenses does not indicate a decrease in production cost, as it may be due to replacing purchased inputs with farm-owned inputs or shifting livestock farming on common property resources. The government has promoted farmers to grow quality fodder on their farms under various schemes like feed and fodder sub-mission under the National Livestock Mission (NLM), which started in 2014-15. Under this sub-mission, the government has provided assistance for quality fodder seed production of thirty thousand quintals till 2023.

Superimposing Figure 2 on Figure 4 gives sufficient reasons to explain why more farmers have adopted farming of animals in some states while it has declined in other states compared to the percentage of agricultural households engaged in farming of animals in 2002-03. The high growth in total receipts from farming animals appears to be one factor that encourages more agricultural households to farm animals in Chhattisgarh, Odisha, Karnataka, Assam and Arunachal Pradesh. Whereas a decrease in paid-out expenses encouraged the farmers of Jharkhand, MP and Rajasthan to take farming animals. In the long run, a growth rate of more than ten per cent in returns from livestock over paid-out expenses was observed to be a threshold for farmers to continue to be engaged in farming animals in a state.

6.2 Resource Use Efficiency in the Livestock Sector

A production process is economically viable based on resource use efficiency. For assessing the resource use efficiency in the Indian livestock sector, the marginal value product of i^{th} input (MVP_i) was estimated using the coefficients (β_i) of log-linear regression, where $MVP_i = \beta_i \bar{Y}/\bar{X}_i$; $\bar{Y}$ and $\bar{X}_i$ are the geometric means of total income from farming of animals and inputs used per household in value terms, respectively. The standard error (SE) of MVP_i = SE of (β_i) $\bar{Y}/\bar{X}_i$. The resource use efficiency in the livestock sector was estimated at state and household levels, for which inputs used were regressed against the total income from farming animals per household. Both the paid-out and imputed value of the inputs were accounted for. At state-level analysis, the inputs considered were (1) animal ‘seed cost’ (animal seed), (2) animal feed, (3) labour charges (human) and (4) other expenses (OE). The results of resource use efficiency in the livestock sector per farm at the state level are given in Table 4.

TABLE 4. RESOURCE USE EFFICIENCY OF LIVESTOCK SECTOR IN INDIA

Variable	Coefficient[1]	MVP_x	Difference (MVP_i - P_i)	Resource-use efficiency
Animal 'seed' cost	0.0595* (0.0349)	2.5626 (1.5031)	1.5626	Optimum
Animal feed	0.4454*** (0.1156)	0.7652 (0.1986)	-0.2348	Optimum
Labour charges	-0.1554*** (0.0378)	-0.8761 (0.2131)	-1.8761***	Overuse
Other expenses[2]	0.3897*** (0.0868)	12.0287 (2.6792)	11.0287***	Underuse
Constant	3.8616*** (0.6713)			
R^2 (per cent)	71.85*** ; Within (23.27); Between (80.18)			
F (4, 24)	24.28			
Sd(u_i + avg(e_i)	0.2894			

Note: Figures in the parentheses are standard errors of the respective estimate. * and *** indicate the significance of estimates at 10% and 1% levels of probability (H_0 for coefficients: β_i=0; H_0 for difference: MVP_x=1);
1: Coefficients of log-linear regression (between regression) are based on state-level panel data for two visits (NSO, 2021b), comprised of 58 observations and 29 groups.
2: Other expenses include veterinary charges, interest on loans utilized for farming of animals, lease rent for land used for farming of animals, cost of livestock insurance, etc.

Overall, the human labour and other expenses were not used at their optimum levels. The labour is being overused ($MVP_L < P_L$) while the other expenses (OE) were underused ($MVP_{OE} > P_{OE}$). In subsistence farming, family members are the major source of labour, which is generally put into more. On the other hand, the expenses for veterinary care, loan interest, and insurance are lower than the optimum level. On average, an agricultural household engaged in farming animals spent Rs 73 and Rs 47 per month on veterinary care and the remaining OE, respectively. The animals covered by insurance are still less than one per cent despite high risk in livestock farming. The cost components counted in OE are of special significance for future developments (investment and insurance costs) of the livestock sector with respect to the size of production and risk mitigation.

Though resources like animal seed and feed are optimally allocated overall, the same was not true among states (Table 5). These inputs were underused in a majority of the states. The MVP of animal seed was less than its acquisition cost in Arunachal Pradesh and Meghalaya, indicating that input was overused. On the same criterion, animal feed is overused in major milk-producing states like Haryana, Punjab, Rajasthan, UP and Odisha. Invariably, labour was overused while other inputs, including veterinary charges, were underused from the optimum point in all states.

TABLE 5. STATE-WISE RESOURCE USE EFFICIENCY IN LIVESTOCK PRODUCTION

Variable	Underuse	Overuse
Animal 'seed' cost	Haryana, J&K, Maharashtra, Mizoram, Punjab, Rajasthan, Telangana, Uttarakhand, UP	Arunachal Pradesh, Meghalaya,
Animal feed	Arunachal Pradesh, Meghalaya, Manipur, Sikkim, Mizoram, Nagaland	Haryana, Odisha, Punjab, Rajasthan, UP
Labour charges		All states
Other expenses	All states	

Note: Other expenses include veterinary charges, interest on loans, lease rent for land used for farming animals, cost of livestock insurance, etc. For states not mentioned in the table, MVPs of resources were different than zero but not significantly different than one, indicating efficient use of resources.

The household-level resource use efficiency analysis almost yields the same results (Table 6). The resource use efficiency at the household level is based on unit-level data of NSO for the 77th round for two visits. Based on land holding size, the households were divided into four farm size groups, namely, landless, Marginal (($\geq$0.004 to < 1 ha), Small (1-2 ha), Medium (2-10 ha) and Large ($\geq$ 10 ha) households. The inputs considered were green fodder, dry fodder, concentrate, veterinary cost, labour charges and other expenses. Using the coefficients of log-linear regression for each farm size group (Appendix 1), the resource use efficiency of inputs was determined, as shown in Table 6.

TABLE 6. RESOURCE USE EFFICIENCY AMONG FARM-SIZE GROUPS

Resources	Underuse	Overuse
Green fodder	Landless, Marginal, Small and Large Households	
Dry fodder	Marginal Households	Small, Medium and Large Households
Concentrate	Landless and Medium households	Small Households
Veterinary Cost	Small and Large households	
Labour charges		Landless, Marginal, Small and Large Households
Other expenses	Marginal, Small, Medium and Large Households	

As evident from the table, most farm-size groups were not using inputs at their optimum/ efficient level. Almost all inputs are underused (Kumar *et al.*, 2012) except human labour, dry fodder & concentrate in some farm-size households. The overuse of dry fodder was recorded in small, medium and large households and of concentrate on small households. Inefficient use of feed and fodder deteriorates the profitability of the livestock sector as total feed cost accounts for 58 to 72 per cent of the total maintenance cost (Babar *et al.*, 2001; Agarwal & Raju, 2021). Both supply and technical factors are responsible for the underuse of resources in livestock sector. On the supply side, removing the scarcity of feed and fodder and providing access to credit will help improve the efficiency of these inputs. One of the major reasons for low resource use efficiency in the livestock sector is the lack of technical knowledge. The farmers may be empowered with technical advice and IT tools about efficiently using costly inputs.

The following section discusses the impact of livestock support services and technical information on the profitability of the livestock sector.

VII

LIVESTOCK SUPPORT SERVICES AND EFFECT OF TECHNICAL INFORMATION

The livestock support services range from the supply of inputs (including credit and insurance) to the marketing of its products (including Cooperative Societies, Processing units, etc.). In the livestock sector, animal health care is one of the important services accessed by agricultural households, followed by breeding and feeding. At a household level, the former accounts for nearly 67 per cent of total expenditure on livestock support services (Pushpa, 2017). In fishery, the most accessed technical information was on management and marketing. Table 7 shows the sources and type of technical details sought by agricultural households during 2018-19.

TABLE 7. PERCENTAGE OF AGRICULTURAL HOUSEHOLDS ACCESSING THE TECHNICAL INFORMATION AND MAJOR SOURCES AND TYPE OF INFORMATION (AGRICULTURAL YEAR (AY) – 2018-19)

Particulars	Cultivation	Livestock	Fishery	Either
First half of AY (July to Dec., 2018)	41.88	7.18	0.68	49.7
Second half of AY (Jan. to June, 2019)	33.64	7.74	0.54	41.92
Major Sources of Technical Information	1. Input dealers 2. Progressive farmers 3. KVK/ Agri. Universities & colleges 4. Govt. Ext. service/ ATMA	1. Veterinary dept. 2. Coop./ DCSs 3. Private Processors/ Kisan call centre	1. NGO 2. Agri. University & Colleges/ KVK 3. Agri-clinic & Agribusiness centre/ Coop. 4. FPOs	
Major type of technical information sought	1. Improved seed/ variety 2. Fertilizer application 3. Plant protection	1. Health care 2. Breeding 3. Feeding	1. Management and marketing 2. Other than seed production & harvesting	

Source: Compiled from NSO (2021b)

The technical information agricultural households sought regarding animal farming was dismally low. Only 7.18 per cent and 7.74 per cent of the agricultural households accessed technical information during the first and second half of the agricultural year (AY) 2018-19, respectively, while the percentage of agricultural households engaged in farming animals is as high as 65 per cent. In a multi-agency extension system, the government and cooperative agencies were the preferred sources of technical information on farming animals and fishery. The merging of the types and the sources of technical information delineates that the livestock holders prefer veterinary department and cooperative agencies for availing health care and breeding services. However, the veterinary institutions providing these services are thinly distributed. On average, a veterinary institute serves 8141 animals (2018-19). In some states, namely West Bengal, Telangana, Jharkhand, Chhattisgarh, Madhya Pradesh, Bihar, Andhra Pradesh and Gujarat, the livestock population served per veterinary institute was more than ten thousand. The National Commission on Agriculture (1976) recommends providing one veterinary institute for every 5000 cattle units to ensure proper veterinary health care. On the other side, there is a need to improve the efficacy of veterinary services besides increasing the intensity of these institutions as 95 per cent of the budget of these institutes goes towards paying salaries and perks to the staff and the government, generally, could not perform it efficiently (Leonard, 1993; Ahuja & Sen, 2006). The core competencies of livestock extension professionals have also been found to be low and require significant improvement (Sasidhar and Suvedi, 2016). It has been observed that investments in the exchange of knowledge are much more effective than programs aimed at input supply alone (Rangnekar, 2015).

The sustainability of the livestock sector is largely dependent on the efficiency and effectiveness of livestock support services. These services improve the productivity and quality of livestock products and ensure the realization of the higher benefits of the livestock revolution by the poor (FAO, 2002). Hence, the efficient delivery of livestock services has been a subject of rising concern to many national and international organizations, including FAO (Kleeman, 1999). A simple Analysis of Variance (ANOVA) model regressing technical information accessed by farmers as regressors against profit from farming of animals (dependent variable) shows that the farmer households accessing technical information earn higher profit. Two ANOVA models of the type $Pro_i = \beta_0 + \sum \beta_i D_i + \mu_i$ were fitted to net profit (Pro_i) (Total receipt minus Total expenses) from farming of animals of an agricultural household (i^{th}) engaged in farming of animals (henceforth agricultural households) for unit level panel data from both the visits of 77^{th} round of NSO. The total number of observations (n) in the panel data was 41046, and the number of group (g) households was 24415. The total expenses include both paid-out-pocket and imputed value of green fodder, dry fodder, concentrate, veterinary cost, labour charges and other expenses (other fodder, animal seed besides interest of loans, land rent of leased in land, livestock insurance, etc.). In the first model, three dummy variables were regressed against the profit of agricultural households accessing and adopting technical information of breeding and feeding (D_1), livestock-related management and other information (D_2) and fishery-related technical information (D_3). The fishery-related technical information accessed by agricultural households is related to fish seed production, harvesting, management & marketing, and others. The coefficients obtained in the model are as shown below:

$$Pro_i = 1795.9650^{***} + 312.3594\, D_1 + 1701.7590\, D_2 + 10572.4700^{***}\, D_3$$

SE (β_i) (120.2386) (549.6544) (1300.1420) (1560.1880)

The ANOVA equation clearly shows that the mean profit of an average agricultural household that accessed technical information on any aspect of fishery was significantly higher by the amount of Rs 10572.47 per month (at 1% level of probability) than the agricultural households not accessing the technical information at all. It implies that the profitability of agricultural households engaged in farming animals increased about six times due to accessing and adopting technical information on the fishery. The coefficients of dummy variables D_1 (technical information on breeding and feeding) and D_2 (management and other technical information) were found to be non-significant, mainly due to fewer observations on these variables. If we combine both these dummy variables and have only two dummy variables, one for households accessing technical information on any aspect of livestock (D_1) and another for households accessing technical information on any aspect of the fishery (D_2), the availing of technical information contributed significantly in the profitability of agricultural households as shown below:

$$Pro_i = 1657.4260^{***} + 1153.9220^{***} D_1 + 10344.35^{***} D_2$$

$$SE(\beta_i) \quad (126.8074) \quad (349.6077) \quad (1558.4480)$$

The later ANOVA model clearly illustrates the significant impact of accessing technical information on profit. The average profit of agricultural households accessing the technical information on any aspects of livestock and fishery were Rs 2811.85 per month and Rs 12001.78 per month, respectively, which were 69.62 per cent and 624.12 per cent higher than the average profit of agricultural households (Rs 1657.43 per month) not accessing any information of technical aspects of livestock and fishery.

The results from simple ANOVA models reaffirm the significant contribution of livestock support services, especially livestock extension and health services, which need to be strengthened in future so that the potential of this sector may be harnessed to sustain the livelihoods in the rural economy of India. The relevance of these services, whether paid or subsidized, is enhanced with the increase of commercialization in livestock production, as is evident from the fishery sector. The provision of subsidized services is well judged on the concern that most livestock farmers are poor and would be deprived if charged. Nevertheless, the point that favours paid services is that it improves the quality of services delivered (Ahuja and Sen, 2006). The willingness-to-pay (WTP) of the farmers for livestock services, especially health services, is comparatively higher, as highlighted by many researchers (Kumar, 2011; Yadav *et al.*, 2021; Cariappa *et al.*, 2022).

VIII

ANIMAL WELFARE, SOCIETAL ACCEPTABILITY AND CONSERVATION

A development in the livestock sector without animal welfare and societal acceptability cannot be considered sustainable. The positive relationship between animal welfare and the economic performance of livestock farms has been explained both theoretically and empirically (Mclnerney, 2004; Henningsen *et al.*, 2016; Hansen, 2023). If socio-economic and environmental issues are essential conditions, animal welfare is a sufficient condition for making the livestock sector sustainable. Animal welfare is a broader aspect than simply meeting the health and feed requirements. According to the World Organization for Animal Health (WOAH), animal welfare refers to the physical and mental state of an animal in relation to the conditions in which it lives and dies. As per Brambell Committee (1965) report, animal welfare includes 'Five Freedoms', i.e. from (1) hunger and thirst, (2) discomfort, (3) pain, injury and disease, (4) to express normal behaviour, and (5) fear and distress. Societal acceptability defines the framework for animal welfare before, during and after the productive life of animals. Thus, animal welfare and societal acceptability go hand-in-hand. In India, the society is against the slaughtering of cattle or animal after productive life, and the same is causing the problem of stray animals. The Gaushalas (cattle shelter home) are one of the socially acceptable solutions for stray animals. Several studies suggest that these gaushalas can be self-sustainable (Singh *et al.*, 2022) to care for stray and unproductive animals.

The concerns for animal welfare in the livestock production system are ever-increasing in developing countries as well (Carnovale *et al.*, 2021; Parlasca *et al.*, 2023). In a country like India, where an extensive and subsistence livestock production system is more prevalent, animal welfare is perceived better than intensive livestock production (Clark *et al.*, 2016; Kumar and Kamboj, 2016). However, various parameters of animal welfare, e.g. adequate floor space with proper light and ventilation, cleaned surroundings with open space, etc., are being neglected in the increasing trend of commercialization of livestock production in the country, especially in urban and peri-urban setup (Sharma & Behl. 2020; Acharya *et al.*, 2022), which adversely affects the productivity and productive life of animal as well as quality of the product and increase the cost of production. Thus, compliance with animal welfare norms puts a high cost on production. Some of these costs, e.g. health care, adequate nutrition, etc., pay for themselves by improving productivity, while other costs like cleanliness, adequate ventilation & space, etc., are private and, hence, require incentivised adoption (Anonymous, 2011). The non-compliance of animal welfare standards is restricting the trade of livestock products, especially in some Western European countries (UK, Scandinavia, Germany, Belgium, Switzerland, etc.), which consider animal welfare criteria seriously. The European Union (EU) animal welfare legislation, such as stunning before slaughter, has forced many meat and other animal products exporting countries to comply with EU legislation on food hygiene and stunning (Broom, 2017). Some of the United Kingdom supermarkets, namely Tesco and Marks & Spenser, carry animal products certified as welfare-friendly issued by the British Royal Society for the Prevention of Cruelty to Animals (RSPCA). Thus, future markets will be aligned with animal welfare principles (Liang *et al.*, 2023).

The relevance and preference for indigenous breeds and their products may also be viewed from the angle of societal acceptability. The scientific contexts for conservation are that indigenous germplasm is endowed with the quality of heat tolerance, disease resistance and the ability to thrive under extreme nutritional stress (Srivastava *et al.*, 2019;) besides non-market benefits. NITI Aayog paper has recognized that the acceleration in growth of milk production after 2005 is due to a shift in emphasis from exotic breeds to indigenous breeds (Chand, 2023). The non-market benefits of indigenous breeds include preference for milk, cultural and religious value, maintenance of soil health, risk of climate change and existence value. The WTP for a higher level of each attribute of non-market benefits was estimated at Rs 2501 per Sahiwal cattle per year (Bhandari *et al.*, 2022). The value of non-market benefits of indigenous cattle (Sahiwal) is 10.12 per cent of the total value of the animal (genetic trail value and non-market benefits). In the event of climatic change and the evolution of new production-related problems, conserving indigenous breeds is inevitable in meeting present and future challenges. India is rich in livestock biodiversity. India's share of world genetic wealth in cattle, goats, and sheep is around 16.5 per cent, 33 per cent, and 20 per cent, respectively. The efforts set in for the conservation of indigenous breeds are still inappropriate. According to an estimate, the government of three states (Rajasthan, Punjab and Haryana) allocate about 57 million for the conservation of the Sahiwal breed of cattle, which is only 8.6 per cent of the total value of the present population of Sahiwal breed in the states (Bhandari, 2020). On average, at least around 10% of the total value of a breed may be allocated for its conservation following the criterion of non-market benefit share.

IX

REDUCING THE ENVIRONMENTAL IMPACT OF THE LIVESTOCK SECTOR

A sustainable livestock production system helps reduce negative environmental impacts such as deforestation, land degradation and water & air pollution. This contributes to the preservation of ecosystems and biodiversity. The demand for environment-resilient livestock production is increasing, especially related to the emission of greenhouse gases like methane. Enteric fermentation produces methane, about 54 per cent of total methane production in the country in carbon dioxide equivalent terms (MOEFCC, 2023). At this level, the contribution of cattle to global warming may be around two per cent in the next hundred years (Johnson and Johnson, 1995). One of the major challenges of the dairy sector identified by NITI Aayog is the increased emission of greenhouse gases by ruminants (Chand, 2023). The poor and lower digestibility of feed and fodder produces more methane. Limiting the emission of greenhouse gases from the livestock sector requires improvement in feed efficiency. With the capping limitation on controlling the enteric methane emission through feed management, the long-run strategy is to produce more with fewer animals, i.e., to enhance livestock productivity.

At 536.76 million, India has a large livestock population, which is more than its carrying capacity in all respects. The stocking density (excluding poultry) in 2018-19 was about 163 animals per square kilometer of total land and about 2.75 heads per hectare of gross cropped area. In some states like Jammu & Kashmir and Jharkhand, the livestock density is seven to eight animals per hectare of gross cropped area. The large size of the livestock herd is also apparent at the household level. The latest Situation Assessment Survey (NSSO 77th round) (NSO, 2021b) shows 123.9 bovines, 188.8 ovine, and 133.9 poultry birds per hundred rural households. Consequently, despite extensive agricultural development, the country faces a huge deficit of feed and fodder. It has been estimated that the country is deficient in green fodder, dry fodder and concentrate to the extent of 11.24, 23.4 and 28.9 per cent, respectively (Roy *et al.*, 2019), which is likely to increase in future. Not only is the allocation for the development of feed and fodder low, but fodder seeds and cultivation have also received low priority, mainly because of subsistence livestock farming. More than the carrying capacity of forests and common property resources (CPRs), 270 million livestock (about 55% of the total population) are grazing in forests, which ultimately results in overexploitation, deterioration and degradation of common grazing lands and forests, both in quantitative and qualitative terms (GoI, 2001; GoI, 2012). The soils covered with grasses are rich in soil organic carbon (SOC) and nutrition. Overgrazing of grasslands has less SOC and results in soil degradation and desertification (Wang & Batkhishig, 2014; Dlamini *et al.*, 2016).

More output per unit of natural resources (environment efficiency), i.e., land, water, and bio-mass, is another criterion for bringing in environmental immunity. With the growing water limitation, economic activities compete for water use. In this context, there is a need to adopt practices that produce more output per drop of water, i.e., higher water use efficiency. The indigenous cattle breeds were found to use less water in terms of consumptive water use (CWU) during their productive life, and water use efficiency is at par with crossbred cows in later stages of productive life (Kumar *et al.*, 2023). Thus, environmental impact significantly differs between species and livestock production forms (FAO, 2009). Due to climate change, the CWU by livestock is likely more in an intensive production system. The intensification of livestock activities also results in water pollution and, hence, requires additional emphasis on livestock-waste management for sustainable production. Many proven options include separation technologies, composting and anaerobic digestion. According to an estimate, the total amounts of nutrients in livestock excreta are either as large as or larger than the total contained in all chemical fertilizers used annually (Menzi *et al.*, 2009). Only 60 per cent of the dung in India is used as manure (Dikshit and Birthal, 2010). Precision Livestock Farming (PLF) may also be considered as one of the alternative strategies to reduce the environmental impact of livestock (Tullo *et al.*, 2019).

X

CONCLUSIONS AND THE WAY FORWARD

A sustainable livestock sector can only enable livelihood sustainability in the rural economy of India. The sustainability of the Indian livestock sector may be monitored on a four-dimensional scale, and these dimensions are (1) Meeting increasing/ changing demand and nutritional security, (2) Animal welfare and Societal acceptability, (3) Livelihood security and (4) Environmental immunity. The graphing of the sustainability of the Indian livestock sector in terms of these dimensions is perceived to be low. The dimensions on which the livestock sector performed comparably better are meeting the growing and changing demand and livelihood security. However, achieving these aspects may not be considered long-term as the increase in milk supply, a major livestock product, is population-driven rather than productivity-driven. The states which contributed the highest to the growth of milk production in the country have attained the same through the increase in the number of lactating animals. The paper emphasizes working on all aspects of increasing the yield effect in milk production growth by comprehensively addressing the breeding, feeding, health care and management aspects. The available bio-mass and infrastructural development cannot sustain a large animal population. The country's livestock population overshoots the carrying capacity, which is reflected in the shortage of feed and fodder. The livestock sector has provided livelihood and nutritional security to poor farmers and their families in the past and requires more technical and system support than the existing level. The strengthening of existing livestock support services will empower livestock farmers to make livestock farming a major source of livelihood on a sustainable basis. The analysis has shown that imparting technical information and animal health services has significantly impacted net income from farming animals, which foresees consolidation of livestock extension systems and veterinary infrastructure in the country. The study establishes that the states with a higher share of net income from farming animals in monthly total income were found to have a higher probability of an agricultural household being engaged in farming animals. The other factor that significantly encourages animal farming is the cropping intensity of a state, which restates the prevalent integrated and mixed farming nature of livestock production systems in the country. A robust crop production system for a sustainable livestock sector is as relevant in the present context as in the past. Nevertheless, research is required to refurbish the functional integration of livestock and agriculture in a changing ecosystem.

The dimensions of sustainable livestock production that need immediate and urgent attention are the environment impunity and animal welfare/ indigenous breed conservation. The large livestock population is not only grazing over the available vegetation but is also a major source of methane production in the country. So, future strategies need to include fewer animals with higher productivity. The research studies targeting a reduction of methane emissions through feeding and shelter management need to be encouraged and strengthened. Animal welfare, which is at stake, especially in commercial production, is a sufficient condition for making the livestock sector sustainable. The research institutes are echoing the issue of animal welfare and developing the guidelines but lacking policy support. Economic and policy research needs to be conducted to count for and address societal and environmental externalities of the livestock sector. The widespread crossbreeding and reckless slaughtering in the past have eroded the country's precious livestock germplasm and require steering guidelines and policy backup. Even the present conservation efforts are not enough to conserve the indigenous germplasm. Integrating conservation efforts with social demand and acceptability is a positive step forward. It may be noted that in the last twenty years, the increase in yield has contributed 71 per cent to the growth of milk production from indigenous cattle.

The last but not the least issue in sustainability of livestock sector is the resource use efficiency, including the environmental efficiency. The paper found that many crucial inputs, like green fodder, concentrate, veterinary health expenses, and expenses on account of loan interest and insurance premiums, are being used less than the efficient level. On the other hand, inputs like dry fodder and labour are being overused. The environmental efficiency can be addressed by optimally using natural resources like bio-mass (green and dry), water and land. More emphasis on farming indigenous livestock breeds will likely reduce water use and environmental impact. More studies are required on environmental impact of the species and livestock production systems.

REFERENCES

Acharya, K. K., Malhotra, R., Sendhil, R., Mohanty, T. K., & Sahoo, B. (2022). Adoption of sustainable dairy management practices among peri-urban dairy farmers in Odisha. *Indian Journal of Extension Education*, *58(3)*, 120–125.

Agrawal, A., & Raju, R. (2021). Economics of milk production in Malwa and Kymore zones of Madhya Pradesh. *Haryana Veterinarian*, 60(2), 170-175.

Ahuja, V., & Sen, A. (2006). *Willingness to pay for veterinary services: evidence from poor areas in rural India. PPLPI: A Living from livestock* (pp. 06-03). Research Report.

Anonymous. (2011). *Economics and farm animal welfare*. Farm Animal Welfare Committee, London, UK.

Anonymous. (2023). Advancing joint risk assessment using the One Health approach in WHO South-East Asia Region: Report of the meeting at Colombo, Sri Lanka, 25–27 July 2023. World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), and World Organisation for Animal Health (WOAH). https://doi.org/10.20506/woah.3510

Babar, V. S., Killedar, N. S., Toradmal, V. M., & Lohar, N. S. (2001). Economics of stall feeding of goats in Western Maharashtra - a case study. *Indian Dairyman*, 53(2), 33-34.

Baltenweck, I., Enahoro, D., Frija, A., & Tarawali, S. (2020). Why is production of animal source foods important for economic development in Africa and Asia? *Animal Frontiers*, 10(4), 22-29.

Battaglini, L., Bovolenta, S., Gusmeroli, F., Salvador, S., & Sturaro,E. (2014). Environmental sustainability of Alpine livestock farms.*Italian Journal of Animal Science*, 13: 3155. https://doi.org/10.4081/ijas.2014.3155

Bennett, A., Lhoste, F., Crook, J., & Phelan, J. (2006). The future of small-scale dairying. *Livestock Report 2006*, 45 55.

Bhagowalia, P., Headey, D., & Kadiyala, S. (2012). Agriculture, income, and nutrition linkages in India: Insights from a nationally representative survey (*IFPRI Discussion Paper No. 01195*). International Food Policy Research Institute.

Bhandari, G., Chandel, B.S., & Malhotra, R. (2022). Beyond economic motives: Value of indigenous dairy cattle breed for the livestock keepers in India. *Indian Journal of Animal Sciences*, 92(5), 630–635.

Bhandari, G. (2020). *Economic valuation of indigenous dairy cattle breeds: A case of Sahiwal in India* (Unpublished doctoral dissertation). Division of Dairy Economics, Statistics and Management, ICAR-National Dairy Research Institute.

Bijla, S., Birthal, P.S., Malhotra, R., Dixit, A.K., Sankhala, G., Singh P., & Maiti S. (2023). Livestock and transitional poverty in rural India. *Agricultural Economics Research Review*, 36(2), 155-168. https://doi.org/10.5958/0974-0279.2023.00029

Birthal, P.S., & Negi, D.S. (2012). Livestock for higher sustainable and inclusive agricultural growth. *Economic and Political Weekly*, 47(26/27), 89-99.

Birthal, P.S., & Taneja, V.K. (2006). The livestock sector in India: Opportunities and challenges for smallholders. In P.S Birthal & V.K Taneja (Eds.), *Smallholder livestock production in India: Opportunities and challenges*. National Centre for Agricultural Economics and Policy Research (NCAP) and International Livestock Research Institute (ILRI).

Brambell, F. W. R. (1965). *Report of the technical committee to enquire into the welfare of animals kept under intensive livestock husbandry systems*. Cmd. Great Britain Parliament, H.M. Stationery Office, London.

Broom, D. M. (2017). Animal welfare in the European Union. Policy Department for Citizens' Rights and Constitutional Affairs, Directorate General for Internal Policies, European Parliament, Brussels.

Buller, H., Blokhuis, H., Jensen, P., & Keeling, L. (2018). Towards farm animal welfare and sustainability. *Animals (Basel)*, *8(6)*, 81.

Cariappa, A. G. A., Chandel, B. S., Sendhil, R., Dixit, A. K., Mani, V., & Meena, B. S. (2022). Do the prices of a preventive animal health product affect dairy farmers' willingness to pay and product use? Evidence from an experimental study. *Journal of Behavioral and Experimental Economics*, 100, 101925. https://doi.org/10.1016/j.socec.2022.101925

Carnovale, F., Jin, X., Arney, D., Descovich, K., Guo, W., Shi, B., & Phillips, C. J. C. (2021). Chinese public attitudes towards and knowledge of animal welfare. *Animals*, *11(3)*, 855. https://doi.org/10.3390/ani11030855

Chambers, R., & Conway, G. (1991). Sustainable rural livelihoods: Practical concepts for the 21st century (*IDS Discussion Paper No. 296*). Institute of Development Studies (IDS), Brighton.

Chand, R. (2023). India's white revolution: Achievements and the next phase (*NITI Working Paper No. 001/2023*). NITI Aayog, Government of India.

Clark, B., Stewart, G.B., Panzone, L.A., Kyriazakis, I., & Frewer L.J. (2016). A systematic review of public attitudes, perceptions and behaviours towards production diseases associated with farm animal welfare. *Journal of Agricultural and Environmental Ethics*, *29(3)*, 455–478. https://doi.org/10.1007/s10806-016-9615-x

DAHD (2024). *Basic animal husbandry statistics*. Ministry of Fisheries, Animal Husbandry & Dairying, Government of India.

Dastagiri, M.B. (2004). Demand and supply projections for livestock products in India (*Policy Paper No. 21*). National Centre for Agricultural Economics and Policy Research (NCAP), ICAR.

Deoghare, P.R. (1997). Sustainability of on-farm income and employment through livestock production in Mathura district of Uttar Pradesh. *Indian Journal of Animal Sciences*, 67(10), 916–919.

DFID (1999). *Sustainable livelihoods guidance sheets*. Department for International Development (DFID), UK Government.

Dikshit, A. K., & Birthal, P. S. (2010). Environmental value of dung in mixed crop-livestock systems in India. *Indian Journal of Animal Sciences*, 80(7), 679–682.

Dlamini, P., Chivenge, P., & Chaplot, V. (2016). Overgrazing decreases soil organic carbon stocks the most under dry climates and low soil pH: A meta-analysis shows. *Agriculture, Ecosystems & Environment*, 221, 258-269. https://doi.org/10.1016/j.agee.2016.01.026

FAO. (2002). Livestock services and the poor: Papers, proceedings, and presentations from the pro-poor livestock policy initiative workshop (28–29 October 2002). Bhubaneswar, India.

FAO. (2009). *The state of food and agriculture 2009 – Livestock in the balance*. Food and Agriculture Organization of the United Nations. ISBN 978-92-5-106215-9.

FAO. (2023a). Sustainable livestock transformation: A vision for FAO's work on animal production and health. Rome: Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cc7474en

FAO. (2023b). Unlocking the potential of sustainable livestock production [Online]. Retrieved from https://www.fao.org/newsroom/detail/unlocking-the-potential-of-sustainable-livestock-production/en

Gandhi, V. P., & Zhou, Z.-Y. (2010). Rising demand for livestock products in India: Nature, patterns, and implications. *Australasian Agribusiness Review*, 18(1), 103–135.

Gao, Q., Fang, C., & Cui, X. (2021). Carrying capacity for SDGs: Review of connotation evolution and practices. *Environmental Impact Assessment Review*, 91, 106676. https://doi.org/10.1016/j.eiar.2021.106676

GoI. (2001). *Status of desertification – Volume 1*. India's National Action Programme to combat desertification in the context of United Nations Convention to Combat Desertification (UNCCD). Ministry of Environment & Forests, New Delhi.

GoI. (2012). *The working group on animal husbandry and dairying: 12th Five-Year Plan 2012–17*. Planning Commission, New Delhi.

GoI. (2014). *Report of the expert group to review the methodology for measurement of poverty* (Rangarajan Committee). Planning Commission, Government of India.

Gujarati, D.N., Porter, D.C., & Gunasekar, S. (2015). *Basic econometrics* (5th ed.). McGraw Hill Education (India) Private Limited.

Hansen, B. G. (2023) 'Animal welfare and farm economy-exploring the relationship between dairy animal welfare indicators and economic efficiency'. Preventive Veterinary Medicine, 221: 106058. https://doi.org/10.1016/j.prevetmed.2023.106058.

Hansen, J.W. (1996) Is agricultural sustainability a useful concept? *Agricultural Systems*, 50(2): 117-143.

Hazell, P.B.R. (1982). Instability in Indian foodgrain production (*Research Report No. 30*). International Food Policy Research Institute, Washington D.C., USA.

Henningsen, A., Czekaj, T. G., Forkman, B., Lund, M., & Nielsen, A. S. (2016). The relationship between animal welfare and economic performance at farm level: A quantitative study of Danish pig producers. *IFRO Working Paper No. 2016/05*. University of Copenhagen, Department of Food and Resource Economics (IFRO), Copenhagen.

Johnson, K. A., & Johnson, D. E. (1995). Methane emissions from cattle. *Journal of Animal Science*, *73(8)*, 2483-2492. https://doi.org/10.2527/1995.7382483x

Jumrani, J., & Birthal, P. S. (2015). Livestock, women, and child nutrition in rural India. *Agricultural Economics Research Review*, 28(2), 223–246.

Kashish, Kaur, M., Sekhon, M. K., & Dhawan, V. (2017). Impact of dairying on income and income distribution of smallholder dairy farmers in Punjab. *Indian Journal of Dairy Science*, 70(6), 781–788.

Kelley, T.G., & Parthasarathy Rao, P. (1994). Trends in cultivated green fodder crops in India. In Joshi, A.L., Doyle, P.T., & Oosting, S.J. (Eds.), *Proceedings of a National Seminar on Variation in the Quantity and Quality of Fibrous Crop Residues* (pp. 98–100). BAIF Development Research Foundation.

Kleeman, G. (1999). Resources of livestock services delivery and its management to the Asian economic crisis. In *Proceedings of the workshop on the implication of the Asian economic crisis for the livestock industry* (pp. 61–80). Food and Agriculture Organization Regional Office.

Kumar, A., Chandel, B. S., Dixit, A. K., & Singh, A. (2023). Water Use Efficiency in Milk Production of Selected Dairy Breeds in Central Region of Bihar: A Lifetime Analysis. *Agricultural Research*, *12(3)*, 339-345. https://doi.org/10.1007/s40003-023-00655-w

Kumar, C., & Kamboj, M.L. (2016). Assessment of dairy cattle welfare in different types of dairy farms in Haryana. *Bhartiya Krishi Anusandhan Patrika*, 31(4), 302–303.

Kumar, N., Suhag, K.S., Kumar, S., Kumar, J., & Chaudhary, K.R. (2012). Resource use efficiency of cattle and buffalo milk production in Haryana. *Indian Journal of Animal Sciences*, 82(8), 930–934.

Kumar, S. (2011). Analysis of willingness to pay for veterinary services by livestock owners in Sangli district of Maharashtra. *Agricultural Economics Research Review*, 24(1), 149–153.

Lebacq, T., Baret P.V., & Stilmant D. (2013). Sustainability indicators for livestock farming: A review. *Agronomy for Sustainable Development*, 33(2), 311–327.

Leonard D.K. (1993). Structural reform of the veterinary profession in Africa and the new institutional economics. *Development and Change*, 24(2), 227-267.

Liang, Y., Chen, R., Liu, H., Han, L., & Yin, S. (2023). Glimpsing the future of animal welfare through a bottle of milk: Insights from Chinese university students. *Foods*, 12(21), 4044. https://doi.org/10.3390/foods12214044

Márquez Romero, F., Julca Otiniano, A., Canto Saenz, M., Soplín Villacorta, H., Vargas Winstanley, S., & Huerta Fernández, P. (2016). Environmental sustainability in coffee farms after an organic certification process at La Convencion (Cusco, Peru). *Applied Ecology* , 15 (2), pp. 125-132. https://doi.org/10.21704/rea.v15i2.752

McInerney, J. (2004). Animal welfare, economics and policy. In: Report on a Study Undertaken for the Farm & Animal Health Economics Division of Defra, 68. Retrieved from http://refhub.elsevier.com/S0921-8009(23)00030-7/rf0130

Menzi, H., Oenema, O., Burton, C., Shipin, O., Gerber, P., Robinson, T., & Franceschini, G. (2009). Impacts of intensive livestock production and manure management on ecosystems. In H. Steinfeld, H. Mooney, F. Schneider & L. Neville (Eds.), *Livestock in a changing landscape: Drivers, consequences, and responses* (Vol. 1). Island Press.

MoEFCC. (2023). India: Third National Communication and Initial Adaptation Communication to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change, Government of India.

NITI Aayog. (2023). India: National Multi-Dimensional Poverty Index – A Progress Review 2023. Government of India.

NSO. (2005). Situation assessment of agricultural households: Land, expenditure and productive assets of farmer households (*NSS Report No. 497*). Ministry of Statistics & Programme Implementation, Government of India.

NSO. (2014). Key indicators of situation of agricultural households in India (*NSS 70th Round*). Ministry of Statistics & Programme Implementation, Government of India.

NSO. (2021a). All India debt and investment survey – 2019 (*NSS Report No. 588*). Ministry of Statistics & Programme Implementation, Government of India.

NSO. (2021b). Situation assessment of agricultural households and land holdings in rural India – 2019 (*NSS Report No. 587*). Ministry of Statistics & Programme Implementation, Government of India.

Ojha, R.K. (2007). Poverty dynamics in rural Uttar Pradesh. *Economic & Political Weekly*, 42(16), 1453–1458.

Otta, S., Quiroz, J., Juaneda, E., Salva, J., Viani, M., & Filippini, M. F. (2016). Sustainability assessment of an extensive cattle breeding model in Mendoza, Argentina. *Journal of the Faculty of Agricultural Sciences*. National University of Cuyo, 48 (1), 179-195.

Parlasca, M., Knößlsdorfer, I., Alemayehu, G., & Doyle, R. (2023). How and why animal welfare concerns evolve in developing countries? *Animal Frontiers*, *13(1)*, 26–33. https://doi.org/10.1093/af/vfac082

Parthasarathy Rao, P., & Bhowmick, T. (2001). Database development, typology construction, and spatial-temporal analysis of crop-livestock systems in India (*Progress Report No. 1*). International Livestock Research Institute.

Parthasarathy Rao, P., & Hall, A.J. (2003). Importance of crop residues in crop-livestock systems in India and farmers' perceptions of fodder quality in coarse cereals. *Field Crops Research*, 84(2), 189–198.

Peña, J., Alegre, J., & Bardales, R. (2018). Effects of cultivated richness on the sustainability of agroforestry systems in the south Peruvian Amazon. *Ecosistemas*, 27(3), 87–95.

Perry, B.D., Robinson, T.P., & Grace, D.C. (2018). Animal health and sustainable global livestock systems: A review article on the challenges and opportunities for sustainable livestock production systems globally. *Animals*, 12(8), 1699-1708

Pradyumna, A., Winkler, M. S., Utzinger, J., & Farnham, A. (2021). Association of livestock ownership and household dietary quality: Results from a cross-sectional survey from rural India. *International Journal of Environmental Research and Public Health*, *18(11)*, 6060. https://doi.org/10.3390/ijerph18116060

Pushpa. (2017). *Impact assessment of livestock services and economic analysis of their delivery mechanism in Gujarat* (Unpublished doctoral dissertation). Division of Dairy Economics, Statistics & Management, ICAR-NDRI, Karnal.

Rademaker, C., Glas, G., & Jochemsen, H. (2017). Sustainable livestock farming as normative practice. *Philosophia Reformata*, 82(2), 216-240.

Rangnekar, D. V. (2006). Livestock in the livelihoods of the underprivileged communities in India: A review. International Livestock Research Institute, Nairobi, Kenya.

Rangnekar, D.V. (2015). Livestock Extension - Need for a Paradigm Change. AESA Blog No. 32, Livestock Extension. Retrieved from https://www.aesanetwork.org/wp-content/uploads/2015/02/AESA-BLOG-32.pdf

Roy, A. K., Agrawal, R. K., Bhardwaj, N. R., Mishra, A. K., & Mahanta, S. K. (2019). Scenario revisiting national forage demand and availability. In A.K. Roy, R.K. Agrawal & N.R. Bhardwaj (Eds.), *Indian fodder scenario: Redefining state-wise status* (pp. 1-21). ICAR-AICRP on Forage Crops and Utilization, Jhansi, India.

Samal, A., Sahu, S. K., Mishra, A., Mangaraj, P., Pani, S. K., & Beig, G. (2024). Assessment and Quantification of Methane Emission from Indian Livestock and Manure Management. *Aerosol and Air Quality Research*, *24*(6), 230204. https://doi.org/10.4209/aaqr.230204

Sarandón, S.J., & Flores, C.C. (2009). Sustainability assessment in agroecosystems: A methodological proposal. *Agroecology*, 4, 19–28. Retrieved from https://revistas.um.es/agroecologia/article/view/117131

Sasidhar, P.V.K., & Suvedi, M. (2016). Assessment of core competencies of livestock extension professionals in India. Urbana, IL: USAID-Modernizing Extension and Advisory Services (MEAS).

Scherer, L., Tomasik, B., Rueda, O., & Pfisher, S. (2018). Framework for integrating animal welfare into life cycle sustainability assessment. *International Journal of Life Cycle Assessment*, 23(8), 1476-1490. https://doi.org/10.1007/s11367-017-1420-x

Sharma, D., & Behl, T. (2020). Expanding the restricted realm of international trade law to animal welfare. *Völkerrechtsblog*. https://doi.org/10.17176/20210107-183516-0

Sidhu R.S., & Bhullar A.S. (2004). Changing structure of the farm economy in Punjab: Impact of livestock on income and employment. *Indian Journal Agricultural Economics*, *59(3),* 578–587.

Singh, A., Kamboj, M. L., & Chandel, B. S. (2022). A study on cow welfare vis-à-vis sustainability of gaushalas (cow orphanages). *Indian Journal of Dairy Science*, 75(3), 267–271.

Srivastava, A.K., Patel, J.B., Ankuya, K.J., Chauhan, H.D., Pawar, M.M., & Gupta, J.P. (2019). Conservation of indigenous cattle breeds. *Journal of Animal Research*, 9(1), 1-12.

Staal, S., Poole, J., Baltenweck, I., Mwacharo, J., Notenbaert, A., Randolph, T., Thorpe, W., Nzuma, J., & Herrero, M. (2009). Strategic investment in livestock development as a vehicle for rural livelihoods. *Bill and Melinda Gates Foundation–ILRI Knowledge Generation Project Report*. International Livestock Research Institute, Nairobi, Kenya.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., & de Haan, C. (2006). *Livestock's long shadow: Environmental issues and options*. Food and Agriculture Organization of the United Nations, Rome.

Thirunavukkarasu, M., & Christy, J. (2002). Socio-economic dimensions of female participation in livestock rearing: A case study in Tamil Nadu. *Indian Journal of Agricultural Economics*, 57(1), 99–103.

Tullo, E., Finzi, A., & Guarino, M. (2019). Environmental impact of livestock farming and precision livestock farming as a mitigation strategy. *Science of the Total Environment*, 650(2), 2751–2760.

Varathan, J. B., Prabu, M., Pandian, A. S. Saravana, & Senthikumar, G. (2013). Employment and income generation through livestock among women self-help groups: A study in Thiruvannamalai District, Tamil Nadu. *Tamil Nadu Journal of Veterinary & Animal Sciences*, 9(3), 172–182.

Varijakshapanicker, P., McKune, S., Miller, L., Hendrickx, S., Balehegn, M., Dahl, G.E., & Adesogan, A.T. (2019). Sustainable livestock systems to improve human health, nutrition and economic status. *Animal Frontiers*, 9(4), 39–50.

Wang, Q., & Batkhishig, O. (2014). Impact of overgrazing on semiarid ecosystem soil properties: A Case study of the Eastern Hovsgol Lake Area, Mongolia. *Journal of Ecosystem & Ecography*, *4(1),* 1. https://doi.org/10.4172/2157-7625.1000140

WHO (2024). One Health fact sheet [Online]. Retrieved from https://www.who.int/news-room/fact-sheets/detail/one-health

World Bank (n.d.). GDP deflator for India [Online]. Retrieved from https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS.AD?locations=IN

Yadav, P., Chandel, B. S., Agarwal, P., Sirohi, S., & Chand, P. (2021). Farmer's willingness-to-pay for animal health and livestock insurance services in milking state of India: Empirical findings from rural areas of Gujarat. *Bhartiya Krishi Anusandhan Patrika*, 36(2), 92-99. https://doi.org/10.18805/BKAP298

APPENDIX 1. COEFFICIENCT OF LOG-LINEAR REGRESSION FOR DIFFERENT SIZE GROUPS (2018-19)

Particulars/ Inputs	Farm Size Groups				
	Landless Households	Marginal Households (≥0.004 to < 1 ha)	Small Households (1-2 ha)	Medium Households (2-10 ha)	Large Households (≥ 10 ha)
Observations (n)/ groups (g)	n = 674 g =673	n = 2430 g = 2113	n = 1551 g = 1273	n = 4855 g = 3283	n =90 g = 64
Constant	324.8517 (323.6799)	236.2271 (210.8904)	530.9106 (339.0030)	1135.6540*** (165.884)	2659.4260 (2097.9010)
Green fodder	2.5798*** (0.1680)	1.8941*** (0.1163)	1.6031*** (0.1678)	0.9366*** (0.0767)	2.2404*** (0.5049)
Dry fodder	0.8575*** (0.2175)	1.2605*** (0.1091)	0.7075*** (0.1342)	0.4713*** (0.0641)	-0.8547* (0.4944)
Concentrate	1.4791*** (0.0795)	1.0223*** (0.0424)	0.9095*** (0.0534)	1.4600*** (0.0492)	1.3070*** (0.2692)
Labour charges	0.4282*** (0.1584)	0.7799*** (0.0930)	0.4643*** (0.1506)	0.9424*** (0.0698)	0.0506 (0.4562)
Veterinary cost	1.6823*** (0.5266)	0.8413*** (0.2292)	1.8662*** (0.3393)	1.2274*** (0.1742)	2.8988*** (1.0833)
Other expenses	1.8525*** (0.2237)	1.0528*** (0.0569)	2.4674*** (0.1248)	1.3062*** (0.0362)	1.7009*** (0.3234)
R^2	87.77*** F(6,666) =796.77	67.78*** F(6,2106) = 903.15	64.76*** F(6,1266) = 405.58	62.95*** F(6,3276) = 1067.96	80.03*** F(6, 57) = 41.65

Source of data: Unit level data of NSO survey of 77th round.

*** The coefficients are significant at a 1% level of probability (H_0: β_i=0)

Note: Other expenses are comprised of other fodder, animal seed besides interest on loans, land rent of leased in land, livestock insurance, etc.