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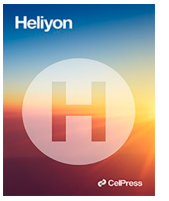

Research article

A preliminary analysis and estimation of the status of feed and fodder in Kerala

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ABSTRACT

The livestock sector is experiencing continuous global growth, projected to surge by 60–70 per cent by 2050, with developing countries bearing the brunt of this expansion. This trend strongly suggests that the demand for and supply of feed and fodder in developing nations must increase proportionally to avoid a crisis. However, severe data scarcity hampers efforts to determine what and how much to produce. This situation is mirrored in the Indian state scenario, including Kerala. This paper addresses these challenges by analysing the dynamics of feed and fodder demand and supply in Kerala, utilizing a blend of primary and secondary data. It examines the unique characteristics and likely reasons behind them, contrasting Kerala's situation with that of other developing countries. The findings reveal a deficit in feed and fodder supply in the state, reflecting broader trends in developing countries, albeit with a surplus of green fodder. The study also delves into the determinants of agricultural income for animal-rearing farmers in Kerala, highlighting distinct social dimensions. Considering these insights, the study recommends critical policy interventions to address the feed and fodder deficit, emphasizing the potential for leveraging indigenous approaches to mitigate the shortfall.

1. Introduction

Agriculture and animal husbandry are deeply intertwined with the complex tapestry of human society, influenced by cultural, religious, and economic factors. Mixed farming and the raising of livestock are essential components of rural life [1]. Livestock can serve as a significant avenue for poverty alleviation in developing nations [2–4]. Additionally, livestock plays a crucial role in rural economic and social dimensions, such as transportation, manure, fuel, milk, and meat. For subsistence farmers, livestock often serves as the primary source of revenue and security against anticipated crop failure [5]. Notably, the livelihood and food security of nearly a billion people worldwide are directly influenced by livestock, and its impact on health is even broader [6,7].

Per the 'livestock revolution' hypothesis [8], [3], the sector is predominantly fueled by increasing incomes and urbanization in developing nations such as India, where there is a surging demand for livestock products such as meat and milk. India boasts the world's largest and most diverse livestock population, a remarkable asset [5]. In India, roughly 70 per cent of households rely on the livestock and agriculture sector for their livelihood [9].

The 18th, 19th, and 20th livestock censuses conducted in 2007, 2012, and 2019 respectively show a steady increase in livestock in India [10–12]. According to National Accounts Statistics (NAS), India estimates for 2022, livestock now contributes 30.13 per cent

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(2020–21) of all agriculture and allied sector Gross Value Added (GVA) (at constant prices), up from 29.33 per cent in 2019–20. In 2020–21, the cattle industry contributed 4.90 per cent of the total GVA [13].

In Kerala, a state situated in southern India, the agriculture sector continues to serve as the mainstay for the majority of the population's livelihoods. Furthermore, livestock emerges as one of the rapidly expanding rural sectors in Kerala [14]. Concerning the overall agriculture and related sector GVA (constant price), the livestock sector contributed 26.44 per cent. In 2021–2022, the state's share of the total GVA of India for the same year was 2.35 per cent. Real GVA in the livestock sector increased marginally from Rupees. 11,701.86 crore in 2020–21 to Rupees. 11,714.01 crore in 2021–22 at constant prices (2011–12) [14].

Like many developing countries, there is a lack of reliable information on feed and fodder production and availability in India and Kerala. There are no comprehensive government efforts to gather data on the land, production, and other relevant aspects of feed and fodder. However, the only database providing information on the area covered by various crops grown in different Indian states for different years is the Land Use Statistics of the Ministry of Agriculture, Government of India. According to this source, India's total planted land constituted just 4.30 per cent (on average from 2005-06 to 2014–15) allocated to fodder crops. The situation in Kerala is significantly lower, with only 0.22 per cent of the state's total planted acreage covered by fodder crops. Consequently, Indian states face a substantial disparity between national feed and fodder demand and actual supply [15]. They observed that arid and semi-arid regions displayed a more acute shortage of feed and fodder, with South Indian states potentially facing a fodder crisis in the future.

Given the scarcity of data on feed and fodder in India and Kerala, there is a lack of major or credible surveys or studies in the domain. Both governments and other agencies have overlooked the issue, and the research available in the public domain is merely speculative [16]. Against this backdrop, this study endeavours to review and estimate the availability of feed and fodder in Kerala. The rationale behind this study is to address the lack of research in this domain, with a specific focus on the state of Kerala in India. Drawing upon field-based first-hand data, this study aims to uncover the ground realities of the feed and fodder sector in the state, with potential implications for other states in India as well as developing countries worldwide.

2. Livestock and feed and fodder in India and Kerala

Table 1 illustrates the scale and dynamics of livestock in India, documented through three consecutive censuses conducted in 2007, 2012, and 2019. Overall, India's livestock population has experienced significant growth across these censuses. However, the data also indicates a relatively stagnant trend in livestock numbers, excluding poultry, which have declined over this period. Conversely, poultry numbers have shown an increase. In essence, there has been approximately a six percent decrease in livestock numbers, excluding poultry, while poultry numbers have increased in the state. The trend observed in the last two censuses reveals that poultry constitute nearly 60 percent of the total livestock population, with other livestock comprising only around 40 percent. This shift in livestock composition suggests an increased demand for poultry products in the consumer market. Among the total livestock population excluding poultry, cattle represent the largest proportion (14 percent), followed by goats (11 percent) and buffaloes (9 percent) as of 2019, consistent with trends observed in previous censuses (2007, 2012).

Table 2 illustrates that in Kerala, the trend mirrors the national pattern but in an intensified manner, with poultry dominating the livestock sector at rates of 81 per cent (2007), 90 per cent (2012), and 91 per cent (2019) of the total livestock in the state. Concurrently, there has been a notable decrease in other livestock from 2007 (19 percent) to 2012 (12 percent) to 2019 (9 percent). Similarly to the national trend, cattle and goats (4 per cent each) represent the primary share of the livestock in the state. However, unlike the national scenario, the proportion of buffaloes in the state is minimal. Moreover, livestock such as sheep and pigs have never constituted a significant category over these years. Fueled by the growth in the poultry sector, the total livestock (including poultry) has substantially increased in the state, becoming the predominant segment of livestock, signalling a shift in people's consumption behaviour.

As previously discussed, there is a lack of comprehensive databases on feed and fodder in India or Kerala. Therefore, we rely on existing studies and reports in this regard. Various feeds and fodders, broadly categorized as roughages, concentrates, feed supplements, and feed additives, are used in the sector to feed livestock in the state. Major issues concerning feed and fodder production in the sector include stagnant fodder production areas, declining pasturelands, and the substitution of coarse cereal crops [17]. Despite a noticeable increase in the volume of livestock and its economic value contributions in Kerala, the intense pressure on commercial crops has impeded commensurate growth in feed and fodder supplies. The livestock sector still needs to make greater efforts to adequately

Table 1
Livestock statistics India (in hundred thousand).

Livestock Type	18th Census (2007)	Percent to Total	19th Census (2012)	Percent to Total	20th Census (2019)	Percent to Total
Cattle	1990.75	16.89	1909.04	15.38	1934.63	13.39
Buffaloes	1053.42	8.94	1087.02	8.76	1098.52	7.91
Sheep	715.58	6.07	650.69	5.24	742.61	5.34
Goats	1405.37	11.92	1351.73	10.89	1488.85	10.7
Pigs	111.33	0.94	102.93	0.83	90.5	0.65
Others	20.48	0.17	19.88	0.16	7.9	0.056
Total (Livestock)	5296.93	44.95	5121.29	41.26	5367.6	38.6
Total (Poultry)	6488.29	55.05	7292.09	58.74	8518.1	61.34
Grand Total	11785.22	100.00	12413.38	100.00	13885.7	100

Source: Author Compiled from 19th and 20th Livestock Census, Government of India.

Table 2
Livestock statistics Kerala (in hundred thousand).

Livestock Type	18th Census (2007)	Percent to Total	19th Census (2012)	Percent to Total	20th Census (2019)	Percent to Total
Cattle	17.4	9.03	13.29	4.92	13.42	4.11
Buffaloes	0.58	0.30	1.02	0.38	1.01	0.309
Sheep	0.01	0.01	0.02	0.01	0.01	0.003
Goats	17.29	8.97	12.46	4.61	12.46	3.82
Pigs	0.59	0.31	0.56	0.21	1.03	0.315
Others	…	….	…	….	….	…
Total (Livestock)	35.87	18.61	27.35	10.12	27.93	8.56
Total (Poultry)	156.85	81.39	242.82	89.88	298.18	91.43
Grand Total	192.72	100	270.17	100.00	326.11	100

Source: Author Compiled from 19th and 20th Livestock Census, Government of India, and Kerala Economic Review, 2019.

meet the simultaneous demand for high-quality feed and fodder to maintain high output and generate quality outputs from the sector [17].

Furthermore, in the context of Kerala, there are other social and institutional dimensions to consider. Kerala's high population density (land shortage) and reliance on cash crops (perennial crops) and spices create unfavourable conditions for producing feed and fodder. In Niger found that the significant factors limiting the productivity of livestock systems are inadequate quantity and quality of feed resources, mirroring the situation in Kerala [18]. The rising costs for farmers due to feed input problems, such as sourcing feed and fodder from another state like Tamil Nadu, are evident in Kerala [19]. This dependency-induced issue of feed and fodder shortage is a well-established problem globally, as seen in comparable developing countries like Pakistan [20].

Moreover, it is evident that the prices for fodder in the state have stagnated for several years, discouraging farmers from producing it [21]. Considering that Kerala is a state that also consumes both feed and fodder, studies noted the limited natural dry and green feed and fodder supply in Kerala. This argument is supported by a robust analysis of the availability, demand, and gap between the demand and supply of feed and fodder in Kerala, using limited data or proxies [22–24].

3. Data and methodology

The paper is derived from a study sponsored by the Ministry of Agriculture and Farmers Welfare, Government of India, titled 'Assessment of Feed and Fodder in Kerala' [17], conducted at the Agro Economic Research Centre (AERC) Chennai, University of Madras. This paper exclusively focuses on the state of Kerala, which is comparable to developing countries worldwide, and relies on both primary and secondary data.

Secondary data from quinquennial Livestock Censuses of India, Land Use Statistics, and Kerala Economic Review Reports are utilized. Utilizing an appropriate extraction ratio, also known as the Residues to Product Ratio (RPR), the availability of dry fodder, greens, and concentrates was determined to estimate the demand and supply of feed and fodder resources (deficit/surplus) for livestock in Kerala [45]. To convert the quantity of green, dry, and concentrate feed into Dry Matter (DM), a factor of 0.25 for green feed and 0.90 for dry feed and concentrate feed was applied [25]. Based on their conversion factors, crop residues and concentrates from different cereals, pulses, and oilseeds were estimated [26]. To convert the DM from each source into Total Digestible Nutrients (TDN), the following conversion factors were used: 0.534 for green fodder, 0.476 for dry fodder, and 0.780 for concentrate feed. For each source's green fodder, dry fodder, and concentrate feed, the conversion coefficients for DM into Crude Protein (CP) were 0.073, 0.016, and 0.180, respectively [27]. The most important fodder crops, including maize, sorghum, pearl millet, Egyptian clover, lucerne, cluster beans, etc., were all taken into account. Fodder productivity was assessed using a weighted average of 40.93 tons/ha, considering the minimum output of each fodder crop, and the area under fodder crops was calculated to be 8.9 million hectares [28].

In addition to the secondary data, A primary survey was conducted to collect data on the socioeconomic and livestock profiles of 440 livestock-rearing farmers in 2018–19 (Table 3). The study's samples were chosen based on the livestock population recorded in the livestock census (Table 2), considering it as the universe. A proportionate sampling technique was used to estimate the sample size in the state's districts. The distribution of livestock population by district was used to select the study's sample districts, and those districts were ranked according to the size of their respective populations of cattle, buffalo, sheep, and goats. Subsequently, the average of these rankings for each district was determined. While accounting for regional representations (North, Central, and South), the top three ranks (districts) were chosen. All three of Kerala's major geographical regions were considered for the study through careful design. Therefore, Kollam represents Southern Kerala, Ernakulam represents Central Kerala, and Malappuram represents Northern

Table 3
Sampling frame.

State	Districts	Cattle	Buffalo	Goat	Total
Kerala	Ernakulam (Central)	68	40	54	162
	Malappuram (North)	65	57	50	172
	Kollam (South)	56	13	37	106
	Subtotal	189	110	141	440

Source: Primary Survey.

Kerala. The farmers in the sample are diverse, engaging in multiple livestock-rearing activities simultaneously (i.e., they may rear buffalo, cattle, and goats concurrently).

Given the limited availability of data and research in this field, this study adopts an exploratory approach, primarily relying on descriptive statistics. However, it extends the research further by employing a multiple regression econometric model, adapted from Mumba et al. [29], to analyze the determinants of agricultural income in Kerala's livestock sector. This choice is influenced by empirical studies in livestock economics, particularly in developing and underdeveloped economies, which commonly utilize multiple regression techniques to explore the correlation between socio-economic factors and agricultural profitability [30–33]. Moreover, contextualizing the analysis within the framework of small-scale animal rearing makes this approach particularly suitable for this study, given that the majority of farmers in Kerala operate on a small or marginal scale. The regression model can be expressed in the following generic form;

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ip} + \varepsilon_i$$

In the regression model, *Yi* represents the value of the outcome variable for case *i,* where β0 is the regression constant. *Xij* denotes the score of case *i* on the jth of p predictor variables in the model, while βj represents the partial regression weight of predictor *j.* Additionally, εi signifies the error for case *i.* The descriptions of the dependent (Y) and independent (X) variables utilized in the study are provided in Table 4.

4. Analysis and discussions

4.1. Livestock farmer profile

According to Table 5, the average age of farmers is 53, indicating a significant presence of the older generation in the sector. The younger generation in the state is scarcely visible in the agricultural and related sectors, as several recent studies have confirmed [21,34]. This is often attributed to the relatively higher levels of education and significant state-wide emigration in Kerala [35]. This mirrors the observations of global studies [36], where the aspirations of young rural individuals are primarily directed towards formal sector employment and modern urban lifestyles, with a widespread reluctance, observed across various contexts, to consider farming as a viable career option. It is evident throughout Southeast Asia that farmers aspire to leave agriculture themselves, and they hope for their children to pursue careers outside of farming [37].

The educational background of the farmers is remarkable and is strongly bolstered by Kerala's renowned achievements in literacy and education, often referred to as the Kerala Model of Development [38]. Approximately 49 per cent of respondents have completed high school, while about 14 per cent have attained education beyond that level. However, the proportion of highly educated farmers is minimal, constituting just 5 per cent, indicating that nearly 70 per cent of farmers have an education beyond high school.

The gender dimension is predominantly male, with more than two-thirds of the farmers being male, indicating the prevailing patriarchal norms in our society. Despite many households engaging in backyard animal husbandry (homesteading), it is typically the responsibility of women in the family to manage these activities, yet their contributions are often overlooked and not fully recognized in society. In some cases, female respondents even insisted on listing their spouses as the primary farmers in official records. This highlights the unaccounted labour and persistent gender inequality in the sector, particularly in Asian countries like India [39,40].

4.2. Feed and fodder fed to livestock

There are various feed and fodder requirements (per day) for different categories of cattle, including milking, dry, male, pregnant and non-pregnant heifers, juvenile stocks, and adult animals. Additionally, the types of fodder vary, encompassing grazing fodder,

Table 4
Variable definitions.

Variable Name	Variable Description
Age	Age in years
Gender (Male)	The dummy variable takes two nominal values as 1 for males and 0 otherwise
Gender (Female)	The dummy variable takes two nominal values as 1 for females and 0 otherwise (Reference category used in the regression)
Education (Illiterate)	The dummy variable takes two nominal values as 1 for illiteracy and 0 otherwise
Education (Primary)	The dummy variable takes two nominal values as 1 for primary schooling and 0 otherwise
Education (Secondary)	The dummy variable takes two nominal values as 1 for secondary schooling and 0 otherwise
Education (Collegiate)	The dummy variable takes two nominal values as 1 for collegiate education and 0 otherwise (Reference category used in the regression)
Farming Experience	Years of experience in farming and animal husbandry
Cooperative Society Membership (Yes)	The dummy variable takes two nominal values as 1 for having membership in an agricultural cooperative society in their locality and 0 otherwise
Cooperative Society Membership (No)	The dummy variable takes two nominal values as 1 for not having membership in an agricultural cooperative society in their locality and 0 otherwise (Reference category used in the regression)
Herd Size	Number of livestock owned by the framer
Family Size	Number of family members

Source: Primary Survey.

Table 5
Socioeconomic profile of the farmers.

Sl. No	Particulars	Number/Percentage
1	Average Age	53.25
2	Education Level (%)	
	Illiterate	3.22
	Primary School	13.36
	Middle School	16.12
	High School	48.38
	Higher Secondary/Diploma	13.35
	Graduate & Above	5.52
4	Gender (%)	
	Male	76.49
	Female	23.50

Source: Primary Survey.

concentrates, dry fodder, and green fodder. The proportion of these feeds significantly varies depending on the type of cattle. Furthermore, availability and cost considerations play a crucial role in selecting specific fodder or combinations of fodders.

The typical daily feed and forage needs for a buffalo in the state are outlined in Table 6. A milking buffalo consumes approximately 42 kg of free green feed and 5 kg of dry feed, which costs 20 rupees per quintal. Moreover, a buffalo requires about 5 kg of concentrates and supplements daily, with each quintal costing around Rs. 63. Milking buffaloes typically spend more than 3 h grazing per day on average.

For a dry buffalo, a total of 25 kg of feed, including both green and dry fodder, is required. Considering that green fodder is provided free of cost, the farmer's only expense is for dry fodder, priced at Rs. 20 per quintal. Additionally, a dry buffalo needs 2 kg of concentrates and supplements, costing approximately Rs. 57 per quintal. Unlike milking buffaloes, dry buffaloes do not need to graze daily.

Male buffaloes require 2 kg of concentrates and supplements, which may cost around Rs. 65 per quintal. They also need a total of 30 kg of combined dry and green fodder, with dry fodder priced at Rs. 20 per quintal. Male buffaloes require longer grazing periods, about 4 h longer each day compared to females. Pregnant buffalo heifers require approximately the same amount of food as milking ones. However, they require less grazing time compared to milking buffaloes. Young stocks (less than a year old) and adult buffaloes (ages 1 to 2) require less feed compared to other categories of buffaloes. Both of these categories require longer grazing periods, with young stocks needing 5 h and adult buffaloes needing 4 h.

Buffaloes aged between one and two years require approximately Rs. 90 per day for fodder, supplements, and concentrates, making it the highest expenditure among all categories of buffaloes. The feed cost for young stock in the state is Rs. 76 per day, which is the least expensive among all categories. This suggests that the price of fodder for different buffalo breeds does not vary significantly, potentially due to the homestead method of raising animals in Kerala. The cost of dry and concentrate components of fodder varies depending on the age and sex of the stock, while green fodder in the state is freely available to all, typically obtained from adjacent locations. In general, milch and pregnant cattle have similar fodder needs and costs, whereas male and dry buffaloes can be compared for the same purpose.

Table 7 illustrates the daily feed and fodder requirements for crossbreed cattle in the state. Milking cattle collectively require 34 kg of green and dry feed, along with approximately 4 kg of concentrates and supplements. The average cost of feed for cattle is comparable to that for buffaloes; the primary difference between the two lies in quantity. Milking cattle typically graze for around 3 h per day, while dry cattle graze for approximately one and a half hours. Dry cattle require roughly half the amount of feed compared to milking cattle. For dry cattle, among others, the total cost of food is expectedly low at Rs. 88 per day. The average daily feeding costs for milking cattle are Rs. 94, indicating no significant difference in costs between milking and dry cattle.

Male cattle require 19 kg of combined green and dry feed daily, along with significantly fewer concentrates and supplements (2 kg daily). Similarly, male cattle graze for just 1 h daily, the shortest grazing time among all categories. This suggests that farmers are less

Table 6
Average feed and fodder requirement for buffalo (per day per animal).

Particulars	Green Fodder		Dry Fodder		Concentrates		Supplements		Grazing (hrs/day)
Quantity/Price/Hours	Qty (kg)	Price (Rs/Qtl)	Qty (kg)	Price (Rs/Qtl)	Qty (kg)	Price (Rs/Qtl)	Qty (kg)	Price (Rs/Qtl)	
Milking	41.364	0	5.190	19.52	3.381	28.28	1.137	35.33	3.27
Dry	22.857	0	1.786	20	1.5	25	1	32	0
Male	26.612	0	3.974	19.31	1.741	27.49	0.351	37.34	3.62
Heifer Pregnant	41.875	0	4.125	18.12	3.5	27.25	1.5	32	3.125
Heifer non-pregnant	0	0	0	0	0	0	0	0	0
<1 year	20.333	0	2.062	18.92	1.097	32	0.052	24.85	4.11
1–2 Year	28.705	0	4.466	18.75	1.926	28.21	0.310	42.21	3.46

Source: Primary Survey.

Table 7
Average feed and fodder requirement for cross breed cattle (per day per animal).

Particulars	Green Fodder		Dry Fodder		Concentrates		Supplements		Grazing (hrs/ day)
Quantity/Price/ Hours	Qty (kg)	Price (Rs/ Qtl)	Qty (kg)	Price (Rs/ Qtl)	Qty (kg)	Price (Rs/ Qtl)	Qty (kg)	Price (Rs/ Qtl)	
Milking	29.24	0.01	3.99	22.04	3.27	31.17	0.80	40.04	2.18
Dry	13.57	0	2.18	19.48	1.65	25.84	0.34	42.38	1.21
Male	16.65	0	1.78	23.20	1.10	28.8	0.37	43.05	1.05
Heifer Pregnant	27.75	0.04	3.24	21.86	2.27	27.67	0.69	39.05	2.17
Heifer non-pregnant	36	0	3.3	36	4	25	0.1	45	4.4
<1 year	13.87	0	1.03	23.04	1.05	28.86	0.29	44.41	1.73
1–2 Year	28.61	0	1.66	23.28	1.28	28.95	0.26	47.14	2.49

Source: Primary Survey.

inclined to raise male cattle and typically do not provide them with the same level of care as they do for milking cows and heifers. Male cattle are no longer considered as valuable for breeding purposes due to the increasing prevalence of artificial insemination. Moreover, in Kerala, buffalo meat is more highly valued than cattle meat in the market. Consequently, this group of cattle receives less attention overall.

Young cattle have the potential to develop into heifers, and farmers value them highly. Young cattle require 17 kg of fodder and 1.5 kg of concentrates and supplements, which is naturally the lowest quantity needed compared to other animals. However, calves aged one to two years need 31 kg of combined green and dry feed, which is approximately equivalent to the feed required by milking cattle. Heifers also require roughly the same amount of time spent grazing. Although the amount of feed a pregnant heifer requires is virtually identical to that needed for milking cattle, it is significantly less expensive. However, the concentrates and vitamins needed for this group are comparable to those for male cattle. This indicates that only the youngest cattle have low daily intake, and as they develop into heifers or mature male cattle, their intake needs approach those of adult cattle.

The non-pregnant heifer reports the highest daily feeding need (44 kg) and the highest daily feeding expense (Rs. 106). This suggests that farmers are eager to have them become pregnant or have calves sooner by making additional feeding efforts. Farmers frequently identify heifer infertility as a sign of insufficient feeding and begin daily feed supplements. Compared to the other heifers, the non-pregnant heifer's average grazing hours are likewise the longest, clocking in at almost 4 h.

In the state, indigenous cattle raising is rare. According to Table 8, all indigenous cattle are provided with free green grass as their sole food source. Milking native cattle require only 8 kg of green feed and 4 h of grazing per day, with even less needed for other categories. This suggests that raising indigenous cattle in Kerala is relatively inexpensive. However, due to their comparatively low milk production, raising indigenous cattle in the state is not feasible, given the high compliance cost.

According to Table 9, male and female goats have differing fodder requirements. Male goats under one year old require less food compared to females of the same age. However, male goats require more concentrates and vitamins than female goats. Both male and female goats need to graze for an average of 3 h per day. The daily feed cost for a male goat is approximately Rs. 70, while for a female goat, it is Rs. 40. This difference in cost may be explained by the high demand for male goats, particularly young ones, in the meat market. Consequently, farmers aim to maximize their weight gain. In contrast, female young goats are intended for raising and breeding over time, so they do not need to grow quickly through eating. As always, green fodder is freely available for raising goats in the state.

In contrast to the previous categories of livestock, the age group of 1 to 2-year-old goats exhibits a distinct pattern in their feed and fodder requirements. Here, the daily feed and fodder needs for male and female goats are approximately equal, costing around 60 rupees on average. The need for grazing time, feed, and fodder seems to follow the same trend for goats older than two years. The notable distinction in this case is that male goats require 4 h of daily grazing. Overall, it implies that the age and sex of a goat are not important factors in determining the feed and fodder requirements. While male goats are given more attention regarding feed and fodder when they are young due to their intended use in the meat market, this trend changes when they reach the age of one year.

The estimated feed and fodder requirements align closely with the findings of several studies conducted across various states of

Table 8
Average feed and fodder requirement for indigenous cattle (per day per animal).

Particulars	Green fodder		Dry fodder		Concentrates		Supplements		Grazing (hrs/ day)
Quantity/Price/ Hours	Qty (kg)	Price (Rs/ Qtl)	Qty (kg)	Price (Rs/ Qtl)	Qty (kg)	Price (Rs/ Qtl)	Qty (kg)	Price (Rs/ Qtl)	
Milking	8	0	0	0	0	0	0	0	4
Dry	1.5	0	0	0	0	0	0	0	0
Male	1.5	0	0	0	0	0	0	0	0
Heifer Pregnant	2	0	0	0	0	0	0	0	0
Heifer non-pregnant	0	0	0	0	0	0	0	0	0
<1 year	1.5	0	0	0	0	0	0	0	0
1–2 Year	0	0	0	0	0	0	0	0	0

Source: Primary Survey.

Table 9
Average feed and fodder requirement for goats (per day per animal).

Particulars	Gender	Green Fodder		Dry Fodder		Concentrates		Supplements		Grazing (hrs/day)
		Qty (kg)	Price (Rs/Qtl)	Qty (kg)	Price (Rs/Qtl)	Qty (kg)	Price (Rs/Qtl)	Qty (kg)	Price (Rs/Qtl)	
<1 year	Male	3.32	0	1	17.5	0.61	20.73	1.34	32.67	3.48
	Female	4.82	0	2.33	5	0.58	19	0.81	15.78	3.27
1–2 Year	Male	4.85	0	1.5	15	0.60	17.33	0.78	31.36	3.32
	Female	4.48	0	1.44	16.11	0.60	18.22	1.00	30.52	3.40
>2 Years	Male	5.5	0	0	0	0.8	18.6	0.14	55	4.2
	Female	5.5	0	0	0	0.74	20.48	0.12	54.28	3.39

Source: Primary Survey.

India, including West Bengal, Rajasthan, Uttar Pradesh, Haryana, and Karnataka, as reported by various studies [41–45]. These states represent India's diverse geography, encompassing extreme tropical climates to high-altitude regions like the Himalayas. Despite this geographical diversity, there is a commonality in feeding patterns across the country, although specific nuances exist for different livestock based on factors such as age and sex. For instance, certain regions exhibit preferences for particular types of livestock, such as the emphasis on buffaloes over male cows in Kerala's meat market, the relatively lower rearing of milking buffaloes or goats in Kerala, and the minimal cost associated with rearing indigenous cows in the same region. These distinct features highlight the nuanced nature of livestock management practices across different regions of India.

4.3. Feed and fodder requirement

According to the standards set by the state's National Agricultural Technology Project (NATP), the total feed and fodder demand for the state is outlined in Table 10. This calculation was derived from the most recent livestock population data available (2019). As per these estimates, milking cattle require approximately 11 kg of combined green and dry feed, along with roughly 1 kg of concentrates daily. However, findings from primary surveys suggest that this standard estimation falls significantly below the actual grain and fodder provided to the cattle.

A total of 6,12,4536 kg of feed and fodder are required for approximately 50,000 milking cattle. For the over one hundred thousand dry cattle, approximately 8,33,370 kg of feed and fodder are needed. Additionally, more than 100,000 young cattle require only around half the feed and fodder compared to dry cattle of the same volume, totaling a need for 1,20,893 kg. Adult male cattle, numbering less than 3000, require a smaller quantity of feed and fodder, amounting to 1,20,893 kg. Across all cattle categories, except for young stock, there is a higher demand for dry feed compared to green fodder. The need for dry and green fodder is nearly equal for young livestock. In-milk cattle have the highest demand for concentrate feeds, followed by dry cattle and adult male cattle. However, farmers claim that green fodder and concentrate are typically fed at 3 to 5 times higher quantities than estimated, as reported in the primary survey. Only the estimation for dry fodder closely matches the findings of the primary survey reports.

When compared to cattle, buffaloes often require more feed and fodder, which may contribute to the relatively lower preference for buffalo rearing in Kerala due to the shortage of feed and fodder resources. In the in-milk category, buffaloes require a total of 12 kg of feed and 1 kg of concentrates. Notably, adult male buffaloes have a maximum requirement for dry fodder of roughly 8 kg. In all other cases, the needs for feed and fodder are higher for in-milk buffaloes, followed by dry, adult male, and young stock buffaloes. Once again, these estimates fall short of the actual quantities reported by farmers in the primary survey. However, the larger percentage of

Table 10
Total feed and fodder requirement as per the NATP standards in Kerala.

Animal category	Number of Animals*	Green Fodder		Dry Fodder		Concentrates	
		(kg per animal)	Total (kg)	(kg per animal)	Total (kg)	(kg per animal)	Total (kg)
Cattle	1342000						
In-milk	562400	4.75	2671400	5.50	3093200	0.64	359936
Dry	106569	3.40	362334.6	4.02	428407.38	0.40	42627.6
Adult Male	11602	4.06	47104.12	6.03	69960.06	0.33	3828.66
Young Stock	111616	2.18	243322.88	2.13	237742.08	0.18	20090.88
Buffalo	101000						
In-milk	5234	5.96	31194.64	6.34	33183.56	1.05	5495.7
Dry	1449	5.44	7882.56	4.95	7172.55	0.52	753.48
Adult Male	6434	4.04	25993.36	7.47	48061.98	0.36	2316.24
Young Stock	77459	2.29	177381.11	2.22	171958.98	0.19	14717.21
Goat	1359161	1.04	1413527.44	0.20	271832.20	0.06	81549.66
Sheep	1979	1.01	1998.79	0.20	395.80	0.04	79.16

Note 1: *Author Compiled from 20th Livestock Census.
Note 2: Feed and Fodder details (Kg per animal) are as given by NATP Standards.
Source: Author Calculations.

young buffalo stock in the state suggests the appeal of raising buffaloes for the meat market. Interestingly, the estimation of feed and fodder for the goat-rearing industry closely aligns with what farmers reported in the primary survey.

Table 11 provides estimates for the state's green fodder supply using standard methods. According to these estimates, the state has approximately 1,12,000 ha of fodder cropland area. Additionally, it is estimated that 32.5 hundred thousand hectares of forest serve as a food source for the livestock industry. The state also possesses around 100,000 ha of cultivable wasteland, fallow land, and barren land to fulfil the needs of the livestock sector. Unlike other Indian states, there are no permanent pastures or other grazing lands in the state. Instead, only a few different tree groves and crops in the state are utilized as feed.

According to most farmers engaged in animal rearing, grazing land serves as the primary source of animal food, as depicted in Table 12. Grazing on public land is a common practice in Kerala for cattle. Notably, leftovers from households, including food waste, are utilized as livestock feed in the state. This unconventional aspect of animal husbandry is prevalent on homesteads throughout Kerala. Moreover, leftovers from neighbouring areas and catering establishments, such as eateries and educational facilities, are collected in rural areas to feed cattle. Another common practice in Kerala is providing porridge water as an alternative to regular water for livestock. Crop leftovers, particularly paddy residue, are also significant sources of animal feed. Paddy remains the primary sector producing residues for animal feeding in Kerala, as vegetable and other cereal agriculture is relatively low in the state.

Table 13 provides estimates of factors in terms of Harvest Indices (HI) and Extraction Rates (ER) of feed resources, including crop residues, oil cakes, grains, brans, and chunnies from various crops within the agricultural sector in the state. It is evident that out of the 13 specified crops with the potential to produce a significant amount of residue for feed, nine have not been cultivated in Kerala. This lack of cultivation underscores Kerala's reliance on other states, such as Tamil Nadu, for inputs, even for its own domestic fodder production facilities. Furthermore, almost all types of millets, which are typically significant contributors to the feed and fodder sector, are reported as having zero production in Kerala. Only two crops, paddy and coconut, contribute significantly to the residue produced for cattle feed, while pulses and sugarcane have a negligible share.

According to estimates, the paddy industry in the state produces approximately 2.5 hundred thousand kg of crop residue and 16,000 kg of bran for use as cattle feed. Coconut fields generate around 5.5 lakh kg of oilcake for the feed industry. However, only about 28 kg of brans and chunnies are contributed to the feed matter by the state's pulse production, which produces 2000 kg of crop residues. Additionally, the paddy sector contributes roughly 4000 kg of grains to the feed industry, while sugarcane only contributes a few hundred kg of crop residues in this regard. Paddy remains the primary source of feed input in various forms for the state, followed by coconut. These two crops are emblematic of the traditional agricultural characteristics of Kerala.

Table 14 summarizes the state's overall feed and fodder supply and demand for the livestock industry. It is evident that the state has a surplus of green fodder compared to the needs of the livestock sector. Despite the lack of dedicated green fodder cultivation, the state's overall greenery contributes significantly to the abundance of green fodder. With approximately 36 hundred thousand tonnes of green fodder available compared to the demand of just 5000 tonnes, it is clear that there is a substantial surplus. This surplus may be one of the main reasons for the state's low preference for fodder cultivation, especially considering the expense involved, even with subsidies, if any.

The surplus profile only applies to green fodder; the situation is vastly different for dry feed and concentrates. In the case of dry fodder, there is an average deficit of 3600 tonnes, which is five times more than the state's dry fodder supply. Similarly, the state faces a significant shortage of concentrates, with 512 tonnes needed compared to just 20 tonnes supplied. In other words, the state's shortage of concentrates is nearly 25 times greater than its supply. Together, these circumstances highlight the heavy dependence of the state on other states for feed and fodder to meet the needs of the livestock sector.

The state's inadequate crop residue profile is the primary factor contributing to the significant disparity between the supply and demand of feed and fodder (excluding green fodder). According to Table 10, Kerala does not cultivate the majority of potential crops that could provide crop residue, largely due to geographical and agricultural constraints. The few crops that are grown in the state, such as coconut and paddy, continue to diminish in terms of the state's agricultural profile. Furthermore, the expansion of cash crops in the state offers little to the overall feed and fodder sector. In the long run, this presents a significant threat to the state's livestock sector. It is also noteworthy that in India, approximately 140 million tonnes of crop residues out of a total of 500 million tonnes are burnt [46].

Table 11
Green fodder yields for land use classification in Kerala.

Sl. No	Land Use Category#	Green Fodder (tons/ha/year) #	Total Area (Ha)*	Total Availability (Tons/Ha)
1	A) Area under fodder crop	40.93	2750	112557.50
2	B) Forest area and on the assumption that only 50 % area was accessible for grazing	3.00 (1.50 if considering the whole forest area)	1081509 (whole forest area)	3244527.00
3	C) Permanent pastures and other grazing lands	5.00	0	0.00
4	D) Cultivable wastelands	1.00	96496.73	96496.73
5	E) Current fallows	1.00	57463.59	57463.59
6	F) Other fallows	1.00	45540.92	45540.92
	G) Barren and uncultivated land*	1.00	10280.57	10280.57
7	H) Misc. Tree Crops and Groves not Included in Net Area Sown	1.00	2117.88	2117.88

Note 1: # As given by FAO (2012), Ramachandra et al. (2007).
Note 2: * As given by Kerala Economic Review (2019).
Source: Author Calculations.

Table 12
Major sources of livestock feeding in Kerala.

Sl. No.	Source of Livestock Feed	Number of Households Reported	Percentage
1	Grazing land	197	90.78
2	Crop residues	100	46.08
3	Improved forage and pasture	55	25.34
4	Household left over	170	78.34
5	Tree legumes grown as hedge or anything similar	59	27.19
6	Feed preservation and storage	18	8.29

Source: Primary Survey.

Table 13
Estimation of harvest indices and extraction rates of feed from crop production in Kerala.

Sl. No	Crop	No. of Acres in the State (Ha) #	Harvest Indices (HI)*				Extraction Rate (ER)*			
			Crop residues*	Total (kg)	Oil Cakes*	Total (kg)	Grains*	Total (kg)	Brans and Chunnies*	Total (kg)
1	Paddy	198026	1.30	257433.80	NA	NA	0.02	3960.52	0.08	15842.08
2	Wheat	0	1.00	0	NA	NA	0.02	0	0.08	0
3	Sorghum	0	2.50	0	NA	NA	0.05	0	NA	NA
4	Bajra/Pearl Millet	0	2.50	0	NA	NA	0.05	0	NA	NA
5	Barley	0	1.30	0	NA	NA	0.10	0	NA	NA
6	Maise	0	2.50	0	NA	NA	0.10	0	NA	NA
7	Ragi	0	2.00	0	NA	NA	0.05	0	NA	NA
8	Small Millets	0	2.50	0	NA	NA	0.10	0	NA	NA
9	Other cereals	0	2.00	0	NA	NA	0.10	0	NA	NA
10	Pulses	956.65	1.70	1626.31	NA	NA	NA	NA	0.03	28.70
11	Ground Nut	0	2.00	0	0.70	0	NA	NA	NA	NA
12	Oilseeds (Coconut)	760946.6	NA	NA	0.70	532662.62	NA	NA	NA	NA
13	Sugarcane	993.27	0.25	248.32	NA	NA	NA	NA	NA	NA

Note 1: * As given by ISEC Bangalore, FAO (2012), Ramachandra et al. (2007).
Note 2: # As given by Kerala Economic Review (2019).
Note 3: NA = Not Applicable.
Source: Author Calculations.

Table 14
Difference between total feed and fodder available and required in Kerala.

Green fodder (Tons)			Dry fodder (Tons)			Concentrates (Tons)		
Required (R)	Available (A)	Difference (A-R)	Required (R)	Available (A)	Difference (A-R)	Required (R)	Available (A)	Difference (A-R)
4982.14	3568984.19	3564002.05	4361.91	791.97	−3569.94	531.39	19.83	−511.56

Source: Author Calculations from Tables 10, 11 and 13.

Optimizing the utilization of such waste and implementing proper management practices for their storage, transportation, and utilization could effectively address both the general and specific shortages of feed and fodder in India and Kerala. Moreover, the state possesses untapped potential in areas such as pineapple plantation residues, which could be leveraged to mitigate the shortage of feed and fodder. The utilization of locally available resources for feed and fodder production has been successfully implemented in developing countries like Bangladesh [47]. These approaches aim to minimize costs for feed production while maximizing the value derived from fruit and vegetable wastage [48].

This segment highlights the contrast in Kerala's feed and fodder portfolio compared to other major Indian states [45]. It is evident that most of the components contributing to feed and fodder supply, according to national estimate standards, are not readily available in Kerala, unlike states such as West Bengal, Rajasthan, or Uttar Pradesh [41–43]. Consequently, Kerala is compelled to rely on importing inputs from other states, making the sector vulnerable to cost fluctuations and supply disruptions influenced by market forces. Additionally, the estimations are notable for their low magnitude compared to the actual reported magnitudes from farmers. Future research in this domain is imperative to gain further clarity on this aspect. Similarly, the oversupply of green fodder in the state requires attention to explore conversion possibilities into dry matter or utilization as inputs for feed production.

4.4. Determinants of agricultural income in livestock farming

Table 15 illustrates the primary determinants of agricultural income in Kerala's livestock sector, aligning with the global findings

[29]. The size of the livestock, farming experience, and educational qualification of the farmer emerge as statistically significant factors influencing agricultural income in the state. These results suggest a positive relationship between the experience of the farmer, farm size, and agricultural income, indicating that increasing farming experience and farm size leads to higher agricultural income. This underscores the importance of scaling up marginal farming practices in Kerala to optimize farmer profitability. The current scenario of marginal landholding may not be conducive to future agricultural success.

Another noteworthy aspect is the significance of farmers' educational qualifications. The findings suggest that compared to farmers with collegiate education, those with only a school education or illiteracy are less likely to generate agricultural income, indicating a negative relationship between agricultural income and lower educational qualifications. This has various implications. Given the ageing profile of the state's farmers, with an average age exceeding 50, the situation is unlikely to improve. Therefore, there is a pressing need for more young people to enter the sector, particularly those with higher levels of education, to achieve profit maximization. An associated observation is the negative relationship between age and agricultural income, although it is not statistically significant in the analysis.

The social and agricultural dimensions of the sector in developing economies like India are noteworthy, as they could serve as key drivers of sustainability [49]. India's expanding population, demographic dividend, and the potential for leveraging demographic advantages such as women's empowerment, coupled with increasing food demand, particularly for protein, pose both challenges and opportunities [49,50]. Kerala holds a comparative advantage in terms of superior human development compared to other states in India, and thus, could seize the opportunity by focusing more on agricultural development and extension efforts.

5. Conclusion

The livestock sector in Kerala is expanding like the national and developing countries' patterns. However, the composition of livestock in the state is notably different due to its unique small and marginal-scale farming practices. Consequently, most farmers in the state raise more than one type of livestock as a means of optimizing revenue, costs, and space. The animal-rearing practices embedded in marginality in Kerala resemble more of a 'homestead (backyard) style' rather than the 'large-scale typical farms' seen in the rest of India and the developing world. One notable advantage of this model is the utilization of residues and leftover home-cooked food to feed the livestock. A prime example of this is the widespread practice of feeding animals with porridge. This approach offers a dual advantage by ensuring a continuous supply of feed options or supplements at no additional cost.

The social dynamics among animal-rearing farmers in Kerala mirror those of developing economies, where the older generation often discourages their children from pursuing agriculture as a livelihood. In Kerala, this trend is further reinforced by the opportunities and cultural emphasis on international migration in pursuit of higher income. Aligned with global trends, education, experience, and herd size emerge as critical determinants of agricultural income in the state. This suggests that older and more experienced farmers with larger livestock volumes tend to generate the most profit.

The state faces an unfavourable cropping profile concerning its feed and fodder requirements. Most crops that contribute to feed and fodder production, such as wheat, sorghum, pearl millet, barley, maize, ragi, small millets, cereals, pulses, and groundnut, are not cultivated in Kerala. Paddy, coconut, and green fodder stand as the main contributors to feed and fodder production in the state. Additionally, some of Kerala's popular crops, like rubber, are perennial, leaving little room for intercropping or sub-cultivation for decades. Consequently, despite the increasing demand for feed and fodder due to the rise in livestock, the state finds itself facing a deficit in both dry and concentrate forms of feed and fodder. To address this shortfall, the state relies on inputs sourced or imported from other states, such as Tamil Nadu. However, this dependence escalates the cost of supply, affecting animal-rearing practices adversely.

Another dimension of the feeding profile in the state is the reported tendency of farmers to overfeed their livestock compared to the estimates provided in the NATP guidelines. This behaviour could be attributed to the escalating cost of animal rearing in Kerala. One possible explanation for this paradox is the lack of sufficient data and research in this area. This discrepancy stands in stark contrast to findings from other studies in the field and thus warrants thorough investigation. Future research is essential to ascertain whether the standards provided by NATP are being underestimated or if farmers are indeed overfeeding their livestock. Such research would pave the way for necessary course corrections and improvements in feeding practices.

Among the diverse array of livestock reared in the state, milking animals require the most feed and fodder, with farmers feeding them according to prescribed ratios. This underscores the significance of milk as an immediate revenue source for farmers in Kerala compared to meat production. Consequently, crossbred cattle, known for their high milk yield potential, receive the most precise feeding regimen among other livestock. Considering this context, it becomes evident that there is a need to educate farmers about the standard requirements and opportunities for cost and revenue optimization within the sector. Presently, such education is largely overlooked in non-milking indigenous animal-rearing practices.

The notable surplus of green fodder in the state could explain this situation. The abundance of green fodder, endorsed by natural factors, allows farmers to feed their animals without restrictions. Particularly, animals reared for meat production, such as male buffaloes and goats, are predominantly fed in this manner. The rationale behind this practice assumes that the body mass or meat yield will be positively correlated with the volume of feed consumed by the livestock. However, this situation warrants further scrutiny. It's essential to explore the possibility of converting the surplus green fodder into dry and concentrate forms. Such an approach may significantly alter the demand and supply dynamics in the feed and fodder market in Kerala.

Another distinctive attribute, reminiscent of scenarios in developing countries, is the locally identified indigenous alternatives for feed and fodder, or supplement feed. Domestic leftovers, like porridge, or commercial residues such as pineapple leaves, hold significant untapped potential in the state. Further scientific exploration of these alternatives could potentially transform the feed supply

Table 15
Multiple regression estimates of factors determining agricultural income.

Variables	Coefficients	Standardised Coefficients	*P*-Value
Age	−3302.371 (3591.764)	−0.070	0.359
Gender (Male)	115998.8 (84375.18)	0.095	0.171
Education (Illiterate)	−310875 (214853.4)	−0.108	0.149
Education (Primary)	−281065 (134908.7)	−0.184	0.038**
Education (Secondary)	−254289.7 (94217.37)	−0.234	0.008*
Farming Experience	5774.879 (2559.907)	0.160	0.025**
Cooperative Society Membership (Yes)	8631.18 (117303)	0.005	0.941
Herd Size	8039.231 (2652.642)	0.210	0.003*
Family Size	13027.55 (20967.69)	0.041	0.535
Constant	483512.3 (223186.9)	.	0.031

Note: (1) Dependent Variable: Agricultural Income.
(2) Standard errors are shown in parenthesis.
(3) *Statistically significant at 1 per cent level, and **Statistically significant at 5 per cent level and.
Source: Author Calculations.

scenario in Kerala, offering a solution to the deficit.

In summary, the feed and fodder demand and supply scenario in Kerala closely mirrors that of the developing world, characterized by a supply deficit. However, there are unique aspects to this situation, such as the surplus supply of green fodder and untapped unconventional residues that hold potential as inputs for feed and fodder, offering a solution to the deficit. Addressing this requires future research that is scientific and data-driven, leading to corresponding policy interventions. The study also recommends a comprehensive revision of existing policies in the state. For example, despite indications that supportive policies for enhancing green fodder cultivation are no longer necessary, ongoing policies remain in place. The findings of this study are applicable beyond Kerala and are generalizable to the developing world, particularly regarding indigenous approaches to addressing feed and fodder deficits for livestock production.

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Ethics declarations

All participants (or their proxies) provided informed consent to participate in the study.
All participants (or their proxies) provided informed consent for the publication of their anonymised case details and images.

Data availability

All data to support the conclusions have been either provided or are otherwise publicly available.

CRediT authorship contribution statement

Ashraf Pulikkamath: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Shafeek A:** Writing – review & editing, Resources, Project administration, Investigation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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