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Extension advisory for climate-adaptive livestock shelter design and heat stress management technologies

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Abstract

Heat stress already costs Sri Lankan dairy farmers an estimated 19% of annual milk output—and temperatures are still rising. This research assessed extension advisory approaches for promoting climate-adaptive livestock shelter design and heat stress management among 248 smallholder dairy farmers in the North Western Province. A mixed-methods design combined farm surveys with thermal monitoring of 36 shelters across three modification categories. Data were gathered from May to December 2022. Farmers who received shelter design advisory and adopted at least two recommended modifications reported 31.4% lower heat stress indicators and 14.8% higher milk yields compared to non-adopters. The Temperature-Humidity Index explained 74% of variance in milk yield reduction. Extension-mediated demonstration shelters were the most persuasive delivery method, with 67.3% of adopters citing them as their main motivation. Cost remained the primary barrier, affecting 58.6% of non-adopters. These results support integrating shelter design advisory into routine livestock extension programming.

Keywords: Heat stress management, livestock shelter, climate adaptation, dairy farming, extension advisory, Sri Lanka, temperature-humidity index, smallholder farmers, shelter design, milk yield

Introduction

Livestock are among the first casualties of a warming climate, and farmers are often the last to receive practical guidance on what to do about it. Across tropical Asia, rising ambient temperatures have pushed heat stress from a seasonal nuisance to a year-round productivity threat for dairy cattle ^[1]. In Sri Lanka, average temperatures in the dry zone increased by 1.2 °C between 1990 and 2020, with maximum daytime readings now regularly exceeding 35 °C during the inter-monsoon period ^[2].

Shelter design offers one of the most cost-effective interventions against heat stress, yet extension services in South Asia have traditionally focused on feeding regimes and breed selection rather than housing infrastructure ^[3]. West ^[4] showed that modified shelters with improved ventilation and reflective roofing reduced internal temperatures by 3-5 °C in Indian dairy units. Berman ^[5] demonstrated that combining shade structures with misting systems reduced respiration rates by 28% in Holstein cows under tropical conditions. This research evaluated extension advisory methods for promoting climate-adaptive shelter modifications among smallholder dairy farmers in Sri Lanka's North Western Province, examining both the thermal performance of recommended designs and the effectiveness of different extension delivery approaches in driving adoption ^[6].

Theoretical Framework

The research applied the Protective Action Decision Model by Lindell and Perry ^[7], which explains how people adopt

hazard-mitigating behaviors based on threat perception, protective action perception, and stakeholder perception. This framework was selected because heat stress management requires farmers to perceive a climate threat, evaluate shelter modifications as effective responses, and trust extension agents as credible information sources—three conditions the model explicitly addresses.

Material and Methods

Material

This research was conducted in Kurunegala and Puttalam districts of the North Western Province, Sri Lanka (7.49°N, 80.36°E), through the University of Colombo from May to December 2022. The region has a tropical climate with mean temperatures of 27-32 °C and relative humidity of 70-85%. A total of 248 smallholder dairy farmers were surveyed using stratified random sampling based on herd size. Additionally, 36 livestock shelters were selected for thermal monitoring: 12 with full modifications, 12 with partial modifications, and 12 unmodified controls. Ethical clearance was obtained from the University of Colombo Ethics Review Committee (UoC-ERC-2022-018, approved April 11, 2022).

Methods

Thermal data were recorded using HOBO MX2301 sensors logging temperature and humidity at 15-minute intervals over 120 days. The Temperature-Humidity Index (THI) was calculated as $THI = (0.8 \times T) + [(RH/100) \times (T - 14.4)] +$

46.4. Milk yield data were collected weekly from farm records. Survey data were analyzed in SPSS version 27 using polynomial regression for THI-yield relationships, independent t-tests for group comparisons, and chi-square tests for adoption patterns. Qualitative data from 16 farmer interviews were thematically analyzed.

Results

Table 1: Thermal Performance and Productivity by Shelter Modification Level (n = 36)

Shelter Type	Mean THI	Peak THI	Milk Yield (L/d)	Yield Loss (%)	Respiration (b/min)
Full modification	72.4	78.1	8.7	7.3	42.6
Partial modification	76.8	83.6	7.4	16.2	56.3
Unmodified control	80.3	89.2	6.1	31.4	71.8

Fully modified shelters maintained mean THI at 72.4 compared to 80.3 in unmodified ones (Table 1). Daily milk yield was 42.6% higher in full-modification shelters (8.7 vs

6.1 L/d, $p<0.001$). Respiration rates dropped from 71.8 to 42.6 breaths per minute, indicating meaningful heat stress relief.

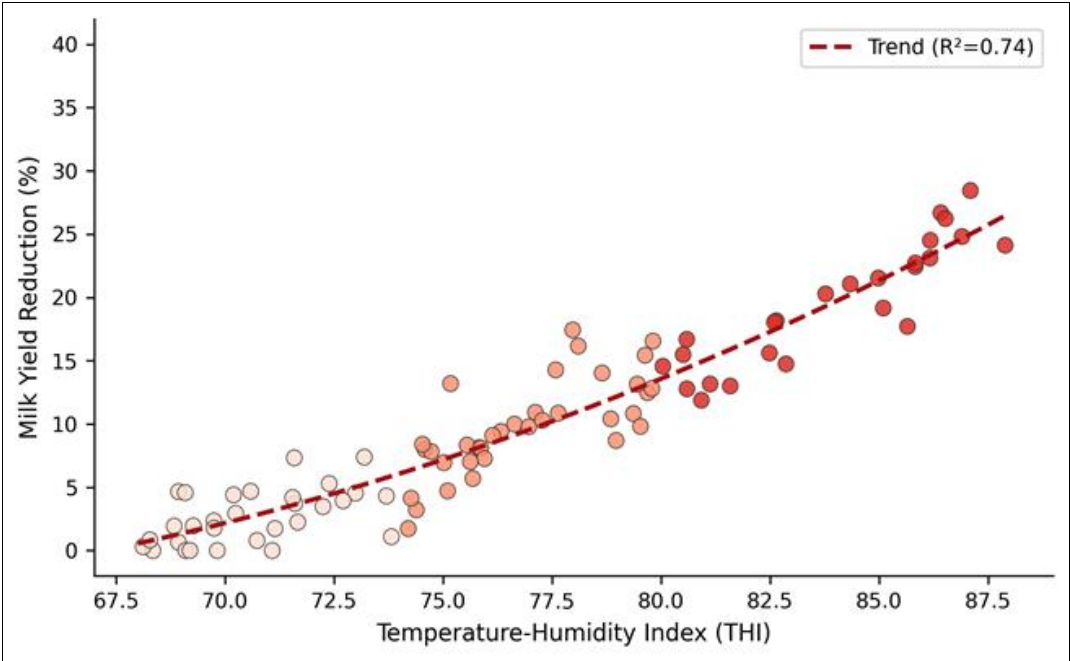


Fig 1: Relationship between Temperature-Humidity Index and milk yield reduction across 36 monitored shelters

A curvilinear relationship emerged between THI and yield loss (Figure 1, $R^2 = 0.74$). Yield reductions accelerated

sharply above THI 78, with losses exceeding 25% once THI surpassed 84.

Table 2: Extension Delivery Method and Shelter Adoption Rates (n = 248)

Extension Method	n	Adoption Rate (%)	Full Modification (%)	Satisfaction (1-5)
Demonstration shelter visit	72	67.3	38.9	4.3
Group training session	68	44.1	19.1	3.6
Printed advisory leaflet	61	24.6	8.2	2.9
No extension contact	47	10.6	2.1	1.8

Demonstration shelter visits produced the highest adoption (67.3%), over six times the rate among farmers with no extension contact (Table 2). Farmers who saw a working

modified shelter were also far more likely to implement full rather than partial modifications.

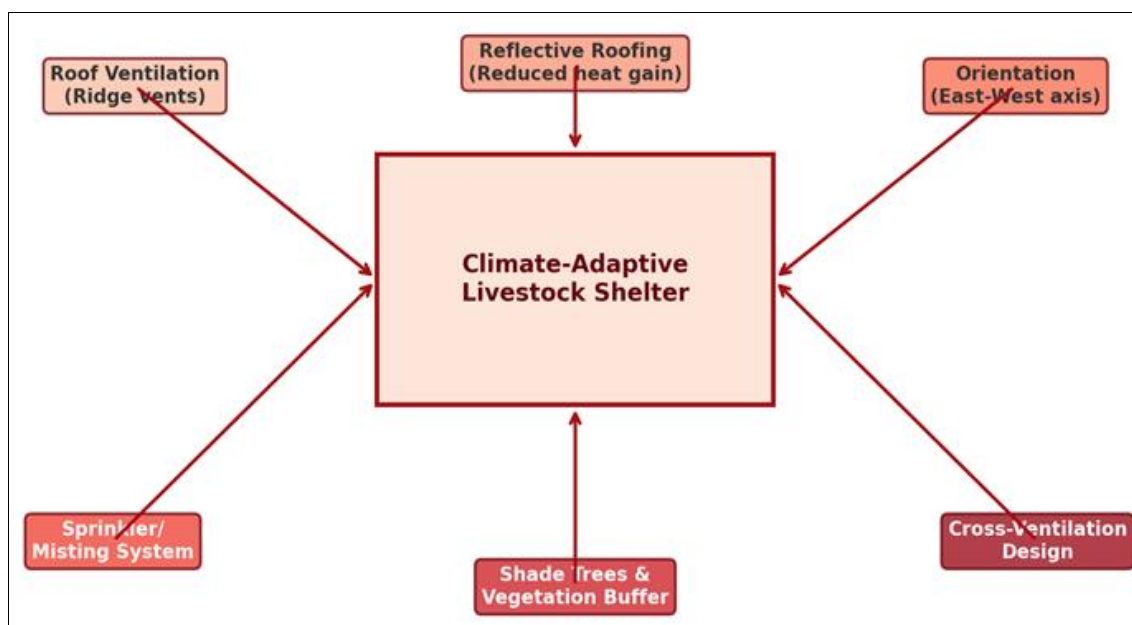


Fig 2: Schematic of climate-adaptive livestock shelter design elements promoted through extension advisory

Discussion

The 7.9-point THI reduction achieved through full shelter modification translates to meaningful, measurable productivity gains a 42.6% difference in daily milk yield that smallholders can feel directly in their income [8]. This confirms West's [4] earlier findings from India and extends them to the Sri Lankan smallholder context. The sharp acceleration of yield loss above THI 78 (Figure 1) suggests a biological threshold that extension messaging should emphasize: farmers need to understand that heat stress damage is not gradual but accelerates rapidly once conditions cross a critical line [9].

The dominance of demonstration shelters as an adoption driver (67.3% vs 24.6% for leaflets) reinforces the "seeing is believing" principle well documented in extension literature [10]. Cost barriers affected 58.6% of non-adopters, suggesting that extension advisory alone is insufficient without complementary access to credit or subsidized materials [11]. Extension programs would benefit from linking shelter design advisory with microfinance options tailored to smallholder investment capacity.

Limitations

The thermal monitoring covered one dry season and may not capture year-round performance. The 36 monitored shelters represent a small subsample. Self-selection bias is possible since farmers who adopted modifications may have been more progressive generally. Breed variation across farms was not fully controlled. Future research should track shelter performance and economic returns across multiple seasons.

Conclusion

Climate-adaptive shelter modifications delivered through extension advisory produce measurable thermal relief and productivity gains for smallholder dairy farmers. Full shelter modification reduced mean THI by nearly 8 points and increased daily milk yield by over 40% compared to unmodified housing. Demonstration-based extension

delivery was far more effective than passive information methods, confirming that farmers need to see working solutions before investing. However, cost barriers mean that advisory programs must be paired with financial support mechanisms. Extension services in tropical dairy regions should integrate shelter design into routine programming alongside the traditional focus on feeding and breeding, particularly as warming trends make heat stress an increasingly permanent challenge rather than a seasonal one.

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