Policy Paper 53

Economic Impact of Forage Varieties

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Preface

The rising demand for livestock products has triggered a ripple effect, significantly increasing the need to produce more of feeds and fodders. This trend is anticipated to persist and intensify in the coming decades due to a substantial rise in demand for livestock products. However, India is grappling with a persistent deficit in feeds and fodders, a situation likely to worsen due to several factors, including the decreasing area under fodder crops, primarily due to competition for agricultural land with food crops, and the quantitative and qualitative deterioration of pastures and grazing lands. This supply-demand mismatch is expected to drive up fodder prices, consequently raising the costs of livestock products and leading to higher consumer prices. These concerns have spurred increased research efforts focused on developing high-yielding, nutrient-rich varieties of forage crops to bridge the gap between supply and demand.

India's agricultural research system has made significant progress in developing high-yielding varieties of fodder crops, yet their impact of these on livestock productivity and farmers' welfare remains understudied. This paper addresses this knowledge gap by evaluating the economic impact of 11 high-yielding forage crop varieties. The findings demonstrate a substantial increase in forage biomass production, which directly translates to improved milk yield and enhanced farm income. These results underscore the importance of continued investment in forage crop research and development.

To tackle existing challenges and fully leverage the potential of these improved forage crop varieties, the study suggests strengthening breeder seed production to ensure a steady supply of high-quality seeds, encouraging participatory seed initiatives to engage farmers in the seed production process, and improving fodder market to enable year-round access to premium fodder.

It is hoped that the suggestion presented in this paper will significantly aid in attracting increased investment in research and development for forage crops. I congratulate the authors for this important contribution.

Pratap Singh Birthal
Director, ICAR-NIAP

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Executive Summary

Increasing population, growing urbanization and rising per capita income are driving significant changes and reshaping domestic demand for agricultural products. Demand for animal-based products—particularly dairy products—is rising fast. If these trends were to continue, the demand for milk is expected to increase to 480 million tonnes by 2047, compared to 186 million tonnes in 2019-20. Meeting this growth in demand will require significant improvements in dairy productivity. However, productivity of India's dairy remains about 40% below the global average, primarily due to scarcity of feed and fodder. However, additional factors like low genetic potential of dairy breeds, inadequate health and management services, and limited access to extension and advisory support—also contribute to the observed productivity gap. If not addressed, this shortage could pose a serious threat to enhancing the milk production.

Livestock in India are raised in a mixed farming system deriving their energy requirements from crop residues, gathered grasses and agricultural by-products. Despite efforts to improve forage resources, the country faces a substantial fodder deficit, with green fodder shortages estimated at 11% and dry fodder at 23%. This issue is particularly severe in the eastern and southern regions, where green fodder deficits exceed 40%. With a growing livestock population and focus on crossbreeding for genetic improvement, there is a pressing need for high-yielding, drought-resistant fodder varieties to bridge the demand-supply gap. Empirical evidence on the performance, adoptability, and economic impact of these varieties is also crucial for justifying research efforts, advocating policies to promote high-potential varieties, and identifying the need for further research to develop improved varieties through continued innovation.

In this paper, we have evaluated the impact of eleven leading and popular varieties of forage crops, namely *Wardan, BL-10 and BB-2* of Berseem (Trifolium *alexandrinum*), *JHO-822* and *UPO-212* of oat (Avena *sativa*), *African tall* and *J-1006* of maize (Zea *mays*), *EC-4216* of cowpea (Vigna *unguiculata*), and *AL-3, RL-88* and *Ananad-2* of Lucerne (Medicago *sativa*).

The total estimated benefits from these varieties amounts to Rs. 20.9 billion a year (Table 1). These benefits are shared between consumers and producers in a ratio of 3:2 indicating that consumers derive relatively greater benefits from investment in forage research. Among the selected varieties, *African Tall* demonstrates the highest annual benefits, followed by *J-1006*, *Anand-2*, *EC-4216*, *BL-10* and *Wardan*.

Table 1. Net economic surplus generated by selected forage varieties (Rs. million)

Crop	Variety	Assessment period	Net economic surplus	
			Total	Per annum
Berseem	Wardan	1999-2022	7888.3	342.9
	BB-2	2002-2022	2927.4	146.3
	BL-10	1999-2022	12104.6	526.2
Oat	JHO-822	2002-2022	276.9	13.8
	UPO-212	2000-2023	383.4	16.6
Cowpea	EC-4216	1999-2023	13613.3	567.2
Lucerne	AL-3	2009-2023	6431.5	459.3
	RL-88	1999-2023	11372.0	473.8
	Anand-2	1999-2023	43186.4	1799.4
Maize	J-1006	1999-2023	59751.5	2489.6
	African Tall	1999-2023	338460.6	14102.5
	Total		496395.9	20937.6

The paper underscores a clear need for policy interventions that prioritize the promotion and adoption of forage crop varieties with high economic impact. Following are a few suggestions.

- Promoting high-return forage varieties like African Tall maize (Kharif) and BL-10 berseem (Rabi) should be focused. However, leguminous forages like cowpea (e.g., EC-4216) and cereal fodders like oat are equally vital for ensuring balanced livestock nutrition, particularly in rainfed and resource-constrained areas.
- The slow varietal replacement rate (VRR) remains a concern. In lucerne, varieties older than 15 years still account for over 60% of breeder seed indents (2017–2022). To improve fodder yield and resilience, accelerating VRR is necessary, alongside breeding for enhanced nutritional quality and digestibility.
- Data revealed a high fluctuation as well as decline in breeder seed production over the study period, highlighting the need for targeted funding, research collaboration, and streamlined regulatory support to sustain breeder seed supply. Strengthening public institutions in this regard is crucial for a robust fodder seed chain. Encouraging private players in fodder seed production is also imperative.

- A Fodder Seed Hub, centrally coordinated by institutions like ICAR-IGFRI, Jhansi, can consolidate efforts in seed production, processing, and distribution. Partnerships with SHGs, NGOs, and farmers will facilitate wider adoption and faster seed replacement, as seen in the success of seed hubs in pulses and oilseeds.
- Scaling up truthfully labelled and certified seed production through participatory models involving farmers and agri-preneurs is essential. This requires financial incentives for certification, training programs, and institutional partnerships (e.g., KVKs, milk unions, research institutes) to build resilient local seed systems.
- Parallel development of fodder markets is also critical. Establishing legalized, state-level market platforms will ensure transparent pricing and better returns. NABARD should support fodder-based rural enterprises, with fodder cultivation recognized as a bankable activity. Buy-back arrangements with pre-agreed procurement terms can de-risk fodder ventures and encourage entrepreneurship.
- Study on economics of green fodder and fodder seed is very limited. Since farmer adoption is driven by profitability, region-specific economic analyses are vital.

1 Introduction

Livestock are integral to India's agricultural and rural economy, acting as a vital catalyst for agricultural advancement and socioeconomic development. This significance is evident in both economic indicators and employment statistics. Livestock contribute approximately 31% to the agricultural gross domestic product (AgGDP) and employ 8.8% of the workforce. They produce nutrient-rich foods like milk, meat, and eggs, thereby more effectively combating malnutrition (Saxena et al., 2019).

Nevertheless, the importance of livestock extends beyond their role in food production and income generation. The distinctive characteristics of livestock and livestock production systems render them a potent instrument in addressing broader societal issues such as income distribution, poverty alleviation, and gender empowerment (Birthal and Taneja, 2006; Birthal and Negi, 2012). Animal husbandry requires relatively low initial investment and can be readily scaled up due to the regenerative capabilities of animals. Animals serve as a form of savings and insurance for rural households, offering a safety net during periods of crop failure or other economic shocks, particularly for small and marginal farmers who are more susceptible to such adversities. In mixed farming systems, livestock derive their energy requirement from crop residues and by-products, making their rearing more economical, particularly smallholder farmers.

In India, livestock ownership in India is concentrated among small landholders, and thus contributes to reduction in rural inequalities and poverty (Birthal et al., 2014; Birthal and Negi, 2012; Bijla et al., 2023). Birthal and Negi (2012) show that livestock production has a more significant impact on poverty reduction compared to crop production. Bijla et al. (2023) demonstrate that livestock plays a significant role in both preventing households from falling into poverty and facilitating their escape from poverty. In addition, livestock production plays a crucial role in promoting gender equality. In India, there is a significant female participation in livestock production, approximately half of the labor force in livestock production systems comprises of females (Saxena et al., 2019). This provides women with opportunities for economic engagement and decision-making power within their households and communities. This not only contributes to gender equality but also enhances overall household welfare, as women often reinvest their earnings in family nutrition, health, and education (Galiè et al., 2019).

This socioeconomic empowerment through livestock is further enhanced by their integration into farming systems. In India, livestock are raised in mixed farming systems. Crop residues and agricultural by-products, which might otherwise be considered waste, are used as animal feed, reducing cost of production of animal-source foods. In turn, the animals contribute significantly to crop production through the provision of draught power and organic manure. This symbiotic relationship reduces the need for external resources and minimizes environmental impact. The use of animal power for ploughing and transportation reduces dependence on fossil fuels, while organic manure improves soil health and reduces reliance on chemical fertilizers. By promoting biodiversity and sustainable land use practices, the crop-livestock integration demonstrates how this symbiotic relationship can be leveraged to address challenges of food security, environmental conservation, and sustainable development of the agricultural economy (Gupta et al., 2025).

While crop-livestock integration offers numerous benefits, it is important to consider how changing dietary patterns may influence this system. In recent decades, dietary habits in India have notably shifted towards more nutrient-rich foods, including animal products, largely due to increased disposable incomes and urbanization. The share of animal-source foods in the food expenditure has increased from 18% in 1983 to 28% in 2022-23 (ICAR-NIAP, 2025). In terms of intake, during this period, per capita milk consumption nearly doubled, while the consumption of meat, eggs, and fish more than tripled (ICAR-NIAP, 2025). The factors underlying the demand for animal-source foods have remained robust and are likely to persist, suggesting substantial increase in their future demand. As indicated in a recent report by NITI Aayog, under a business-as-usual scenario where current economic and demographic trends persist, the demand for milk is anticipated to increase to 480 million tonnes by 2047, compared to 186 million tonnes in 2019-20 (GoI, 2024). Similarly, the demand for meat, eggs, and fish is expected to increase to 74 million tonnes from 24 million tonnes. By 2047, India aspires to achieve developed nation status, with an estimated economic growth rate of approximately 8%, higher than 6.3% observed during the most recent decade. At this time, the population is projected to reach 1.6 billion, with half residing in urban areas, further increasing the demand for animal-source foods.

While the need to produce more animal-source foods remains as urgent as ever, livestock production systems will come under a significant pressure of several biotic and abiotic pressures. The increasing demand necessitates a substantial expansion and intensification of livestock farming systems, amidst several challenges pertaining to breeding, health, and nutrition. Among these challenges, the issue of feed and fodder availability stands out as a critical factor limiting livestock productivity. Birthal and Jha (2005) have identified the limited availability of quality feeds and fodders as the most pressing constraint in realizing the full production potential of livestock.

The ICAR-Indian Grassland and Fodder Research Institute (ICAR-IGFRI), Jhansi, in collaboration with other research institutions has been actively engaged in the genetic improvement of forage crops and restoration of pasture lands. This effort has yielded over 350 improved varieties of different forage crops, with one-fourth of them are already integrated into the seed chain. However, like the research on food crops, the impact of research on forage crops has not been systematically documented (La Rovere et al., 2010; Birthal and Negi 2012; Rowell et al., 2022).

In India, experimental field trials on feeding improved forage varieties have shown a positive impact on livestock productivity (Ghosh et al., 2016; Sharma et al., 2021). Nevertheless, the comprehensive evidence at the national-level remains largely absent. To address this knowledge gap and provide a more comprehensive understanding of forage crop research impacts, this study assesses the economic impact of a few improved varieties of berseem (Trifolium *alexandrinum*), oat (Avena *sativa*), maize (Zea mays), cowpea (Vigna *unguiculata*), and lucerne (Medicago *sativa*). The empirical evidence on the economic benefits of forage varieties is crucial for attracting more investment in forage research. Further, it enables policymakers and research institutions can make informed decisions about resource allocation and prioritize projects with the highest potential impact.

2 Feed and Fodder Situation of India

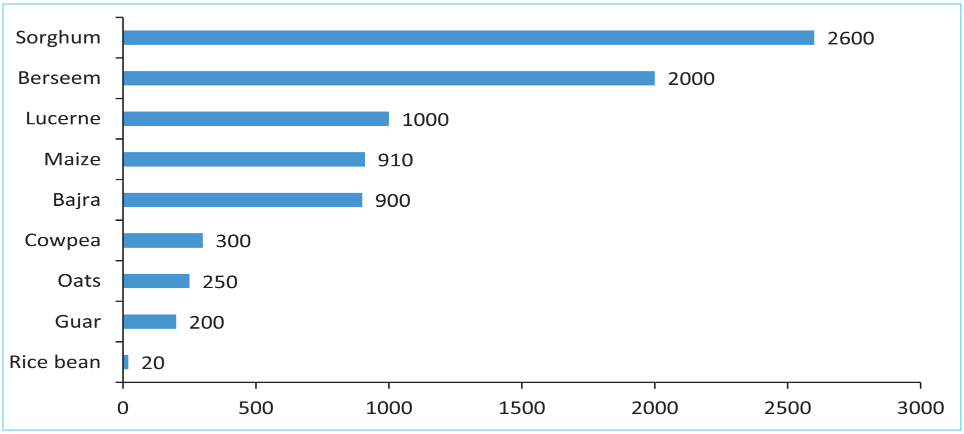
2.1 Sources and composition of fodder supply in India

Fodder supply in India primarily comes from three major sources: crop residues, cultivated fodder from arable land, and fodder derived from common property resources (CPRs) such as forests, permanent pastures, and grazing lands. Among these, crop residues are the most significant, accounting for around 54% of the total fodder supply (Singh et al., 2024). These residues are bulky, high-fibre feedstuffs (~18% fibre). The type and availability of crop residues are closely linked to the predominant crops grown in each region, which vary seasonally as well as regionally. In the eastern and coastal regions, rice straw is the main residue used for livestock feeding, while wheat straw predominates in the northern and central parts of the country. In western and peninsular India, livestock feed is primarily composed of residues from sorghum, pearl millet, guar, and maize stover. Besides, various other agricultural by-products, including pulse straw, groundnut haulms, sugarcane tops, vegetable waste, horticultural residues, tree fodder (top feed), and kitchen waste also serve as valuable components of livestock diets, especially in household and peri-urban dairy systems. The increased availability of crop residues in recent years is largely attributed to the increase in crop production, particularly of paddy and wheat, which has led to higher grain yields and a corresponding increase in the volume of associated straws and residues.

Fodder is cultivated on around 8.4 million hectares (Singh et al., 2024), making up about 5% of the gross cropped area, which has remained nearly constant over the last few decades. States, such as Haryana, Punjab, Gujarat, and parts of Rajasthan, have a slightly higher share of cultivated green fodder in the total cropped area. Notably, these regions also report the highest levels of livestock productivity (Roy et al., 2019), highlighting a strong correlation between fodder supply and improved animal output.

Sorghum (*Sorghum bicolor*) is the most widely cultivated fodder crop, covering an area of approximately 2,600 thousand hectares (Figure 1), followed by berseem (*Trifolium alexandrinum*) and lucerne (*Medicago sativa*). Maize (Zea mays), Pearl millet (Pennisetum glaucum), Bajra x Napier hybrid, cowpea (*Vigna unguiculata*), guar (*Cyamopsis tetragonoloba*), rice bean (*Vigna* *umbellata*), are also cultivated in various pockets. These important crops also contribute significantly to the overall fodder supply in the country.

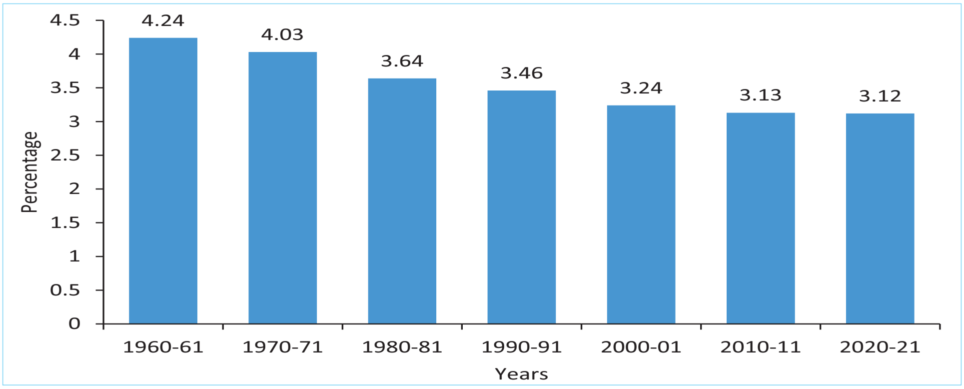
Figure 1. Area under major fodder crops in India (000' ha)



Source: Singh et al., 2024.

Common grazing lands, encompassing permanent pastures, grazing lands, cultivable and uncultivable wastelands, as well as fallows (excluding current fallows), constitute around 16 % of the India's geographical area. Grazing-based livestock husbandry remains a cornerstone of the rural economy, with about 50% of livestock depending on grazing for their nutritional needs (Roy and Singh, 2013). This system continues to support millions of rural livelihoods, especially in feed-deficient or resource-poor regions. However, the grazing intensity in India is notably high, with an average of 12.6 adult cattle units (ACU) per hectare, compared to just 0.8 ACU per hectare in developed countries (Roy et al., 2019). This significantly higher grazing pressure places strain on the land, leading to steady decline in area under permanent pastures and grazing lands over the years (Figure 2).

Figure 2. Area under permanent pasture and other grazing lands as percentage of total geographical area

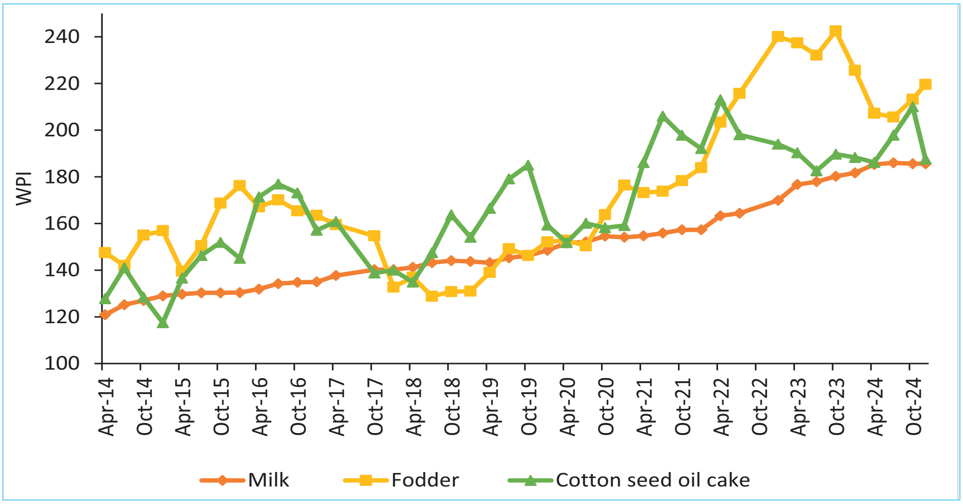


2.2 Feed and fodder deficits, and regional disparities

Concentrate feeds are essential for balanced diet of animals, which are generally not met from the crop residues. At different growth stages, 1.5 to 2.0 kg concentrate for cattle and 2-2.5 kg for buffalo are recommended. In cattle feed, about 90 per cent of the input is feed ingredients like, maize, brans, meals and oil cakes and feed additives like, multivitamins, mineral mixes, amino acids, etc. Presently, the estimated annual availability of total concentrate feed is only 61 million tonnes, which falls 28.9% short of the demand (Roy et al., 2019). This has resulted in exorbitant prices of concentrates in many parts of the country. The all-India trends in monthly wholesale price index of important feed ingredients clearly indicate the extent of seasonal fluctuations in prices. The wholesale price index (WPI) of cotton seed oil cake–one of the important feeds used by dairy farmers in India – has remained higher than the WPI of milk and the gap between two is widening over the years (Figure 3).

Yet, a paradox exists. In several regions, there is an abundance of fodder during the monsoon, but a shortage during the lean season. This issue is particularly pronounced in remote areas. Some studies suggest that allocating approximately 10-14% of land for fodder cultivation would be ideal for addressing the country's fodder shortages (Choudhary et al., 2024). However, for the past few decades, fodder has been cultivated on nearly 5% of the land area.

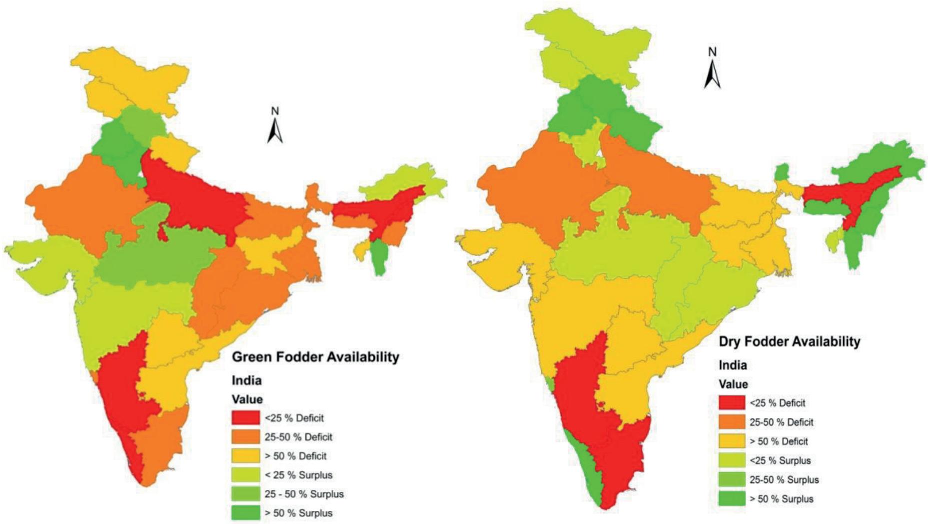
Figure 3. Wholesale price index of cattle feed, fodder and milk (Base 2011-12)



Source: Ministry of Commerce and Industry, GoI.

Thus, the supply of feed has always remained short of normative requirement, resulting in non-realization of the true production potential of livestock. The current net deficit in green fodder is around 11.24%, while the deficit of dry fodder is even more pronounced at 23.4% (Roy et al., 2019). However, substantial regional variations in fodder availability persist across Indian states (Figure 4). For instance, Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Madhya Pradesh, Assam, Jharkhand, and Odisha experiencing green fodder shortages ranging from 40 to 60%. In Tamil Nadu and Kerala, the shortfall exceeds 60%. Similarly, the scarcity of dry fodder in states like Himachal Pradesh, Rajasthan, Gujarat, and Maharashtra also falls within the 40 to 60% range (Roy et al., 2019). This current shortfall is concerning, and future projections paint an even more alarming picture.

Figure 4. Green and dry fodder availability scenario across Indian states

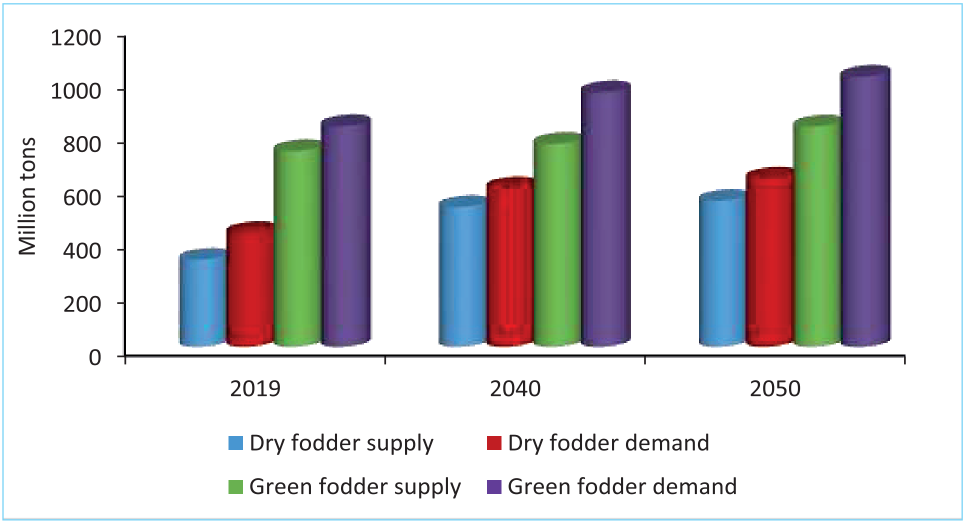


Source: Roy et al., 2019.

Looking ahead to 2050, the situation regarding fodder availability in India appears to be worsening, with projections indicating a significant increase in the deficit of green fodder to 18.4% but a reduction in the deficit of dry fodder (Figure 5). Green forage supply must rise at a rate of 1.69% per annum to bridge the deficit, necessitating greater emphasis on improving the productivity of fodder crops. In India, agricultural land is limited and projected to decline in future (Birthal et al., 2025). As the competition between food and fodder crops for these diminishing land resources intensifies, the scarcity of fodder crops is expected to escalate.

The widening gap between the availability and the requirement of green fodder highlights the pressing need for the implementation of innovative strategies to address the growing demand for fodder. This will have substantial repercussions for animal agriculture, potentially impacting the production of animal-source foods and, consequently, affecting food and nutrition security, agricultural growth, and socioeconomic development. Addressing the fodder deficit requires a comprehensive approach that considers both immediate needs and long-term sustainability.

Figure 5. Demand and supply projections of dry and green fodder



Source: Roy et al., 2019 for the year 2019 and IGFRI, 2015 for projected year.

Promoting high-yielding forage varieties along with improved cultivation practices is crucial, as these can significantly increase biomass production per unit area. Additionally, exploring alternative feed resources can help supplement traditional fodder sources and alleviate pressure on existing fodder production systems. These alternatives may include crop residues, agro-industrial by-products, and unconventional feed sources that can be processed to enhance their nutritional value and palatability for livestock.

The consequences of failing to address the growing fodder deficit could be severe. Inadequate fodder availability would directly impact livestock productivity, leading to reduced milk and meat production. This, in turn, would affect the livelihoods of rural communities dependent on animal husbandry for income and sustenance, and the nation's food and nutrition security.

3 Data and Analytical Approach

3.1 Data and assumptions

The study employed secondary data sourced from both published and unpublished material. The most crucial data pertain to the adoption of forage varieties or the area covered by these varieties, which are not available in published sources. To obtain this information, the study relied on breeder seed data, with production data acquired from the annual reports of the All India Coordinated Project (AICRP) on Forage Crops, implemented by the ICAR-IGFRI. The dataset, available from 1999 onwards, facilitates the estimation of the impact of varieties developed prior to that year. However, acknowledging the limitations of relying exclusively on public sector data, the study also recognized the significant role of the private sector in the fodder seed supply chain. Data on the production of forage crop seeds by private seed companies are unavailable. To address this data gap, a qualitative approach was adopted, involving focused group discussions (FGDs) with representatives from private seed companies to gain insights into their contributions to the forage seed supply chain. This mixed-method approach enabled a more comprehensive understanding of the overall seed supply. Table 2 presents the share of the private sector in the seed supply chain.

Table 2. Share of public and private sector in seed chain of forage crops

Crop	Public sector	Private sector
Berseem	30	70
Oat	60	40
Cowpea	60	40
Lucerne	20	80
Maize	50	50

Source: FGDs and experts' views.

The study makes several other assumptions (Table 3) regarding the adoption of improved forage varieties and their impact. It posits a 10-year timeline from initiation of research to widespread distribution through formal seed channels. Specifically, it assumes 5 years for variety development and an additional 5 years for distribution following its official release. The paper also makes assumptions about the seed production process and distribution channels. It considers a 2-year gap between breeder seed production and availability of certified seed, accounting for the various stages of seed multiplication. A 20% loss is assumed within the seed chain, likely due to factors such as storage losses, quality control rejections, and distribution inefficiencies. The paper assumes that certified seeds are distributed equally between organized and unorganized seed chains, reflecting the complex reality of seed system. Lastly, the research assumes no difference in cultivation costs between the improved varieties and their controls, which simplifies the economic analysis but may require further investigation.

Estimating the economic impact of improved forage varieties is indeed complex due to the indirect nature of their benefits. Unlike crops directly consumed by humans, forages primarily serve as animal feed, creating a multi-step process in assessing their economic value. The benefits of enhanced forage varieties cascade through the livestock production system, affecting animal health, weight, milk production, and overall farm productivity. However, estimating how much green fodder is actually distributed among livestock presents a challenge. To address this, we assumed that green fodder is primarily fed to in-milch animals by farmers aiming to maximize milk production. Accordingly, the enhanced green forage biomass was apportioned between in-milch cattle and buffaloes based on their relative population.

Table 3. Assumptions used in the study

Assumptions	Assumed Values
Variety development period	5 years
Release to formal seed chain	5 years
Lag between breeder to certified seed	2 years
Loss of certified seed in seed chain	20%
Breeder to certified seed ratio	No difference in public and private sector
Cost of cultivation	No difference in improved varieties and check varieties
Apportioning of green fodder among in-milch cattle and buffalo	In proportion to cattle to buffalo population

The data on milch cows and buffaloes were collected from livestock censuses conducted between 1997 and 2019 (Table 4). This information was crucial for evaluating the changing proportions of these dairy animals over time.

Table 4. Number of milch cattle and buffalo (in million)

Years	Cattle	Buffalo	Proportion (Cattle: Buffalo)
1997	49.87	42.73	54:46
2003	52.18	47.32	52:48
2007	62.45	48.64	56:44
2012	67.54	51.05	57:43
2019	74.18	51.17	59:41

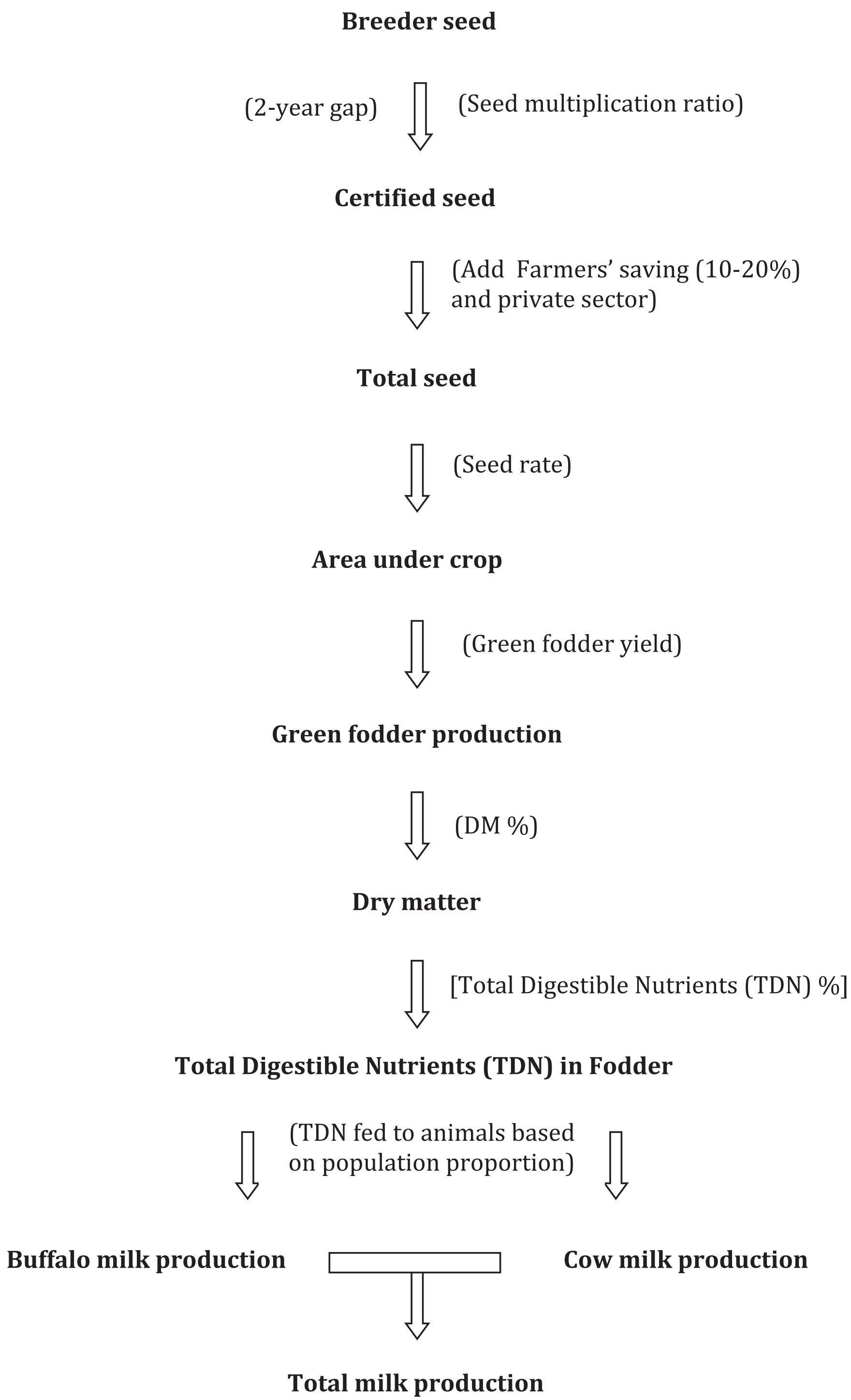
Source: Livestock census, Department of Animal Husbandry and Dairying, GoI, various years.

The economic impact extends beyond the farm level, potentially affecting other stakeholders within the animal products value chain, including consumers, and thus must consider the benefits to these groups. Changes in milk yield resulting from improved forage varieties may affect the market supply of milk, which can impact prices faced by consumers. Data on milk prices was thus crucial to quantify these broader economic benefits. Annual wholesale milk prices were obtained from the Department of Consumer Affairs, Government of India. These current prices were adjusted to real prices, using 2022–23 as the base year.

3.2 Estimation of equivalent milk from green forage biomass

The nutritional values and digestibility of forage varieties vary, influencing milk yield. For example, legume forages such as alfalfa generally possess higher protein levels and greater digestibility compared to grass forages, which may result in enhanced milk production. Estimating the milk production equivalent from forage biomass involves a complex interplay of factors, including the forage's dry matter content and energy density. The conversion process enables to know their impact on milk yield from a specific forage variety. This approach, as illustrated in Figure 6, serves as a valuable tool for optimizing forage selection and management strategies to maximize milk production efficiency.

Figure 6. Conceptual framework for conversion of feed into milk



The amount of certified seed produced from breeder seed was computed using the seed multiplication ratio (SMR) specific to each crop (Table 5). Further, by including contributions from the private sector (Table 2), the total annual seed production was estimated.

Table 5. Seed rate and nutrient composition of fodder varieties

Forage crop	Variety	Seed rate(kg/ha)	SMR	DM (%)	TDN (%)
Berseem	Wardan	25	1:16	26.8	60.00
	BB-2	27			
	BL-10	23			
Oat	JHO-822	100	1:15	25.29	52.00
	UPO-212	100			
Lucerne	Anand Lucerne-3	15	1:25	20.00	62.00
	RL-88	25			
	Anand-2	20			
Cowpea	EC-4216	35	1:40	26.00	62.10
Maize	J-1006	45	1:80	20.03	60.00
	African Tall	40			

Note: SMR is seed multiplication ratio; DM is dry matter; TDN is total digestible nutrients.
Source: ICAR, 2012.

The cultivated area under each annual forage variety was determined according to the recommended seed rate specified in Table 5. The annual green fodder production was then calculated by multiplying the green fodder average yield by the area under cultivation. The dry matter (DM) and total digestible nutrient (TDN) content in the forage biomass were subsequently calculated based on their respective percentage values (Table 5).

Table 6. Nutritional requirement per kg of milk production from lactating cow and buffalo

TDN requirements for	Cow	Buffalo
Maintenance TDN (kg)	3.27	3.88
Safety margin (@10%)	0.327	0.38
Correction factor (@10%)	0.327	0.38
Milk production	0.33	0.48
Total (Kg)	4.26	5.12

Source: ICAR, 2012.
Note: Cow weighing 350 kg, yielding 3 kg milk with 4.5% fat; ** Buffalo weighing 450 kg, yielding 6 kg milk with 7% fat.

TDN is the simplest form of energy evaluation wherein the animal requirements and the value of feeds in meeting these requirements are expressed in terms of the weight of digestible material in the feed. The TDN requirements for lactating cow and buffalo for producing 1 kg of milk were 4.26 kg and 5.12 kg, respectively (Table 6).

Once the total green fodder production from the varieties is estimated, the equivalent milk produced from cows and buffaloes by feeding green forage biomass (in tonnes) from the i^{th} variety in the t^{th} year were estimated using the following formula.

$$\text{Cow milk (kg)}_{it} = \frac{(green\ forage\ biomass)_{it} \times dry\ matter\,(\%) \times TDN(\%) \times 1000}{4.26}$$

$$\text{Buffalo milk (kg)}_{it} = \frac{(green\ forage\ biomass)_{it} \times dry\ matter\,(\%) \times TDN(\%) \times 1000}{5.12}$$

3.3 Estimation of economic surplus

There are three most common methods for the economic assessment of the benefits of research: econometric methods, programming methods, and economic surplus methods (William et al., 1996). Econometric approaches aim to estimate the marginal productivity of research over a long period and across a variety of research activities, while programming methods aim to identify one or more optimal technologies or research activities from a set of options. The economic surplus method is widely used and the most popular approach as it requires the least data, and can be applied to the broadest range of situations. It works on the economic principles of consumer and producer surplus generated because of shifts in supply function as a result of increase in production due to high yielding technologies. Taking clues from Alston et al. (1995) and William et al. (1996), the present study used the economic surplus method to estimate the economic impact of the selected forage varieties. The list of parameters used to estimate the economic surplus for the selected crop varieties is presented in Annexure 1.

The important steps followed in computing economic impact of each selected variety are discussed underneath:

Estimating production increases due to the research: the J parameter: The J parameter can be defined as the total increase in production that would be caused by adopting the new variety, in the absence of any change in costs or price. It can readily be estimated as:

$$J = \frac{(\Delta Y \times t)}{Y}$$

Where, ΔY represents the yield difference between the new and old varieties (kg/ha), Y is the average yield of new variety, i.e., total production divided by total acreage (ha), and t represents the adoption rate, i.e., the acreage under the new variety divided by the total acreage under the variety.

Estimating supply shifts: the K parameter: The K parameter may be defined as the net reduction in production costs induced by the new technology, combining the effects of increased productivity and adoption costs. It corresponds to a vertical shift in the supply curve, given J and could be computed using the elasticity of supply curve (e_s) as follows.

$$K = \left[\frac{J}{e_s}\right] - C$$

Where, C represents the increase in adoption cost, i.e., the increase in input costs required to cultivate the improved variety. In our analysis, this parameter is treated as zero, as we assumed there is no difference in the cost of cultivation between the improved varieties and the check.

Estimating equilibrium quantity change (ΔQ): The change in quantity actually caused by research (ΔQ) depends on the shift in supply and the responsiveness of supply and demand. The ΔQ can be computed as:

$$\Delta Q = [Q \times e_S \times e_d \times k]/[e_S + e_d]$$

Where, ΔQ is the total (aggregate) production of the variety (kg) and e_d is the elasticity of demand, drawn from economists' estimates.

Computing social gains and net gains: Economic benefits from the adoption of research are calculated as:

$$\text{Social gains(SG)} = [k \times P \times Q] \pm \frac{1}{2}[k \times P \times \Delta Q]$$

In the above formula, we subtract the second term when data are observed after adoption (an ex-post study) and add if adoption has not yet occurred (ex-ante). The present study is an ex-post impact assessment of the developed varieties. Net economic benefits is estimated after subtracting the costs of research (R) and extension (E) from the social gains as

$$Net\ Surplus = SG - (R + E)$$

Estimation of consumer and producer surplus: The gains were distributed between producer surplus (PS) and consumer surplus (CS) using following expressions.

$$CS = (K*real\ price\ of\ the\ commodity*\ quantity\ of\ commodity\ produced\ (1 + 0.5*K*\ e_d))$$

$$PS = (K*real\ price\ of\ the\ commodity*\ quantity\ of\ commodity\ produced*(1\text{-}0.5*K*\ e_s)$$

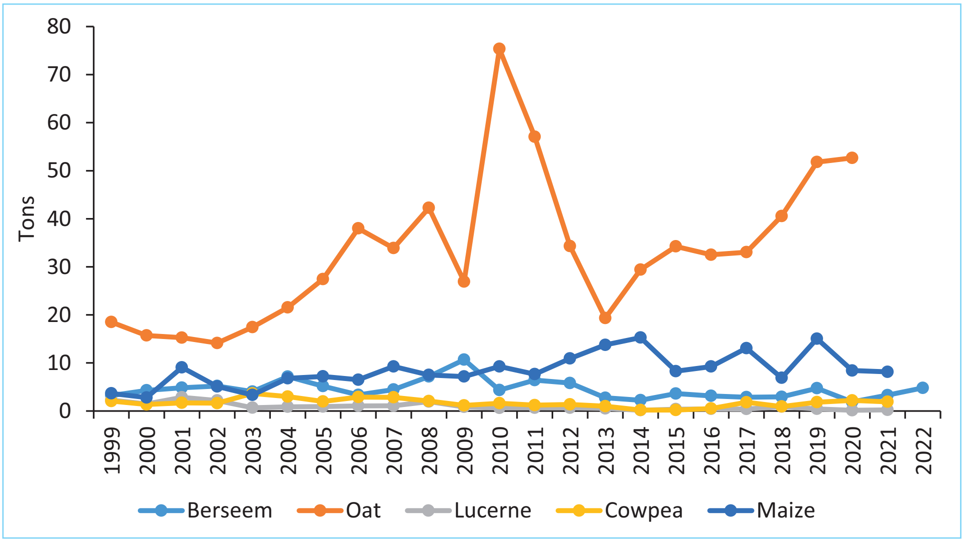
4 Estimates of Economic Impacts

4.1 Breeder seed production scenario

The trends in breeder seed production for selected crops from 1999 to 2022 exhibited significant fluctuations, with oat consistently dominating the seed production chain throughout the period (Figure 7), reaching a total production volume of approximately 731 tonnes (Table 7).This steady dominance can be attributed to the high demand for oat seeds, driven by their widespread use in both animal feed and human consumption, as well as the crop's adaptability to various climatic conditions and higher seed rate. Maize breeder seed production during the same period totalled around 194 tonnes, reflecting the crop's importance in both food and fodder production, but also indicating a more moderate production trend compared to oats.

For berseem, a critical forage crop, breeder seed production was about 108 tonnes, which, while significant, still pales in comparison to the

Figure 7. Trend in breeder seed production of selected crops



production of oat. The lower output may be influenced by factors such as limited cultivation areas or suitability of the crop in Northern Indian plains.

In the case of the other two crops, breeder seed production remained below 40 tonnes, signaling either a niche market demand or possible challenges in their cultivation and seed multiplication processes. These variations in production volumes underscore the influence of factors such as crop-specific demand, regional agricultural practices, and economic viability, all of which contribute to the overall dynamics of fodder breeder seed production in the country.

In the present study, the selected maize varieties—J 1006 and Africa Tall—dominated the maize seed chain, collectively accounting for a substantial 95% of the market share. This dominance highlights the significant role these varieties play in maize production, driven by their proven performance, adaptability, and widespread cultivation across various regions. Similarly, the selected varieties of Lucerne, including Anand-2, AL-3, and RL-88, contributed to 84% of the Lucerne seed chain, underscoring the importance of these varieties in the forage sector. These varieties are favored for their high yield potential, disease resistance, and suitability to diverse environmental conditions.

Table 7. Crop wise breeder seed production and share of the selected varieties during the assessment period (1999-2022)

Crop	Total seed production (tons)	Share of selected varieties (%)
Berseem	108.48	34.34%
Oat	731.49	17.02%
Lucerne	21.78	84.97%
Cowpea	39.15	44.64%
Maize	194.40	95.01%

Source: Authors estimates.

In contrast, the selected varieties of cowpea and berseem occupied smaller shares of their respective seed chains, with 44% and 34% share, respectively. The relatively lower share in the cowpea seed chain can be attributed to the existence of other competing varieties or regional preferences, while berseem's share reflects its more localized demand, primarily driven by the specific needs of forage farmers.

For oats, the two selected varieties—JHO-822 and UPO-212—represented only 17% of the oat seed chain. It is noteworthy that the oat seed chain is predominantly dominated by the variety "Kent," which was released in 1975 and has not been included in the current study.

4.2 Berseem

Berseem (*Trifolium alexandrinum*), also known as king of fodder crops, is one of the oldest cultivated fodder in the world. The crop was domesticated in Egypt and later spread across the world (Singh et al., 2019). It is now widespread in the irrigated regions of west and south Asia. Among the berseem growing countries, India is having highest area (~2 million ha) followed by Egypt (1.1million ha), and Pakistan (0.71 million ha) (Chand et al, 2023). It is an annual leguminous crop, well adapted to the semi-arid conditions of the Northern India. Berseem fodder is highly palatable due to its succulence and is nutritionally rich with 20% crude protein (CP) and 60% TDN for livestock. The crop provides fodder for a long season i.e., from November to May and behaves as a most potent milk multiplier in the lactating cattle and buffaloes. Keeping its importance, research has been one of the top priorities and is actively pursued in India.

Among the three considered varieties, *wardan* and *BB-2* were developed by ICAR-IGFRI, Jhansi while *BL*-10 is high forage yield variety of berseem (95 t/ha) released from Punjab Agricultural University, Ludhiana. BL-10 is a late-maturing variety that provides green fodder until mid-June, making it particularly favored by dairy farmers in north-western regions such as Punjab, Haryana, and Himachal Pradesh. In assessing the impact of *wardan* and *BL-10*, *mescavi* having yield potential 80 t/ha was used as check variety for*BB-2* (yield potential 95 t/ha*) wardan* variety was used as check which has yield potential of *90* t/ha (Table 8).

The current adoption rate for Wardan is approximately 22%, while BB-2 and BL-10 both have adoption rates around 20% (Table 9). For all three varieties, the existing adoption rates fall short of their estimated maximum adoption potential, suggesting that there may be barriers preventing farmers from fully embracing these varieties, such as lack of awareness, limited access to resources, or insufficient support for adoption at the local level.

Table 8. Proportionate yield change of selected varieties

Forage crop	Varieties		Average yield (t/ha)		Proportionate yield change
	Selected	Check	Selected	Check	
Berseem	Wardan	Mescavi	90.0	80.0	0.13
	BB-2	Wardan	95.0	90.0	0.06
	BL-10	Mescavi	95.0	80.0	0.19
Oat	JHO-822	Kent	60.5	55.0	0.10
	UPO-212	Kent	59.5	55.0	0.08
Lucerne	AL-3	Anand-2	120.0	77.5	0.54
	RL-88	LLC 3	122.0	70.0	0.74
	Anand-2	*NA*	77.5	*NA*	0.10
Cowpea	EC-4216	*NA*	30.0	*NA*	0.10
Maize	J-1006	*NA*	43.0	*NA*	0.10
	African Tall	*NA*	59.5	*NA*	0.10

Source: Roy et al., 2020.

Table 9. Adoption rate of forage varieties (2023-24)

Variety	Varieties of assessment period	Existing adoption rate (%)	Maximum adoption rate during assessment period (%)
Wardan	1999-2022	22.40	43.80
BB-2	2002-2022	20.53	38.33
BL-10	1999-2022	20.90	40.40
JHO-822	2002-2022	12.23	18.24
UPO-212	2000-2023	18.81	18.81
EC-4216	1999-2023	43.94	86.54
AL-3	2009-2023	13.04	71.54
RL-88	1999-2023	0.70	26.84
Anand-2	1999-2023	73.19	93.22
J-1006	1999-2023	17.43	56.77
African Tall	1999-2023	69.62	78.67

Source: Authors estimates.

The annual average forage biomass produced from each selected berseem variety was approximately 4 million tonnes. This increase in biomass resulted in a corresponding rise in equivalent milk output, which ranged from 0.1621 to 0.1650 million tonnes (Table 10).

Table 10. Annual average fodder and milk production from selected varieties during the assessment period

Crop	Varieties	Green forage biomass (million tons)	Milk production (million tons)
Berseem	Wardan	4.66	0.1621
	BB-2	4.67	0.1626
	BL-10	4.74	0.1650
Oat	JHO-822	0.51	0.0153
	UPO-212	0.75	0.0215
Cow pea	EC-4216	1.93	0.0678
Lucerne	AL-3	1.38	0.0399
	RL-88	1.91	0.0514
	Anand-2	10.36	0.2780
Maize	J-1006	36.92	0.9624
	African tall	100.48	2.6167

Source: Authors estimates.

The enhanced forage production from these varieties contributed significantly to improving overall milk yield, demonstrating the vital role of the crop in livestock production. The estimated economic gains from the selected berseem varieties were valued at around Rs. 22920.3 million. This includes Rs. 12104.6 million from BL-10, Rs. 7888.3 million from Wardan, and Rs. 2927.4 million from BB-2 (Table 11). The distribution of these economic gains between consumer and producer surpluses was consistent across all three varieties, with a 60:40 split in favour of consumers, indicating that, while both consumers and producers benefited, the consumer surplus was slightly higher in each case.

4.3 Fodder oat

Oats (*Avena sativa* L.) is one of the most important rabi fodder crops in India which is a highly palatable, rich source of energy, protein, vitamin B1, phosphorus, iron and other minerals. The crop is being cultivated in an area of one lakh hectares with maximum area in Uttar Pradesh (34%), followed by Punjab (20%), Bihar (16%), Haryana (9%) and Madhya Pradesh (6%) (Kumar *et al*. 2021). In 1989, two varieties of oat were developed and released, JHO-822 by the Indian Grassland and Fodder Research Institute in Jhansi, and UPO-2012 by GBPUA&T in Pantnagar for India's central region. Since 2002, the adoption rate of both varieties has increased sixfold. Currently, JHO-822 accounts for approximately 12% of the fodder oat area, while UPO-2012 covers about 18.8% (Table 9).

Table 11. Summary of economic impact of forage varieties (Rs. million)

Forage crop	Variety	Estimation period	Consumer Surplus	Producer Surplus	Total Economic Surplus	Research & Extension cost	Net Surplus	Annual net surplus
Berseem	Wardan	1999-2022	4734.0	3156.0	7890.0	1.70	7888.3	342.9
	BB-2	2002-2022	1757.3	1171.5	2928.9	1.40	2927.4	146.3
	BL-10	1999-2022	7263.7	4842.5	12106.2	1.60	12104.6	526.2
Oat	JHO-822	2002-2022	166.3	110.9	277.2	0.30	276.9	13.8
	UPO-212	2000-2023	230.2	153.5	383.7	0.30	383.4	16.6
Cowpea	EC-4216	1999-2023	8168.2	5445.4	13613.6	0.30	13613.3	567.2
Lucerne	AL-3	2009-2023	3859.0	2572.7	6431.7	0.20	6431.5	459.3
	RL-88	1999-2023	6823.4	4548.9	11372.3	0.30	11372.0	473.8
	Anand-2	1999-2023	25912.0	17274.7	43186.7	0.30	43186.4	1799.4
Maize	J-1006	1999-2023	35851.1	23900.8	59751.9	0.40	59751.5	2489.6
	African Tall	1999-2023	203076.5	135384.4	338460.9	0.30	338460.6	14102.5

Source: Authors estimates.

The additional annual average green forage biomass from oat varieties ranges from 0.51 to 0.75 million tonnes, and the corresponding annual average milk output from oats is significantly lower, ranging from 0.01 to 0.02 million tonnes. Despite the modest direct impact on milk yield, oats are crucial for maintaining a balanced diet during the rabi season, when other green fodder sources are scarce. As a cereal fodder, oats complement protein-rich legumes like berseem, improving overall feed quality, enhancing digestibility, and supporting animal health and productivity. Moreover, the importance of oats cannot be overlooked, particularly in meeting fodder requirements in cooler, temperate climates such as hilly regions, where frost is common. Moreover, in the areas where moderate rainfall or supplemental irrigation is available, oats can be a vital rabi crop for providing reliable green forage during challenging growing conditions. Economically, UPO-2012 has had a greater impact, generating Rs. 383.4 million, compared to Rs. 276.9 million from JHO-822 (Table 11). The benefits derived from both the varieties are distributed between consumers and producers in a 60:40 ratio.

4.4 Fodder cowpea

Cowpea (*Vigna unguiculata*) is a quick growing leguminous forage crop and can be grown in kharif as well as in *zaid* (summer) season. It is usually grown mixed with cereal fodders and grasses to improve the nutritive value of the herbage. The digestibility of cowpea fodder is above 70%. As a fodder crop, it is used for green feeding, hay making, grazing, and also for ensiling in mixtures with sorghum or maize.

In 1977, Indian Agricultural Research Institute, New Delhi developed a cowpea variety EC-4216 through selection from exotic material and was released for cultivation in the entire cowpea growing area in the country (Roy et al. 2020). Despite its age, EC-4216 remains highly relevant due to its high crude protein content and moderate drought resistance, traits that have contributed to its widespread adoption. This variety has maintained a significant presence, covering over 40% of the cowpea cultivation area and achieving the maximum adoption rate of 86% (Table 9). This enduring popularity highlights the variety's suitability and farmer preference, though it also suggests a need for ongoing evaluation and potential development of newer varieties to address evolving fodder challenges. Furthermore, policies aimed at strengthening the seed supply chain and incentivizing seed production of newer varieties would be imperative for ensuring a diverse and resilient fodder production system.

The results reveal a substantial economic impact attributed to the cowpea variety EC-4216, with its green fodder contributing to an estimated annual average milk output of approximately 0.06 million tonne (Table 10). Over the period from 1999 to 2023, the total economic impact of EC-4216 has reached Rs. 13613.3 million (Table 11). This figure underscores the variety's vital role in boosting dairy production and highlighting its enduring economic significance over two decades.

4.5 Lucerne

Lucerne (*Medicago sativa*) is known as 'Queen of forage crops' and is generally grown during rabi season as an important fodder crop in areas where water supply is inadequate for berseem and winter period is short. Its deeper root system makes it very well adaptable to dry areas with irrigation facilities. It grows well as a rainfed or un-irrigated crop in high water table areas. Lucerne is perennial (3-4 years), persistent, productive, and drought tolerant forage legume and supplies green fodder for a longer period (November - June) in comparison to Berseem (December - April). The crop can also withstand well under fairly low temperatures. To date, 16 varieties of Lucerne have been released at both state and national levels. Among these, the breeder seed production of three varieties—Anand-2, Anand Lucerne-3 (AL-3), and RL-88—has remained consistent over the years, indicating widespread acceptance among farmers. Anand-2, developed by Gujarat Agricultural University, Banaskantha in 1984 through the selection of perennial lucerne types. It is primarily grown in the Bhuj area of the Kutch region in Gujarat, where the unique climate and soil conditions favor its growth. Anand-2 has proven to be highly adaptable and productive in arid and semi-arid regions, and it has become a dominant variety in Gujarat, Rajasthan, and Maharashtra. Currently, it covers approximately 73% of the total lucerne cultivation area in these states (Table 9).

The variety's widespread adoption is a testament to its resilience and the suitability of its traits for these regions. Its ability to withstand drought conditions and produce high-quality forage throughout the year has made it a crucial crop for livestock farmers, particularly in areas with limited water resources. Another variety, AL-3 developed in 2006 by Anand Agricultural University, is suitable for the sub-tropical regions of Gujarat and Maharashtra. This variety is well known for its high herbage yield and resistance to major diseases. The current adoption rate of the variety is 13%, reflecting its steady, yet gradual acceptance among farmers. However, it is noteworthy that the adoption rate of this variety has previously surged to as high as 71% (Table 9).

RL-88, developed by MPKV, Rahuri in 1995, is another important variety suitable for year-round cultivation under irrigated conditions across India. This variety is distinguished by its rapid regrowth and superior vigour, which allow it to thrive in a range of environmental conditions. The ability to regrow quickly after being harvested makes RL-88 an excellent choice for farmers who need a continuous supply of fresh forage for livestock throughout the year. Despite its advantages, the national adoption rate of RL-88 remains below 1%, indicating that it has not yet achieved widespread use across the country. However, its highest adoption rate reached approximately 26% (Table 9). This suggests that while the variety has potential, further efforts are needed to promote its benefits and overcome any barriers to broader adoption.

Among the three lucerne varieties, the annual average milk output from the Anand-2 variety was the highest, reaching 0.27 million tonnes. This is approximately five times higher than that of RL-88 and seven times higher than that of AL-3 (Table 10). It is important to note that this significant difference in milk output is largely attributed to the higher adoption rate of Anand-2, despite its relatively lower productivity potential compared to the other two varieties (Table 8). The widespread adoption of Anand-2, especially in regions with challenging climatic conditions, has allowed it to contribute more significantly to milk production. Farmers have preferred this variety for its resilience and ability to thrive in arid and semi-arid environments, which has ultimately led to its larger share in total milk output.

Therefore, efforts are needed to increase the availability of high-quality seeds for varieties like RL-88 and AL-3 to encourage their adoption, particularly in regions where they are better suited due to their higher productivity potential. Government support for seed production and distribution, along with incentives for farmers to switch to these more productive varieties, would be crucial. Additionally, providing training and extension services to educate farmers about the benefits and best practices for adopting high-yielding varieties would be imperative.

The estimated economic impact of lucerne crop varieties reveals significant contributions from Anand-2 and RL-88, amounting to approximately Rs. 43186.4 million and Rs. 11372 million, respectively. The AL-3 variety, introduced later, also demonstrated a notable impact, amounting to Rs. 6431.5 million.

4.6 Maize

Maize (*Zea mays*) is an ideal forage crop, as it is quick growing, high yielding, palatable and nutritious. Among the cultivated non-legume fodders, maize is the most important crop that can be grown round the year under irrigated conditions. It is free from any anti-nutritional components, and is considered a valuable fodder crop. It contains high concentrations of protein and minerals and possesses high digestibility. Two maize varieties, namely, African tall (released in 1983) and J-1006 (released in 1989) were developed and released for commercial cultivation in India. African Tall, in particular, has been outstandingly popular, with a current adoption rate of over 69%. Collectively, both varieties dominate the seed chain, covering approximately 87% of the area designated for fodder maize (Table 9). This strong adoption rate underscores their effectiveness and popularity in meeting the fodder needs across the country.

The African tall maize variety has proven exceptionally impactful, contributing around 2.6 MT in annual milk production and has generated a total economic impact of Rs. 338460.6 million from 1999 to 2023, including Rs. 203076.5 million in consumer surplus and Rs. 135384.4 in producer surplus. Additionally, the estimated economic impact of the J-1006 variety is Rs. 59751.5 million, with economic benefits distributed between consumers and producers at a 60:40 ratio, respectively.

5 Conclusions and Implications

India is grappling with a severe fodder shortage, with 11% deficit in green fodder and 23% shortfall in dry fodder. The increasing livestock population and government focus on genetic enhancement of cattle by targeted crossbreeding programmes may widen the forage demand-supply gap in future. Despite substantial research and the introduction of around 350 forage crop varieties over the last fifty years, advancements in forage crops have not kept pace with improvements in staple crops like rice and wheat. While developing superior forage varieties is essential, there is a need for strong economic justification to support public investment in this research sector. This policy paper seeks to fill this gap by evaluating the economic impact of eleven leading forage crop varieties, aiming to reinforce focussed needs in forage research and development.

The study used secondary data from published and unpublished sources, including breeder seed production data from ICAR-AICRP on Forage Crops since 1999. Data on milch animals was sourced from livestock censuses (1997-2019), while wholesale milk prices were collected from the Department of Consumer Affairs, adjusted to 2022-23 prices. Besides, focused group discussions were conducted to assess the share of public and private sector in forage seed production. Green fodder production was estimated by multiplying yield potential of varieties by their respective cultivated area. The study used equivalent milk production from green fodder biomass for assessing impact, which was estimated by utilizing the Total Digestible Nutrient (TDN) content of the forage biomass and considering TDN requirements for producing one kilogram of milk. The estimated equivalent milk production from fodder and wholesale price of milk at constant prices were integrated into the economic surplus model to evaluate the economic benefits of the selected varieties.

The evaluation of various fodder crops and their respective varieties reveal a substantial economic impact at national level. The berseem varieties—*wardan*, BB-2, and BL-10— showcase considerable advancements in fodder production and economic gains, with BL-10 emerging as a particularly effective variety due to its extended growth period and high yield. The impact of these berseem varieties on dairy production underscores the critical role of high-quality fodder in enhancing milk output and economic returns. Oats, with varieties like JHO-822 and UPO-2012, have seen a significant rise in adoption, indicating their growing importance in fodder systems and their role in improving dairy nutrition and economic benefits. Cowpea variety EC-4216, despite its age, remains a staple due to its high protein content and drought resistance, contributing significantly to milk production and economic benefits. Lucerne varieties Anand-2, AL-3, and RL-88 further demonstrate the value of perennial fodder crops in providing sustained green fodder and economic returns over multiple years. The maize varieties African Tall and J-1006 stand out for their widespread adoption and substantial economic impact, highlighting the crucial role of maize in fodder supply and dairy production during summer season.

The vision of becoming self-reliant in fodder resources by bridging the demand-supply gap of feed and fodder to sustain our livestock production system in long run will not be materialized without proactive policy support of both central and state governments. There is a need to adopt a multi-pronged strategy for ensuring year-round availability of adequate quality fodder for livestock and to provide a buffer to the farmer even in times of climatic risks and uncertainties. Based on the field experiences and findings of the present study, we propose the following policy options that will be crucial in bridging demand-supply gaps in fodder to a large extent and ensuring sustainable growth in the livestock and dairy sector:

1. Varietal improvement and promotion for adoption

- There is a need for scaling up the adoption of forage crop varieties that offer high economic returns. In particular, African Tall maize for the kharif season and BL-10 berseem for the rabi season warrant focused attention, given their proven adaptability across diverse regions and their significant contribution to economic gains. Equally important is the promotion of leguminous forage crops such as cowpea during the Kharif season and cereal fodder crops like oat during the Rabi season, as these are essential for providing livestock with a balanced and nutrient-rich diet. EC-4216 variety of cowpea exemplifies its enduring relevance and the need to maintain and expand its cultivation, particularly in rainfed and resource-constrained areas where resilience is paramount.
- Varietal promotion efforts must be aligned with regional agro-climatic conditions to ensure agronomic suitability, farmer adoption, and long-term impact. For instance, lucerne is more suitable for cultivation in southern, specific western regions and high altitude areas of India due to their favorable climatic regimes. Within lucerne varieties, Anand-2 should be prioritized for promotion in appropriate zones, especially in

perennial fodder systems. Regional tailoring of varietal strategies will thus enhance productivity, minimize resource wastage, and optimize returns for both farmers and the broader livestock economy.

- The dominance of old varieties in the seed chains of the fodder sector indicates a stagnant varietal replacement rate (VRR). For instance, in case of lucerne, the varieties having more than 15 years of age (only three varieties) had 61.70% contribution to the total breeder seed indent during the period 2017–2018 to 2021–2022. Increasing the VRR is crucial to introduce newer varieties that offer higher fodder yield.
- The genetic improvement of fodder varieties should also emphasize enhancing their nutritional quality and digestibility. A study by Kristjanson and Zerbini (1999) revealed that a mere 1% enhancement in the digestibility of sorghum and pearl millet residues through genetic improvement could boost milk and meat production by 6–8%. Therefore, integrating nutritional traits into varietal development strategies, along with accelerated dissemination and replacement of outdated varieties, is essential for maximizing economic gains from research investments in fodder variety development.

2. Seed system

- The data on breeder seeds production of many forage varieties from the public sector showed a critical decline during the inter-study period. This underscores the interventions to bolster breeder seed production through targeted funding and strong research collaborations with streamlined regulations. The need for strengthening infrastructure for breeder seed multiplication, seed processing, and storage centers for fodder seeds has been consistently raised (NAAS 2022, Singh et al., 2024). Addressing these gaps would enhance the capacity of public institutions to produce and maintain adequate breeder seed stocks, ensuring the timely availability of quality seeds for subsequent stages of seed multiplication, and would ultimately strengthen the overall fodder seed chain.
- Field experiences and focused group discussions during the study revealed a low seed replacement rate in forage crops. Moreover, there is a shortage in the production of high-quality seeds for cultivated fodder crops and grasses (Singh et al., 2024). Therefore, there is a pressing need to prioritize the production of quality seeds for fodder crops. A well-coordinated Fodder Seed Hub can address challenges in quality fodder seed production to a large extent by centralizing production, processing, and distribution, while promoting collaboration among farmers, research institutions, and other key stakeholders. The seed hub

has proven to be a vehicle for faster seed replacement and an effective means for seed extension, especially in pulses and oilseeds. IGFRI can serve as the central node of the hub, with Self-Help Groups (SHGs), farmers, NGOs, and research institutions as key stakeholders.

- Increasing production of truthfully labelled and certified fodder seeds through participatory seed production models involving farmers and agripreneurs would be imperative to enhance local quality seed availability to a large extent. For this, providing financial incentives for seed certification and conducting training programs for participatory fodder seed production would be essential. Fostering partnerships between research institutions, agricultural extension services, and grassroots organizations like milk unions and Krishi Vigyan Kendras to facilitate knowledge exchange and effective scaling of participatory seed production initiatives should be prioritized, as these collaborations can significantly strengthen local seed systems and improve adoption of quality fodder seeds.

  To operationalize these seed system reforms, clear institutional responsibilities must be assigned. The table 12 outlines the suggested roles of key institutions for implementing fodder policy options across the seed and extension value chain.

3. Market development

- Another important area that needs attention is ensuring parallel development of supporting market environment for fodder encompassing backward and forward market linkages. Provision of dedicated market space with legal credentials across states will facilitate transparency and remunerative prices for fodder growers and traders. As the government is set to promote startups and rural enterprises, NABARD can be directed to promote rural enterprises working in fodder-space. There is a need to support fodder cultivation as a bankable project to those entrepreneurs who wish to take up fodder cultivation/seed production as an economic activity to obtain bank loans. Arrangement for buy back guarantee with prior agreement for procurement of green fodder and fodder seed from the entrepreneurs should be made.

Table 12: Institutional responsibility matrix for fodder policy implementation

Institutes/organizations	Primary roles and responsibilities
ICAR- IGFRI, Jhansi and AICRP-Forage crops / SAUs/ CAUs	✓ Research and developments for new fodder varieties and agro-technologies ✓ Breeder seed production and maintenance of varieties having more economic impact ✓ Training to 'Master trainers' for fodder technologies including seed production The specific roles of ICAR–IGFRI may include ✓ Central node for national seed planning ✓ Farmer engagement & training ✓ Technical backstopping to states
State Agriculture Departments	✓ Conduct varietal trials for agro-climatic adaptation ✓ Identify local seed needs - Support regional seed planning ✓ Extension activities ✓ Training to district level officers and progressive farmers
Krishi Vigyan Kendras (KVKs)	✓ Localized extension and demonstrations ✓ Farmer training on fodder technologies
National Dairy Development Board (NDDB)	✓ Facilitate fodder extension through dairy cooperatives ✓ Promote participatory seed production models ✓ Capacity building of milk unions
Milk Unions and dairy Cooperatives	✓ Last-mile delivery of seed and advisory ✓ Organize certified seed production through member farmers
National Seed Corporation/ Sate Seed Corporations/ Private Companies	✓ Foundation & certified seed production at scale ✓ Contract production with farmers ✓ Quality assurance of seed
NABARD / Banks / Rural Financial Institutions	✓ Credit to fodder entrepreneurs, SHGs, and FPOs ✓ Design fodder-focused financial products ✓ Offer incentives/subsidies for seed enterprises
FPOs / SHGs / Progressive Farmers	✓ Act as decentralized seed producers ✓ Implement participatory models ✓ Serve as rural seed hubs

4. Research gaps

- Unlike field crops, research on the cost of cultivation of green fodder and fodder seed is very limited. Farmers' choices are guided by the costs and benefits associated with the adoption of any technology. While a few studies have been conducted in dairy-progressive states like Punjab (Grover and Kumar, 2013; Agnotra et al., 2023), these studies do not capture the cost differentials arising from the adoption of improved fodder varieties. Systematically assessing region-specific cost structures for green fodder cultivation would provide clear evidence of the economic viability of these improved varieties for farmers. This, in turn, would enhance the confidence of extension agencies in promoting their wider adoption by effectively demonstrating their profitability.

References

Agnotra, K., R. Kumar, and S. Ranguwal. 2023. Berseem seed and fodder production for Punjab's dairy sector - A comparative economic analysis. *Indian Journal of Dairy Science* 76(2): 168-175

Alston, J. M., G. W. Norton, and P. G. Pardey. 1995. *Science under scarcity: Principles and practice for agricultural research evaluation and priority setting*, International Service for National Agricultural Research, Cornell University Press, Ithaca, NY.

Bijla, S., P. S. Birthal, R. Malhotra, A. K. Dixit, G. Sankhala, P. Singh, and S. Maiti. 2023. Livestock and transitional poverty in rural India. *Agricultural Economics Research Review* 36(2): 155–168.

Birthal, P. S., and A. K. Jha. 2005. Economic losses due to various constraints in dairy production in India. *Indian Journal of Animal Sciences* 75(12):1470-1475.

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

Birthal, P. S., and V. K. Taneja. 2006. *The livestock sector in India: Opportunities and challenges for small holders*. In: P. S. Birthal, V. K. Taneja & W. Thorpe (Eds.), Smallholder livestock production in India: Opportunities and challenges. Pp. 4-64, National Centre for Agricultural Economics and Policy Research (NCAP) and International Livestock Research Institute (ILRI). New Delhi, India.

Birthal, P. S., S. K. Srivastava, R. Saxena, S. Godara, P. Chand, P. Kishore, J. Jumrani, A. Kandpal, P. Sharma, and D. K. Pant. 2025. Indian agriculture to 2047: Reshaping policies for sustainable development. Policy Paper 50. ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi.

Birthal, P. S., D. S. Negi, A. K. Jha, and D. Singh. 2014. Income sources of farm households in India: Determinants, distributional consequences and policy implications. *Agricultural Economics Research Review* 27(1): 37-48.

Chand, S., A. K. Roy, T. Singh, R. K. Agrawal, V. K. Yadav, S. Kumar, D. R. Malaviya, A. Chandra, and D. K. Yadav. 2023. Twenty-four years lucerne (*Medicago sativa* L.) breeder seed production in India: A retrospective study. *Frontiers in Plant Science* 14:1259967.

Choudhary, B. B., P. Chand, P. Singh and S. Pandey. 2024. *Marketing of feed and fodder in India: Issues, challenges and way forward*. In: Essentials of Agricultural Science, pp. 45–56. ISBN 978-81-97682-53-7.

Galiè, A., N. Teufel, L. Korir, I. Baltenweck, A. Girard, P. Dominguez-Salas, and K. Yount. 2019. The women's empowerment in livestock index. *Social Indicators Research 142*(3): 799–825

Ghosh, P. K., D. R. Palsaniya, and R. Srinivasan. 2016. Forage research in India: Issues and strategies. *Agricultural Research Journal* 53(1): 1-12.

GOI. 2024. Working Group Report on Crop Husbandry, Agriculture Inputs, Demand & Supply. NITI Aayog, Government of India, New Delhi.

Grover, D. K., and S. Kumar. 2013. Sorghum (Fodder) cultivation in Punjab — An economic analysis. *Agricultural Economics Research Review* 26 (1): 55-62.

Gupta, G., D. R. Palsaniya, M. S. Sannagoudar, B. B. Choudhary, S. Barman, M. Choudhary, D. Upadhyay, R. K. Patel, S. K. Singh, K. Chand, S. Pandey, and M. Suman. 2025. Livelihood and energy-carbon dynamics of livestock-based integrated farming system: Assessment and implications for sustainable farming. *Farming System 4*(1), 100183. https://doi.org/10.1016/j.farsys.2025.100183

ICAR. 2012. *Nutrient requirement of animals (cattle and buffalo)*. Indian Council of Agricultural Research, New Delhi, India.

ICAR-NIAP. 2025. *Agricultural development report, 2024*. ICAR-National Institute of Agricultural Economics and Policy Research, New Delhi.

IGFRI. 2015. Vision 2050. Indian Grassland and Fodder Research Institute (Indian Council of Agricultural Research) Gwalior Road, Jhansi, Uttar Pradesh.

Kristjanson, P. M., and E. Zerbini. 1999. *Genetic enhancement of sorghum and millet residues fed to ruminants: An ex-ante assessment of returns to research*. ILRI Impact Assessment Series 3. International Livestock Research Institute, Kenya.

Kumar, S., G. V. R. Jayaramaiah, P. Koler, and S. T. Bhairappanavar. 2021. Growth, yield and quality parameters of fodder oats (*Avena sativa* L.) under varied dates of sowing and nitrogen application. *Mysore Journal of Agricultural Sciences* 55(1): 37-45.

Kurosaki, T. 1996. Milk, fodder, and the Green Revolution: The case of mixed farming in the Pakistan Punjab. *The Pakistan Development Review 35*(4): 537–548.

La Rovere, R., G. Kostandini, A. Tahirou, J. Dixon, W. Mwangi, G. Zhe, and M. Bänziger. 2010. *Potential impact of investments in drought-tolerant maize in Africa*. International Maize and Wheat Improvement Center, Addis Ababa.

NAAS. 2022. *Entrepreneurship for quality fodder production*. Policy Paper 118, National Academy of Agricultural Sciences, New Delhi.

Rowell, C. D., O. P. Valerien, M. R. Roderick, H. Bhandari, G. M. MonirulAlam, and R. S. Andrade. 2022. Assessing returns to research investments in rice varietal development: Evidence from the Philippines and Bangladesh. *Global Food Security* 33:100646.

Roy, A. K., and J. P. Singh. 2013. Grasslands in India: Problems and perspectives for sustaining livestock and rural livelihoods. *Tropical Grasslands – Forrajes Tropicales*: 240–243.

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

Roy, A. K., R. K. Agrawal, S. Chand, S. Ahmad, R. V. Kumar, A. K. Mall, N. R. Bhardwaj, R. Mawar, D. N. Singh, S. R. Kantwa, and S. A. Faruqui. 2020. *Database of forage crop varieties: 2020*. AICRP on Forage Crops & Utilization, ICAR-IGFRI, Jhansi, India.

Saxena, R., B. B. Choudhary, and D Joshi. 2019. Enhancing farmers' incomes from livestock in eastern India with special emphasis on dairying: Major drivers and strategies. *Indian Journal of Dairy Science* 72: 659–667.

Sharma, P., B. B. Choudhary, P. Singh, S. Kumar, G. Gupta, and I. Dev. 2021. Can forage technologies transform Indian livestock sector? Evidences from smallholder dairy farmers in Bundelkhand region of central India. *Agricultural Economics Research Review* 34(conference issue):73-82.

Singh, A. K., M. Tomar, V. K. Yadav, P. Singh, R. P. Saini, S. Swami, D. R. Palsaniya, and P. Kaushal. 2024. Forage seed production in India: Status, challenges and strategies. ICAR-Indian Grassland and Fodder Research Institute, Jhansi, India. 54.

Singh, T., R. Srinivasan, S. K. Mahanta, V. C. Tyagi, and A.K. Roy. 2019. *Tropical Forage Legumes in India: Status and Scope for Sustaining Livestock Production*. IntechOpen. doi: 10.5772/intechopen.81186.

William, A. M., B. Coulibaly, M. Sidibe, and A. Williams. 1996. *The economic impact of agricultural research: A practical guide*. Department of Agricultural Economics, Purdue University, West Lafayette, United States.

Annexure A1. List of parameters for the selected crop varieties

Parameter	Crop varieties										
	Wardan	**BB-2**	**BL-10**	**JHO-822**	**UPO-212**	**EC-4216**	**AL-3**	**RL-88**	**Anand-2**	**J-1006**	**African tall**
Assessment period	1999-2022	2002-2022	1999-2022	2002-2022	2000-2023	1999-2023	2009-2023	1999-2023	1999-2023	1999-2023	1999-2023
Initial year production in domain areas (million tonnes)	0.108	0.024	0.097	0.002	0.003	0.044	0.672	0.040	0.457	0.402	1.018
Initial year price in Rs. per tonnes (2022-23 prices)	56082	57828	56082	57828	53902	56082	59063	56082	56082	56082	56082
Demand elasticity*	0.40										
Supply elasticity*	0.60										
Depreciation rate	1										

*Source: Kurosaki, 1996

Publications

Policy Papers

39. Saxena, R., S.K. Srivastava, S.J. Balaji, A. Jhajhria, and M. A. Khan. 2023. *Changes in Indian Agriculture: Household-level Evidence*.
40. Nikam, V., H. Veesam, T.M. Kiran Kumara, and P. Chand. 2023. *Farmer Producer Organizations in India: Challenges and Prospects*.
41. Birthal, P.S., J. Hazrana, D. Roy, and K.J.S. Satyasai. 2024. *Can Finance Mitigate Climate Risks in Agriculture? Farm-level Evidence from India*.
42. Chand, P., T.M. Kiran Kumara, S. Pal, and K. Naik. 2024. *A Spatial Assessment of Sustainability in Indian Agriculture*.
43. Kishore, P., D. Roy, P.S. Birthal and S.K. Srivastava. 2024. *Regulation and Policy Response to Groundwater Preservation in India*.
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45. Sharma, P., M. Yeasin, R. K. Paul, D.C. Meena and M. E. Anwer. 2024. *Food Price Volatility in India*.
46. Srivastava, S.K., P. Kishore, P.S. Birthal and P.B. Shirsath. 2024. *Harnessing the Potential of Solar-Powered Micro-Irrigation for Sustainable Intensification of Agriculture*.
47. Saxena, R., P. S. Birthal, R. C. Agrawal, P. Sharma, S. J. Balaji, D. K. Pant, and N. Joshi. 2024. *From Local to Global: Opportunities to Accelerate Agriculture Exports from India*.
48. Kishore, P., P. S. Birthal, and S. K. Srivastava. 2025. *The Dilemma of Agricultural Price Policy Reforms: Balancing Food Security, Farmers' Interests, and Sustainability of Natural Resources*.
49. Kumar S., P. S. Birthal, S. Kumar, and R. K. Yadav. 2025. *Economic Impact of Subsurface Drainage Technology: Institutional and Policy Imperatives for Upscaling*.
50. Birthal, P.S., S.K. Srivastava, R. Saxena, S. Godara, P. Chand, P. Kishore, J. Jumrani, A. Kandpal, P. Sharma and D.K. Pant. 2025. *Indian Agriculture to 2047: Reshaping Policies for Sustainable Development.*
51. Balaji, S.J., P.S. Birthal, B.D. Pal, J. Thurlow, E. Gotor, P. Sharma, S.K. Srivastava, I.T. Kingsly, and N. Naresha 2025. *The Future of Food in India: A 2050 Perspective*.
52. Shekhawat, R.S., P. Chand, K.T.M. Kumara, P.C. Moharana, V.S. Rathore, N.R. Panwar, and D. Kumar 2025. *Valuation of Ecosystem Services from Sand Dune Stabilization in Indian Thar Desert*.

Policy Brief

57. Chand, K., P.S. Birthal and S. Kachhawaha. 2024. *Impact of Prophylactic Vaccination in Cattle against Lumpy Skin Disease*.
58. Vatta, K., B.K. Sidana, R. Jain, L. Priscilla, A. Kandpal and G. Kaur. *2024. Is DSR Economically Viable?*
59. Kiran Kumara, T.M. and P.S. Birthal. 2024. *Re-purposing Agricultural Subsidies to Ecosystem Services*.
60. Kumar, N.R. and P.G. Athare. 2025. *Farm Mechanization in India. The Crucial Role of Custom Hiring Services*.
61. Birthal, P.S., S.K. Srivastava and J. Singh. 2025. *From Cereals to High-Value Foods*.
62. Kumar, A. and P. S. Birthal. 2025. *Leveraging Potential of Dung for Energy Security and Sustainable Agriculture*.
63. Srivastava, S.K., P. Kishore, P. S. Birthal, J. Singh and R. R. Sethi. 2025. *Tiered Electricity Pricing for Sustainable Groundwater Use for Irrigation*.
64. Kumar, S., A.K. Sharma, R. Jain, R.K. Yogi, A. Kandpal and P.K. Rai. 2025. *Economic Impact of Improved Mustard Varieties: A Case of Giriraj*.
65. Jain, R., A. Ashok, Nisha and V. Kumar. 2025. *Harvesting Benefits of Drone Technology in Agriculture*.
66. Nikam, V., T.M. Kiran Kumara , S. Godara and P.S. Birthal. 2025. *Enhancing Financial Viability of Farmer Producer Organizations*.
67. Jumrani, J. 2025. *Intra-household double burden of malnutritions in India: Prevalence, Variations and Implications*.
68. Balaji, S.J., M.L. Nithyashree and P.S. Birthal. 2025. *Farm-Nonfarm Linkages in India: Multiplier Effects and Policy Implications*.
69. Chand, K., T.K. Bhattacharya, A. Bhardwaj, Y. Pal, S.C. Mehta and A. Singh. 2025. *From Beast of Burden to Dairy Animal: Transforming Donkey Husbandry for Human Nutrition and Health*.
70. Kumar, B., K.T.M. Kumara, S.L. Jat, and H.S. Jat. 2025. *Economic Impacts of Maize Hybrids*.
71. Sharma, P., D.C. Meena, N.P. Singh, and N. Joshi. 2025. *From Regulation to Liberalization: Impact of Deregulating Horticultural Markets*.

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