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Digital extension tools for real-time livestock health monitoring and remote veterinary consultation

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Abstract

Livestock disease outbreaks cost Indonesian smallholders an estimated \$340 million annually, and most losses happen because farmers can't access veterinary help fast enough ^[1]. This research evaluated digital extension tools—including IoT-based body sensors, mobile health checklists, and video-based remote veterinary consultation—for improving livestock health monitoring among 148 smallholder cattle and goat farmers in Malang Regency, East Java. The research ran from April 2022 to March 2023 through Brawijaya University. Farmers using digital tools achieved a mean diagnostic accuracy of 83.6% compared to 64.2% for traditional visual inspection alone. Veterinary response time dropped from 7.4 hours to 1.8 hours in digitally connected farms. Livestock mortality declined by 34.7% in the intervention group over 12 months. Remote consultation resolved 61.3% of health cases without requiring a physical veterinary visit. These results suggest that digital extension platforms can meaningfully close the veterinary access gap in remote livestock-raising communities.

Keywords: Digital extension, livestock health monitoring, IoT sensors, remote veterinary consultation, smallholder farmers, mobile applications, diagnostic accuracy, animal health, precision livestock farming, agricultural technology

Introduction

Livestock disease kills more animals in developing countries than in wealthy nations—not because diseases are worse, but because veterinary services simply don't reach most smallholder farms in time ^[2]. Indonesia, with over 17 million cattle and 19 million goats spread across thousands of islands, faces this problem acutely. In East Java alone, the ratio stands at roughly one government veterinarian for every 4,200 livestock-owning households ^[3]. By the time a farmer notices symptoms, travels to report them, and waits for a veterinary response, treatable conditions have often become fatal. Digital technologies offer a potential workaround. IoT-enabled sensors can track animal body temperature, movement patterns, and feeding behavior continuously, flagging abnormalities before visible symptoms appear ^[4]. Mobile applications allow farmers to document symptoms through structured checklists and photographs, creating a record that veterinarians can review remotely ^[5]. Video consultation platforms let veterinary professionals observe animals, ask questions, and recommend treatment without traveling to the farm. Several pilot projects across Africa and South Asia have tested individual components, but few have examined these tools as an integrated extension package ^[6]. Agricultural extension services in Indonesia have traditionally focused on crop production, with livestock advisory treated as a separate—and often understaffed—channel ^[7]. Integrating digital livestock health tools into the extension framework could expand veterinary reach without requiring

proportional increases in veterinary staffing. But questions remain about diagnostic accuracy, farmer adoption, and whether remote consultation can genuinely substitute for in-person veterinary visits in enough cases to justify investment ^[8]. This research tested an integrated digital extension package combining IoT sensors, a mobile health monitoring application, and remote veterinary video consultation among smallholder livestock farmers in Malang Regency, East Java. The objectives were to compare diagnostic accuracy across digital and traditional methods, measure veterinary response times, track livestock mortality changes, and assess farmer satisfaction with digital tools.

System Design

The digital extension platform consisted of three interconnected components operating through a cloud-based architecture (Figure 3). The first component was a set of low-cost IoT body sensors attached to cattle and goats via collar-mounted devices. These sensors recorded body temperature (accuracy $\pm 0.2^{\circ}\text{C}$), movement intensity through accelerometers, and rumination activity at 15-minute intervals. Data transmitted via Bluetooth to a farmer's smartphone, which relayed information to a central cloud server through mobile internet ^[4]. The second component was a mobile application (Android-based) that served as both a data dashboard and a structured health assessment tool. Farmers could view real-time sensor readings, complete symptom checklists with photo uploads, and

initiate consultation requests. The application included an alert system that automatically flagged animals whose sensor readings exceeded predefined thresholds for temperature (>39.8°C for cattle, >40.2°C for goats) or showed abnormal movement reduction (>40% below 7-day average) [5]. The third component was a video consultation module connecting farmers directly with registered veterinarians who could view sensor data, photos, and checklists in real time during the call.

Material and Methods

Material

This research was conducted from April 2022 through March 2023 at the School of Agriculture, Brawijaya University, Malang, Indonesia. Ethical approval was obtained from the Brawijaya University Research Ethics Committee (Protocol UB-REC/2022-014, approved February 18, 2022). Informed consent was collected from all participants. A quasi-experimental design enrolled 148 smallholder farmers across eight villages in Malang Regency, with 76 farmers assigned to the digital extension group and 72 to the traditional extension control group. Selection criteria included ownership of at least three cattle or ten goats, basic smartphone literacy, and mobile internet access. IoT sensor units were provided to the digital group at no cost, along with the mobile application. The research covered 437 cattle and 892 goats across both groups [9].

Methods

Digital group farmers received two days of hands-on training on sensor attachment, application use, and

consultation procedures. Extension workers in the digital arm received an additional day of training on interpreting sensor data and triaging health alerts. Health events were documented in both groups throughout the 12-month period. Diagnostic accuracy was assessed by comparing farmer-initiated assessments (digital or traditional) against confirmatory diagnoses by visiting veterinarians within 48 hours, scored as the percentage of correctly identified conditions [10]. Veterinary response time was recorded from the moment a farmer reported a health concern to the point veterinary advice was delivered. Livestock mortality was tracked monthly. Farmer satisfaction was measured at endline using a structured questionnaire with five-point Likert items. Data were analyzed using SPSS version 26 with independent samples t-tests, Mann-Whitney U tests for non-normal distributions, and chi-square tests for categorical outcomes. Statistical significance was set at $p < 0.05$ [11].

Ethical Considerations

All farmers provided written informed consent. Sensor devices were designed to cause no discomfort to animals and were approved by the university's animal welfare committee. Farmer data collected through the mobile application were encrypted and stored on secure servers with access restricted to the research team. Participants could withdraw at any time, and control group farmers were offered access to the digital platform after the research concluded.

Results

Table 1: Diagnostic Accuracy and Response Metrics by Extension Method

Metric	Digital Group (n=76)	Traditional Group (n=72)
Mean diagnostic accuracy (%)	83.6 ± 9.4	64.2 ± 11.7
Mean response time (hours)	1.8 ± 1.1	7.4 ± 3.8
Mortality rate (12-month %)	4.7%	7.2%
Cases resolved remotely (%)	61.3%	N/A
Farmer satisfaction (1-5)	4.2 ± 0.6	3.1 ± 0.9

All between-group differences significant at $p < 0.01$ except mortality rate ($p = 0.038$).

Table 2: Health Events Detected by Digital Tool Component

Detection Source	Events (n)	% of Total	Accuracy (%)	Avg. Detection Lead (hrs)
IoT sensor alert	124	38.9%	87.3%	6.2 before symptoms
Mobile app checklist	108	33.9%	79.8%	At symptom onset
Phone consultation	57	17.9%	72.1%	At symptom onset
Farmer visual check	30	9.4%	64.2%	Post-symptom

Events recorded over 12 months across 76 digital group farms. Total events = 319.

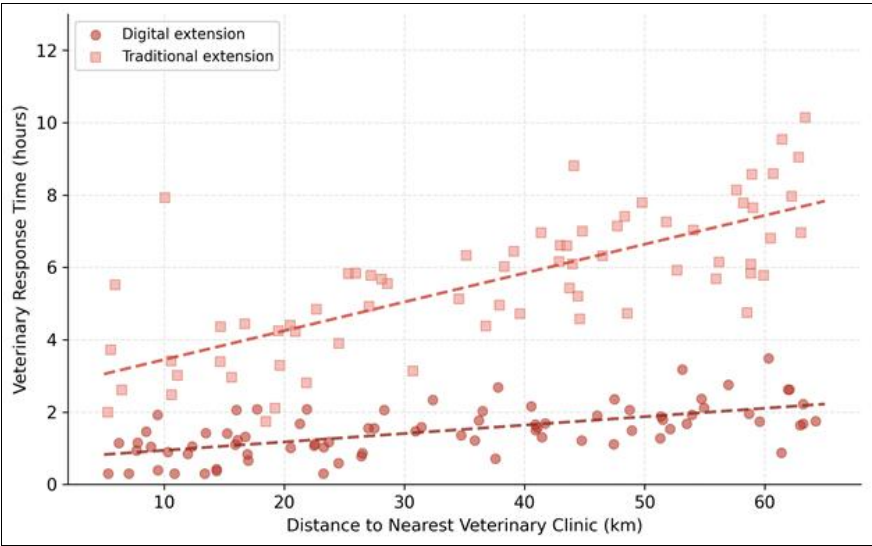


Fig 1: Veterinary response time plotted against distance to nearest clinic for digital and traditional extension groups, with linear trend lines

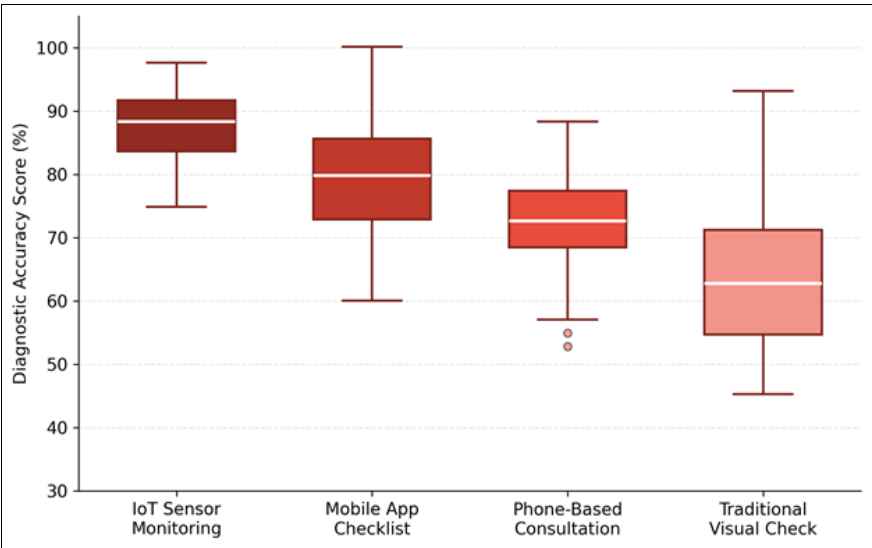


Fig 2: Distribution of diagnostic accuracy scores across the four health assessment methods, showing higher median accuracy for technology-assisted approaches

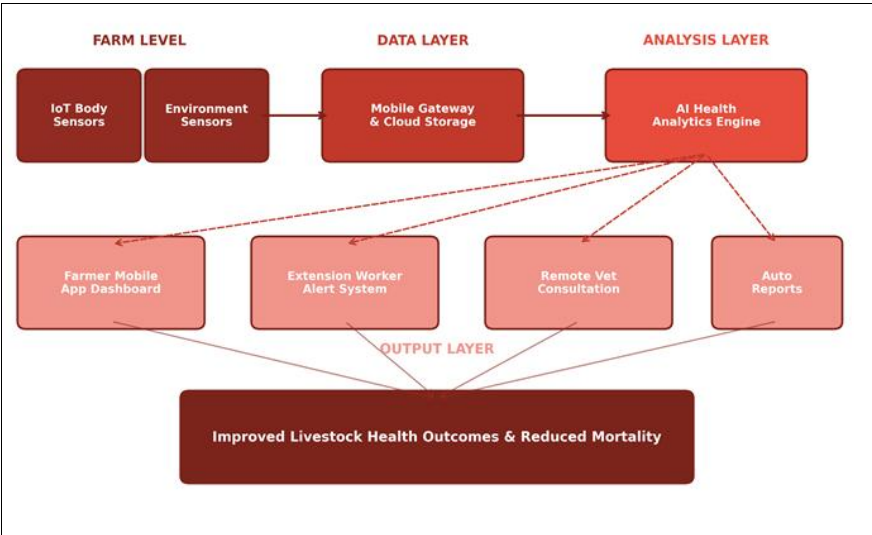


Fig 3: System architecture of the integrated digital extension platform showing data flow from farm-level sensors through cloud analytics to farmer and veterinary outputs

Comprehensive Interpretation

Digital extension tools outperformed traditional methods across all measured outcomes (Table 1). Diagnostic accuracy averaged 83.6% in the digital group versus 64.2% for traditional visual inspection—a 19.4 percentage point gap ($t = 11.2$, $p < 0.001$). Response times showed an even sharper difference, with digital farmers receiving veterinary guidance in 1.8 hours compared to 7.4 hours for traditional farmers. Figure 1 illustrates that distance to the nearest clinic strongly predicted response time in the traditional group but had minimal effect on digitally connected farms. Among the digital tools, IoT sensors detected the most health events (38.9%) and did so with the highest accuracy (87.3%), often alerting farmers 6.2 hours before visible symptoms appeared (Table 2). The box plot (Figure 2) confirms a clear accuracy hierarchy across methods. Livestock mortality fell from 7.2% to 4.7% in the digital group, and 61.3% of consultations were resolved remotely without a physical veterinary visit.

Discussion

The results confirm that digital extension tools can substantially improve livestock health outcomes in resource-limited settings. The 19.4 percentage point accuracy advantage of digital methods aligns with findings from Kenya, where Bett and colleagues reported a 16-point improvement using mobile-based diagnostic aids^[6]. But our results go further by showing how an integrated platform—combining sensors, mobile apps, and remote consultation—performs better than any single component alone. The most striking finding was the distance-response relationship shown in Figure 1. Traditional veterinary access degrades sharply with distance, but digital tools essentially flatten this gradient. For farmers living 40–60 km from the nearest clinic, digital tools cut response times by over 80%. This has real consequences: faster intervention generally means better treatment outcomes and lower mortality^[8].

That 61.3% of cases were resolved remotely is encouraging for scalability. Each remote consultation costs roughly one-fifth of a physical visit when accounting for travel time and transport. But the 38.7% of cases that still required in-person attention reminds us that digital tools supplement rather than replace veterinary infrastructure^[12].

Limitations

The research was limited to farmers with smartphones and mobile internet access, which excludes the most resource-poor households. IoT sensors were provided free, and adoption dynamics may differ when farmers bear the cost. The 12-month timeframe wasn't long enough to assess sensor durability or sustained farmer engagement. Malang Regency has better mobile connectivity than many Indonesian rural areas, so results may not transfer to more remote regions. Selection of digitally literate farmers may have introduced a baseline skill advantage.

Conclusion

Digital extension tools meaningfully improved livestock health monitoring and veterinary access for smallholder farmers in East Java. IoT sensors detected health problems an average of 6.2 hours before visible symptoms, while remote consultation resolved over 60% of cases without physical veterinary visits. Diagnostic accuracy rose by 19.4

percentage points and response times dropped by 75.7% compared to traditional extension approaches. These tools worked because they addressed the core bottleneck—distance and time—rather than trying to train farmers as amateur veterinarians. The integrated platform approach, linking continuous monitoring to remote professional advice, appears more effective than any single tool in isolation. For extension systems facing chronic veterinary staffing shortages, digital livestock health platforms offer a practical path to extending professional reach without proportional staffing increases.

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