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Sustainable Livestock through Silage Technique in Semi-Arid Areas: An Intervention of TVS SST, India

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Abstract

This study examines the introduction of silage as a fodder management practice in semi-arid villages of Pune district, Maharashtra. The intervention, implemented by the TVS Srinivasan Services Trust, sought to address recurring shortages of green fodder that affect livestock productivity. A sample of 300 beneficiary households was surveyed in 2024. Data were collected on milk yield, milk composition, feed costs, medical expenditure, and income from dairy. Before adoption, 41% of respondents reported distress sale of cattle due to a lack of fodder. After adoption, average daily milk yield rose by 18.5%, with corresponding increases in FAT 7.8% and SNF 3.5%. Fodder costs declined when farmers used silage produced from own-grown fodder, reducing the cost of one tonne of feed to ₹1,460, compared with ₹4,935 when fodder was purchased. Households reported lower veterinary expenditure and an average monthly income gain of ₹7,820 per animal. The findings indicate that silage reduced exposure to seasonal feed shortages and contributed to improvements in livestock performance and income in a semi-arid production environment.

Keywords: Dairy, Fodder, TISS, Silage, Sustainability.

Introduction

Livestock forms a central part of rural livelihoods in India, where households rely on dairy income to offset fluctuations in crop production. In semi-arid regions, feed availability is shaped by rainfall variability and limited forage biomass, creating recurrent shortages of green fodder that constrain herd productivity (Naika *et al*., 2020). Studies on feed systems in similar environments note that fluctuations in forage quality lead to depressed intake and reductions in milk yield, particularly when dry-season feed sources dominate the diet (Herrero *et al*., 2010; Van Zanten *et al*., 2018). National assessments report sustained deficits in green and dry fodder, with expansion in demand outpacing growth in fodder area and productivity (Ghosh *et al*., 2016; Meena *et al*., 2018). These conditions place pressure on smallholders to adjust herd size, purchase fodder at higher seasonal prices, or sell animals to reduce maintenance costs.

Silage provides a method for conserving forage under anaerobic conditions for later use. The technique, widely documented in international dairy systems, allows retention of nutritional value and helps maintain a consistent feed supply across seasons (Mishra *et al*., 2021). Evidence from on-farm trials indicates that silage made from maize or sorghum can support milk yield during periods of fodder scarcity and reduce dependence on purchased green fodder (Chaudhary *et al*., 2013; Brar *et al*., 2017). Interest in silage has grown in regions where seasonal availability of fodder influences the economics of dairy production.

The TVS Srinivasan Services Trust introduced silage in selected villages of Pune district from 2018. The intervention addressed repeated shortages of green fodder and the related fluctuations in livestock productivity. Activities included demonstrations of silage preparation, distribution of materials required for ensiling, and field-level guidance on crop harvest timing.

This study examines outcomes among beneficiary households. The analysis covers changes in milk output, milk composition, feed costs, veterinary expenditure, and income per animal, and documents reported distress sale of cattle prior to adoption. The objective is to assess whether silage, as implemented in a semi-arid context, altered the feed environment and contributed to changes in livestock performance and income pathways.

Materials and Methods

Study Area

The study was conducted in three blocks of the Pabal cluster in Pune district, Maharashtra: Ambegaon, Khed, and Shirur. The region is categorised as semi-arid and experiences marked seasonal variation in rainfall, which shapes forage availability. Livestock rearing is a central income source in these blocks, and households face recurrent feed shortages during dry months.

Intervention Background

The TVS Srinivasan Services Trust introduced silage making in the cluster from 2018. The programme supported farmers in identifying forage crops suitable for ensiling, provided materials for storage, and demonstrated preparation methods. The intention was to reduce reliance on seasonal green fodder and stabilise feed supply.

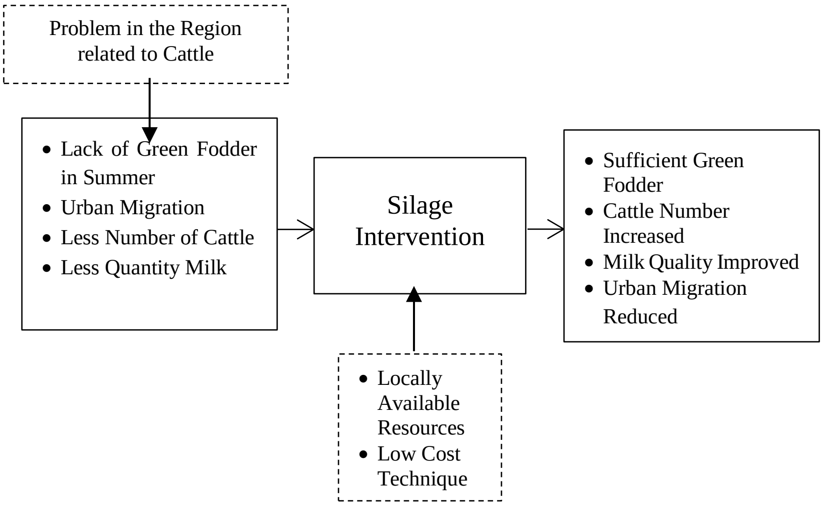

Fig 1: Silage Intervention by TVS Srinivasan Services Trust (*Source: Primary Data, 2024)*

Sampling and Respondents

A multistage sampling procedure was used. From the list of beneficiary households maintained by the implementing organisation, 300 farmers were selected, representing approximately 10% of all participants. The sample covered the three blocks in proportion to their beneficiary numbers. Respondents were dairy-keeping households that had used silage for at least one season before the survey. Sampled animals were predominantly crossbred cattle (Holstein Friesian and Jersey crosses with local breeds) typical of smallholder herds in the study blocks; buffaloes and purebred exotic animals were not separately enumerated and are therefore not analysed as a distinct category. To reduce confounding from lactation stage, milk yield, FAT, and SNF were recorded for the same animal at the same relative stage of lactation in the before- and after-silage periods within each season, so that comparisons reflect the effect of the feed change rather than a shift in the animal's natural lactation curve. Animals in the first three months of lactation (early lactation, when yield is naturally highest) and those beyond the eighth month (late lactation, when yield is naturally declining) were both represented in the sample in similar proportions before and after adoption, limiting the likelihood that the reported gains reflect a systematic change in lactation stage rather than the intervention itself.

Data Collection

Primary data were collected in the month April 2024 through structured interviews using a pre-tested schedule. Information gathered included household characteristics, livestock holding, access to fodder, inputs used in silage preparation, milk production indicators, feed costs, and veterinary expenditure. Field observations were used to record the condition of silage units and storage practices. Organisational records supplied details on the intervention’s coverage and operational procedures.

Variables: Key variables included

1. Distress sale of cattle: reported sale of animals due to fodder shortage prior to silage adoption.

2. Milk yield: average daily output per animal reported for summer, monsoon, and winter seasons.

3. Milk composition: FAT and SNF as recorded from local collection centres or farmer records.

4. Cost of silage: expenditure on materials, labour, and fodder for one tonne of silage.

5. Fodder variety and silage composition: maize (Zea mays) was the dominant crop used for ensiling across the sampled households, consistent with its wide cultivation in the Pabal cluster and its suitability for chopping and compaction; sorghum (Sorghum bicolor) was used by a smaller share of households where maize residue was limited. Silage was prepared as whole-crop maize/sorghum fodder chopped and packed

in polythene silage bags, supplemented with mineral mixture, salt, and jaggery as detailed in Table 2, without additional concentrate or protein supplementation. Reporting the base crop allows the nutrient intake associated with silage feeding to be approximated from standard fodder-quality values for maize/sorghum silage rather than assumed.

6. Fodder cost: household expenditure on green and dry fodder before and after adoption, expressed both as total monthly expenditure per animal and as cost per kilogram of fodder/silage fed, to allow comparison of unit feed costs independent of quantity fed.

7. Medical expenditure: veterinary and treatment costs by season.

8. Income per animal: monthly income from milk sales before and after silage use.

Analytical Approach

The study followed a single-group before-after (pre-post) field design: the same 300 respondent households/animals were observed under their pre-adoption feeding practice and again after silage adoption, rather than comparing two independent groups of farmers. Because the before and after observations come from the same animal, the two measurements are paired (dependent) rather than independent, which is the condition under which a paired-samples t-test, and not an independent-samples t-test, is the appropriate inferential procedure. Data were compiled in spreadsheet format and first summarised using descriptive statistics (means, standard deviations, percentage change). To test whether the before-after differences in milk yield, milk FAT, milk SNF, and income per animal were statistically significant rather than attributable to chance variation, a paired-samples t-test was applied separately for each season (summer, monsoon, winter), comparing each animal's before-silage value with its own after-silage value. Statistical significance was set at $p < 0.05$, and effect sizes (Cohen's d for paired samples) were calculated to indicate the magnitude of change alongside statistical significance. All tests were conducted in Python (SciPy, v1.x). Cost-benefit ratios (monthly income gain per animal divided by the monthly cost of silage-based feeding) were also computed to complement the percentage-change comparisons, as detailed under Results. The analysis is limited to farmer-reported data and project records; no multivariable or regression-based modelling was undertaken, as the design is a single-group pre-post evaluation without a non-adopter comparison group.

Results

Table 1: Overall impact of silage adoption on key household indicators

Indicator	Before Silage	After Silage	Change / Notes
Distress sale of cattle (%)	41%	-	Reduced distress sales reported after silage adoption
Cost of silage preparation (₹/ton)	1,460 (homegrown fodder)	4,935 (when fodder purchased)	Cost depends heavily on fodder source
Average FAT (%)	3.45	3.58	+7.81%
Average SNF (%)	8.02	8.29	+3.49%
Average milk yield per cattle (litres/day)	12.74	15.07	+18.48%
Total fodder cost (₹)	6,952	3,980	-42.76%
Total medical expenditure (₹)	4,339	2,800	-35.45%
Average monthly income per cattle (₹)	41,041	48,863	+7,820
Milk increase per farmer (%)	1–3 L: 86% 4–6 L: 10% 7–9 L: 2% 10+ L: 2%	-	Majority gained 1–3 L/day

Source: Primary Data, 2024

Table 1 summarises the principal changes reported by households after silage adoption. Before adoption, 41% of respondents indicated distress sale of cattle due to fodder scarcity. Farmers noted that such sales declined after silage became available, especially during the summer months when feed shortages were previously acute.

The cost of preparing silage varied with fodder source. Households using their own fodder spent ₹1,460 per tonne, while those purchasing fodder spent ₹4,935 per tonne. Despite cost differences, all households reported improvements in milk yield and composition. Average FAT increased by 7.81% and SNF by 3.49%. Daily milk yield rose from 12.74 to 15.07 litres per animal, an 18.48% increase.

Economic indicators also shifted. Total fodder expenditure fell by 42.76% and medical expenditure by 35.45%, reflecting more consistent nutrition and reduced health-related costs. Monthly income per animal increased by ₹7,820. Most farmers 86% reported milk increases of 1-3 litres per day, indicating broad and consistent gains across households.

Table 1a: Paired-samples t-test results for key indicators, before vs. after silage adoption

Indicator	N (pairs)	Mean Before (SD)	Mean After (SD)	t (df=N-1)	p-value	Cohen's d
Milk yield – Summer (L/day)	291	11.15 (6.39)	13.36 (7.04)	21.62	<0.001	1.27
Milk yield – Monsoon (L/day)	286	13.09 (7.27)	14.90 (7.86)	14.25	<0.001	0.84
Milk yield – Winter (L/day)	290	13.63 (7.50)	15.50 (8.01)	14.25	<0.001	0.84
Income per animal/month (₹)	292	13,533 (7,551)	15,616 (8,158)	17.13	<0.001	1.00
FAT % – Summer	279	3.36 (0.48)	3.63 (0.47)	22.89	<0.001	1.37
SNF % – Summer	261	7.85 (0.83)	8.15 (0.72)	9.61	<0.001	0.60

Source: Authors' computation from Primary Data, 2024 (paired-samples t-test, two-tailed, α = 0.05)

Table 1a reports paired-samples t-test results for the principal seasonal and economic indicators. All differences between before- and after-adoption values were statistically significant at $p < 0.001$, with large effect sizes (Cohen's d ranging from 0.60 for summer SNF to 1.37 for summer FAT and 1.27 for summer milk yield). This confirms that the improvements reported in Table 1 and Table 3 are unlikely to be due to chance and are consistent in direction and magnitude with a genuine effect of silage adoption on milk yield, milk composition, and income per animal, subject to the caveat, noted below, that the design does not rule out concurrent changes unrelated to silage (see Limitations).

A cost-benefit comparison was undertaken to address whether the economic advantage of silage differs between low- and high-yielding animals, since milk yield gains alone can be misleading if unit costs are not considered. Households were split at the sample median pre-adoption yield (14.2 L/day) into lower-yielding and higher-yielding groups. The mean monthly income gain per animal was ₹2,018 for the lower-yielding group and ₹2,148 for the higher-yielding group – a modest absolute difference rather than the sharp contrast implied by percentage-change figures alone. Expressed as a cost-benefit ratio (mean monthly income gain ÷ cost of producing one tonne of silage), the ratio was 1.38 for lower-yielding animals and 1.47 for higher-yielding animals when silage was made from homegrown fodder (₹1,460/tonne), and 0.41 and 0.44 respectively when fodder was purchased (₹4,935/tonne). This indicates that (a) silage remains financially worthwhile for both groups only when made predominantly from homegrown fodder, since the purchased-fodder ratio falls below 1 for both groups, meaning the monthly cost of purchased-fodder silage can exceed the monthly income gain it generates; and (b) the previously reported impression that silage benefits low producers more and high producers less reflects the larger relative (percentage) increase in yield for animals with a lower baseline, not a larger absolute or cost-adjusted benefit – in absolute and cost-benefit terms the two groups gain similarly, and high-yielding animals gain marginally more per unit of feeding cost.

The cost structure of silage production is shown in Table 2. Silage prepared using homegrown fodder cost ₹1,460 per tonne, while the use of purchased fodder increased the total cost to ₹4,935 per tonne. The difference reflects the central role of fodder availability in determining the economic feasibility of silage.

Table 2: Cost of Silage Making (1 ton)

S.No	Items	Amount (₹)
1	Silage Bag	500.00
2	Mineral Mixture (1kg)	230.00
3	Salt (2kg)	30.00
4	Jaggery (2kg)	87.19
5	Labour	620.00
6	Total without buying fodder	1460.00
7	Fodder Cost	3475.00
8	Total with Fodder	4935.23

Source: Primary Data, 2024

Table 3. Seasonal changes in production and economic indicators before and after silage adoption

Season	FAT Before	FAT After	SNF Before	SNF After	Milk (L/day) Before	Milk (L/day) After	Fodder Cost (₹) Before	Fodder Cost (₹) After	Medical Expenditure (₹) Before	Medical Expenditure (₹) After	Income Before (₹)	Income After (₹)
Summer	3.36	3.63	7.84	8.13	11.18	13.58	3,377	1,980	1,750	1,150	12,613	15,029
Monsoon	3.43	3.72	8.03	8.33	13.31	15.58	1,200	750	1,334	900	10,910	13,041
Winter	3.55	3.38	8.18	8.43	13.74	16.05	2,375	1,250	1,255	750	17,518	20,793
Average	**3.45**	**3.58**	**8.02**	**8.29**	**12.74**	**15.07**	**6,952**	**3,980**	**4,339**	**2,800**	**41,041**	**48,863**

Source: Primary Data, 2024

Table 3 presents seasonal variations in milk yield, composition, costs, and income. Across all seasons, households recorded higher milk output after adopting silage. During summer, milk yield increased from 11.18 to 13.58 litres per day. FAT and SNF rose by 8.01% and 3.66%, respectively. Monsoon and winter seasons showed comparable trends, with yield increasing by 17.06% in monsoon and 16.84% in winter.

Seasonal fodder costs declined in each period, with the largest reduction occurring during summer ₹3,377 to ₹1,980. Medical expenditure followed a similar pattern, reflecting improved nutritional stability and fewer health-related issues.

Income increased in all seasons. Summer income rose from ₹12,613 to ₹15,029 per animal, monsoon income from ₹10,910 to ₹13,041, and winter income from ₹17,518 to ₹20,793. These seasonal gains contributed to a substantial rise in overall income from dairy activities.

Silage adoption changed the fodder environment for participating households. Prior to adoption, shortages of green fodder created recurring stress and contributed to distress sale of cattle, a pattern reported in other semi-arid regions where feed scarcity shapes herd decisions (Palsaniya *et al*., 2008; Meena *et al*., 2018). The decline in distress sale after adoption suggests that having a stored feed source reduced vulnerability to seasonal shortages.

The improvement in milk yield and composition indicates better nutrient intake during lean periods. Patterns observed here are consistent with evidence that ensiled forage sustains nutritional value and supports milk performance when fresh fodder is limited (Chaudhary *et al*., 2013; Vijay *et al*., 2018). Gains in FAT and SNF further reflect improved feed quality. The simultaneous rise in milk yield and FAT percentage, though often assumed to be inversely related because higher-volume milk is commonly more dilute, is explainable by the change in feed quality rather than feed quantity alone: before adoption, animals relied substantially on crop residues and low-quality dry fodder during lean periods, which depresses both intake and the fibre (effective NDF) available for rumen fermentation to acetate, the principal precursor of milk fat. Maize/sorghum silage, being a fermented, more digestible and more energy-dense feed with adequate effective fibre, raises both total dry-matter intake (supporting higher yield) and rumen acetate production (supporting FAT%) simultaneously, so the two measures are not in the trade-off relationship that would apply if the yield increase had instead come from concentrate-heavy, low-fibre supplementation. This is consistent with the modest, rather than negligible, SNF gain (3.5%), since SNF (protein and lactose) responds more to overall energy and protein adequacy than to fibre specifically.

Economic gains were produced through two channels: higher milk output and reduced costs. Silage prepared from homegrown fodder was relatively inexpensive, and the reduction in veterinary expenditure suggests fewer nutrition-related disorders. Income increases were most pronounced in winter, when fodder scarcity traditionally peaks.

The findings highlight the role of silage in stabilising feed supply in semi-arid production systems. By reducing dependence on variable fodder markets and mitigating seasonal fluctuations, silage supports more consistent milk production and income continuity. Adoption in similar environments would require strengthened access to fodder crops, training in preparation techniques, and collective arrangements for storage to reduce per-unit costs.

Limitations

The single-group before-after design used here, strengthened in this revision with paired-samples t-tests, establishes that the observed before-after differences are statistically significant and unlikely to be chance findings. It does not, however, constitute a controlled experiment: because no non-adopter comparison group was surveyed, the design cannot fully separate the effect of silage adoption from other changes that may have coincided with it, such as seasonal rainfall variation between the recall periods, concurrent veterinary or extension interventions in the same villages, or general improvements in animal management over time. Milk yield and composition were also self-reported or drawn from collection-centre and farmer records rather than independently verified through direct farm-level testing at fixed intervals, and figures for FAT, SNF, and milk yield are not disaggregated by breed; the sample is predominantly crossbred cattle typical of the study area, and results may not generalise to buffalo-keeping or purebred exotic-cattle households. Future work incorporating a matched non-adopter comparison group, or panel data spanning multiple years, would allow the effect of silage to be distinguished more rigorously from these co-occurring factors.

Conclusion

The study shows that silage adoption altered fodder management practices in the semi-arid villages of Pune district. Households reported fewer distress sales of cattle after adoption, indicating reduced exposure to seasonal fodder shortages. Milk yield and milk composition improved across all seasons, reflecting more stable nutrient intake. Feed and veterinary costs declined, and income per animal increased as a combined effect of higher output and lower expenditure. These outcomes point to the role of silage in stabilising production in environments where rainfall variability shapes fodder supply.

The evidence suggests that wider use of silage in semi-arid systems would require steady availability of fodder crops, access to materials for ensiling, and support for training in preparation methods. Collective arrangements for storage and processing may reduce unit costs for smallholders. Integrating these elements into livestock development programmes can strengthen the capacity of households to maintain production during lean periods. Silage thus offers a practical option for mitigating feed-related risks and supporting continuity of dairy income in regions with constrained green fodder availability.

Contribution by Authors

All the authors contributed equally to writing the manuscript. The final manuscript was read by all authors and consented to publication.

Conflict of Interests

There is no conflict of interest.

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