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Application of Internet of Things in Livestock Farming in Afghanistan: Opportunities, Challenges, and Future Directions

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Abstract: Livestock rearing underpins the rural economy of Afghanistan, sustaining a large share of household income and food security across a mountainous, largely subsistence-based agrarian landscape. Yet herders in Afghanistan continue to rely on manual observation, itinerant veterinary visits and word-of-mouth market information to manage animal health, breeding, feeding and mobility. The Internet of Things (IoT) offers wearable and environmental sensing, wireless connectivity and cloud-based analytics that could support early disease detection, theft prevention and precision feeding at low marginal cost once initial infrastructure is in place. This paper examines the opportunities, challenges and future directions of applying IoT technologies to livestock farming in Afghanistan. A three-tier conceptual architecture (perception, network and application layers) is proposed for constrained-resource, low-connectivity rural settings, and candidate communication technologies including LoRaWAN, cellular GSM/GPRS and satellite backhaul are compared. Key barriers are organised into four categories: infrastructural, economic, socio-institutional and governance-related, drawing on the country's security situation, weak electrification and limited digital literacy. The discussion highlights near-term opportunities such as solar-powered gateways, SMS/USSD fallback interfaces and cooperative-based data-ownership models that could make IoT adoption realistic in the near term. The paper concludes that a phased, low-cost and locally governed deployment strategy, combined with capacity building and supportive ICT4Ag policy, is the most viable pathway toward IoT-enabled livestock management in Afghanistan.

Keywords: Digital agriculture; Internet of things; Livestock farming; Precision livestock farming; Smart sensors; Wireless sensor networks.

Introduction

Livestock has long been the backbone of rural life in Afghanistan. Roughly three-quarters of the population lives in rural areas, and about two-thirds of rural households keep at least some animals — sheep, goats, cattle, or the hardy pack animals of the northern provinces (Wang, 2006). Sustained rural development work in the country, including that of the International Fund for Agricultural Development, underscores how central these small herds are to household resilience (International Fund for Agricultural Development (IFAD, 2022). Agriculture as a whole contributes close to a quarter of national GDP and remains the largest single employer of the rural Tripathy et al., 2021). For many Afghan families, animals are not a side activity but the primary buffer against a harsh, semi-arid climate: a flock of sheep can be moved to fresh pasture when a field fails, sold in a bad year, or relied upon to feed a household when markets are inaccessible (World Bank, 2018).

That resilience, however, is fragile. Decades of conflict, recurring drought, and a persistent agricultural investment gap have left the sector under-capitalised and poorly connected to markets (Diplomat, 2016; World Bank, 2018). Livestock keepers still rely almost entirely on direct observation to judge whether an animal is sick, whether a ewe is close to lambing, or whether a pasture can support another season of

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grazing. Veterinary coverage is thin outside provincial centres, and Ministry of Agriculture, Irrigation and Livestock (MAIL) staff frequently cannot reach insecure or mountainous districts at all (Food and Agriculture Organization of the United Nations [FAO], 2018). The result is a sector that behaves reactively: disease outbreaks, theft, and feed shortages are usually discovered only after damage has already been done.

Elsewhere, a rather different model of livestock management has been taking shape over the past decade, built around the Internet of Things (IoT) — networks of small, often battery- or solar-powered sensors that continuously observe a physical process and relay the resulting data over a wireless link to a server, where it can be stored, analysed and turned into an alert or a recommendation (Atzori, Iera, & Morabito, 2010; Gubbi, Buyya, Marusic, & Palaniswami, 2013; Al-Fuqaha, Guizani, Mohammadi, Aledhari, & Ayyash, 2015). What began as an idea for connecting industrial equipment and smart-city infrastructure has, over roughly the last fifteen years, moved decisively into agriculture, where wireless sensor networks originally built for environmental monitoring (Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002) have been adapted to track soil, crops and animals in real time (Friha, Ferrag, Shu, Maglaras, & Wang, 2021; Liu, Ma, Shu, Hancke, & Abu-Mahfouz, 2021).

Precision livestock farming — the animal-specific branch of this movement — now includes wearable collars that record body temperature, rumination and activity (Chatterjee, Ray, & Mohanty, 2021; Neethirajan, 2017), GPS ear-tags that keep a herd inside a virtual fence, smart feeders that adjust rations automatically, and machine-learning models that flag the subtle behavioural changes that precede clinical illness (Neethirajan, 2020; Astill, Dara, Fraser, Roberts, & Sharif, 2020). In well-resourced dairy and poultry operations, these systems have measurably reduced disease losses and improved reproductive performance (Sharma, Jain, Gupta, & Chowdary, 2021; Astill et al., 2020). Reviews of IoT in agriculture more broadly describe a maturing ecosystem of low-power communication standards, cloud platforms and analytics pipelines that is steadily becoming cheaper and easier to deploy (Friha et al., 2021; Talavera et al., 2017; Elijah, Rahman, Orikumhi, Leow, & Hindia, 2018).

Very little of this literature, however, has been written with a country like Afghanistan in mind. Studies of "IoT for developing-country agriculture" tend to focus on relatively better-connected regions of South and East Asia or sub-Saharan Africa, where at least a baseline of mobile-network coverage, electrification and market infrastructure can be assumed (Kamilaris, Kartakoullis, & Prenafeta-Boldú, 2017; "IoT and AI for Smart Agriculture in Resource-Constrained Environments," 2025). Afghanistan combines the ordinary constraints of a low-income agrarian economy with an unusually difficult operating environment: mountainous terrain that limits both physical access and radio line-of-sight, patchy and unreliable electricity, and, in many districts, active insecurity that keeps both government staff and private technicians away from the areas that most need support (FAO, 2018; World Bank, 2018). Any discussion of IoT adoption for Afghan livestock farming has to take these constraints as a starting point rather than an afterthought.

This paper asks, in that spirit, a fairly practical question: given what IoT can plausibly deliver in agriculture, and given the specific conditions under which Afghan herders actually work, what would a realistic first step toward IoT-enabled livestock farming look like? Rather than propose a fully built system, we develop a conceptual architecture and a set of design models adapted to constrained connectivity and low purchasing power, and use these to organise a discussion of the opportunities and barriers that would shape any real deployment. The Method section sets out the review approach and the proposed models; the Result and Discussion section presents and discusses the resulting opportunities, challenges and future directions; and the Conclusion closes the paper.

Method

Review Approach

This study is a conceptual and analytical design exercise rather than a field trial. Direct data collection with Afghan herders was not attempted, for the same access and security reasons discussed in the Introduction; instead, the paper synthesises two bodies of literature and uses that synthesis to build a proposed system model.

The first body of literature covers IoT and precision-livestock-farming technology: architecture and survey papers on the Internet of Things in general (Atzori et al., 2010; Gubbi et al., 2013; Al-Fuqaha et al., 2015; Sicari, Rizzardi, Grieco, & Coen-Porisini, 2015; Khan, Khan, Zaheer, & Khan, 2012), the wireless-sensor-network foundations on which most agricultural IoT still rests (Akyildiz et al., 2002; Wang, Zhang, & Wang, 2006), low-power wide-area networking (Raza, Kulkarni, & Sooriyabandara, 2017), and IoT applications specifically in agriculture and animal production (Friha et al., 2021; Liu et al., 2021; Senoo et al., 2024; Tripathy, Tripathy, Agarwal, & Mohanty, 2021; Sharma et al., 2021; Chatterjee et al., 2021; Ojha, Misra, & Raghuwanshi, 2015; Talavera et al., 2017; Elijah et al., 2018; Neethirajan, 2017; Neethirajan, 2020; Astill et al., 2020; Kamilaris et al., 2017; "IoT and AI for Smart Agriculture," 2025; "Kissan-Dost," 2026). These sources were located through IEEE Xplore, ScienceDirect and Springer using combinations of the terms "IoT," "precision livestock farming," "wireless sensor network agriculture" and "smart farming developing countries," favouring, where possible, work published after 2010 so that the review reflects mature, commercially realistic sensor and network technology rather than early proof-of-concept prototypes.

The second body of literature describes the Afghan agricultural and rural-development context: reports and briefings from the Food and Agriculture Organization (FAO, 2018), the World Bank (World Bank, 2018), the International Fund for Agricultural Development (International Fund for Agricultural Development (Friha et al., 2021; Liu et al., 2021 reference sources on Afghan livestock and farm structure (Diplomat, 2016; ESRJ, 2025). These were used to identify the specific constraints — electrification, connectivity, security, income and institutional capacity — against which any IoT design proposal must be evaluated.

The two streams were then combined qualitatively: general IoT system models were adapted, feature by feature, to the constraints identified in the Afghan-context literature, producing the layered architecture, connectivity comparison and barrier model presented in the remainder of this section.

Proposed Layered IoT Architecture

Most IoT surveys describe the technology stack in three logical tiers — perception, network and application (Atzori et al., 2010; Al-Fuqaha et al., 2015; Khan et al., 2012) — and that structure is retained here because it maps cleanly onto how a livestock-monitoring deployment would actually be built and paid for in stages. Figure 1 shows the resulting model as adapted to Afghan livestock farming.

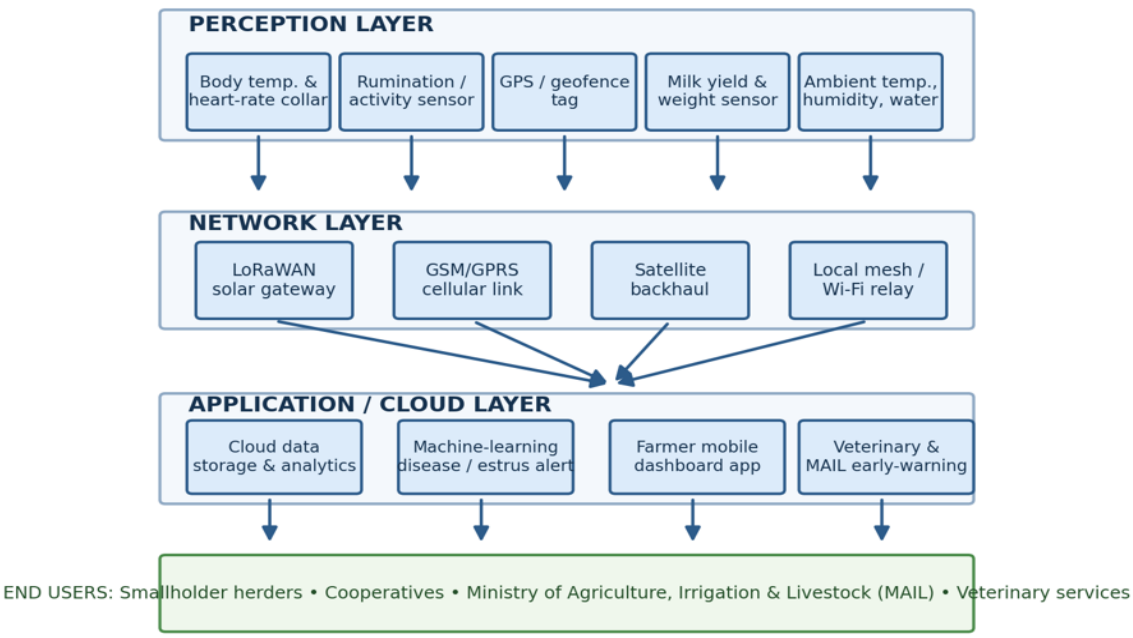

Figure 1. Proposed three-tier IoT architecture for livestock monitoring in rural Afghanistan.

At the perception layer, low-cost wearable and fixed sensors attached to or near the animal collect the raw physiological and environmental signals: body temperature and heart rate, rumination and activity counts from an accelerometer, GPS/geofence position, and, where a herd includes dairy animals, milk yield and body-weight readings (Chatterjee et al., 2021; Neethirajan, 2017; Neethirajan, 2020). Table 1 summarises the sensor categories most consistently reported in the reviewed literature, together with the management indicator each one is used to infer.

Table 1. Perception-Layer Sensor Categories Used in the Proposed Architecture

Sensor category	Typical measurement	Management indicator inferred
Wearable temperature / heart-rate collar	Body temperature, heart rate	Early fever or illness onset
Accelerometer-based activity / rumination sensor	Movement counts, rumination time	Estrus detection, illness, heat stress
GPS / geofence tag	Location, boundary crossing	Grazing pattern, theft or straying alert
Milk yield / body-weight sensor	Daily yield, live weight	Productivity trend, nutrition status
Environmental probe	Ambient temperature, humidity, water level/quality	Heat-stress risk, water-point status

Source: synthesised by the authors from the sensor and precision-livestock-farming literature reviewed above.

At the network layer, sensor readings are relayed from the animal, or from a fixed environmental node, to a local gateway and onward to a wider network. Because Afghanistan's terrain and electrification profile rule out any single "obvious" choice of network technology, four candidate options are compared in Table 2: a solar-powered LoRaWAN gateway, GSM/GPRS cellular data, satellite backhaul, and short-range Wi-Fi or mesh relay. LoRaWAN in particular is attractive for this setting because its long range in open, low-obstruction terrain and very low power draw suit mountain valleys with scattered grazing and unreliable mains electricity (Raza et al., 2017); several agricultural-IoT reviews identify it as the leading low-power wide-area option for exactly this combination of constraints (Friha et al., 2021; Elijah et al., 2018).

Table 2. Comparison of Candidate Connectivity Technologies for Rural Afghanistan

Technology	Typical range	Power use	Relative cost	Suitability
LoRaWAN (solar gateway)	2–15 km, line-of-sight dependent	Very low	Low after install	High in open valleys; needs relays in dense terrain
GSM/GPRS cellular	Tower-coverage dependent	Moderate	Moderate (data fees)	Good near towers; weak in remote districts
Satellite (e.g., IoT-VSAT)	Global	Higher	High	Best fallback with no terrestrial coverage
Wi-Fi / local mesh	< 1 km per hop	Moderate–high	Low hardware, many nodes	Village-level short-range relay only

Notes: (1) Ranges are indicative and depend strongly on terrain and obstruction. (2) Relative cost refers to marginal cost per additional monitored animal once a gateway is installed.

At the application layer, data arriving at a gateway or cellular base station is forwarded to a cloud or regional server for storage and analysis. A lightweight anomaly-detection model, of the kind already demonstrated in commercial and research cattle-health systems (Sharma et al., 2021; Chatterjee et al., 2021; Neethirajan, 2020), flags combinations of elevated temperature, reduced rumination and reduced movement as candidate early-illness cases, and geofence breaches as possible theft or straying events. Because most Afghan herders will not own smartphones or have reliable data connectivity, outputs are designed to degrade gracefully to an SMS or USSD alert on a basic feature phone, alongside a richer dashboard for cooperative staff, veterinarians and MAIL extension officers. Figure 2 traces this full path from animal to end user, in a form intended to be buildable at village scale before any wider rollout is attempted.

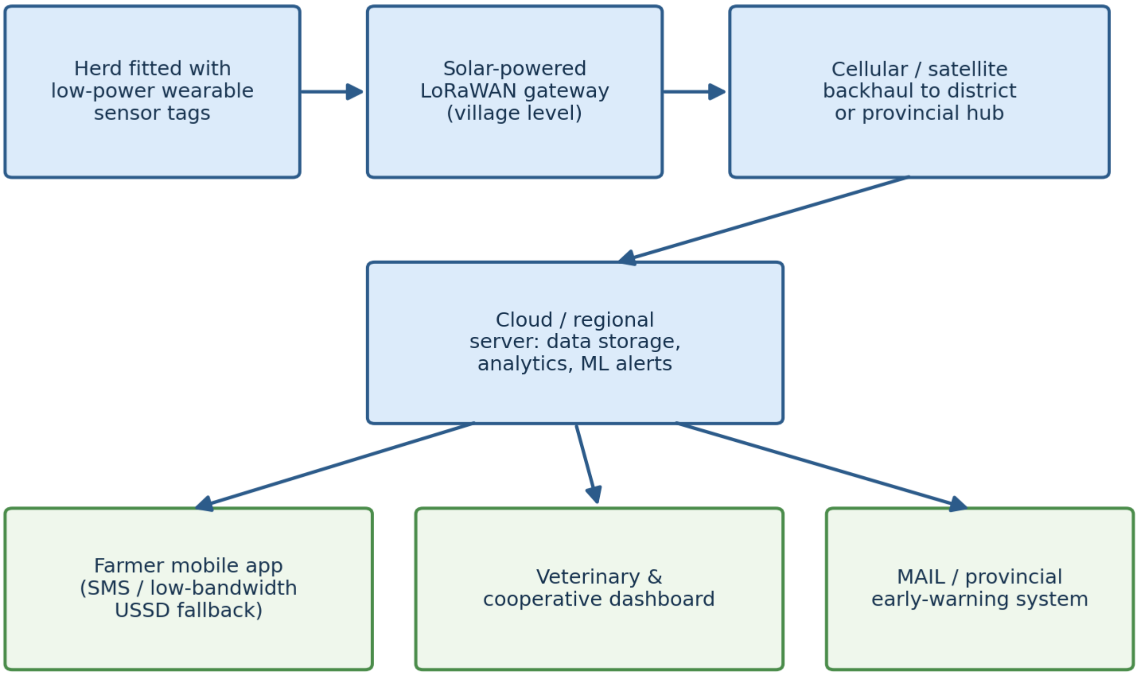

Figure 2. Conceptual deployment model linking a herd, a village gateway, backhaul connectivity, and the farmer- and institution-facing applications.

Barrier Model

To organise the challenges discussed in the Result and Discussion section, barriers identified across the reviewed literature were grouped into four categories, shown in Figure 3: infrastructural, economic, socio-institutional, and governance/policy. This grouping follows a pattern used in general reviews of IoT and AI adoption in resource-constrained agricultural settings ("IoT and AI for Smart Agriculture," 2025; Kamilaris et al., 2017), adapted here with barriers specific to Afghanistan drawn from the FAO, World Bank and IFAD sources discussed above.

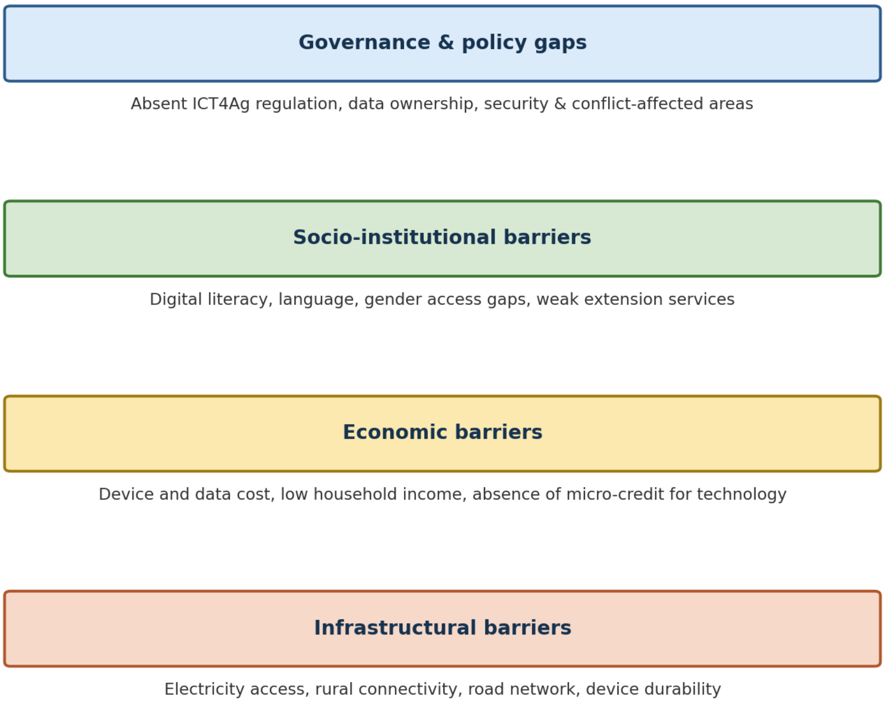

Figure 3. Layered model of barriers to IoT adoption in Afghan livestock farming.

Result and Discussion

Opportunities

Several plausible use cases emerge once the architecture proposed in the Method section is mapped onto the realities of Afghan livestock farming described in the reviewed reports.

Early disease detection is probably the most immediately valuable application. Sheep and goats — the dominant Afghan livestock species — are vulnerable to diseases such as peste des petits ruminants and foot-and-mouth disease, both of which spread quickly through unvaccinated, free-ranging herds and are far cheaper to contain in their first days than after an outbreak has spread across a valley. Wearable temperature and activity sensors of the kind already validated for cattle (Chatterjee et al., 2021; Neethirajan, 2017; Neethirajan, 2020) could, in principle, give herders a day or more of warning before visible clinical signs appear, which is particularly valuable where the nearest veterinarian may be a full day's travel away (FAO, 2018).

Anti-theft and loss prevention is a second, more Afghanistan-specific opportunity that is less prominent in the general IoT-livestock literature. GPS/geofence tags, used elsewhere primarily for grazing management (Neethirajan, 2020), take on an added security function in a setting where livestock theft and animal loss during displacement are recognised risks to household assets (World Bank, 2018). A geofence-breach alert routed by SMS to both the owner and a village elder or cooperative contact could shorten the window in which a stolen or strayed animal can be recovered.

Water and pasture management ties directly to ongoing donor-funded investment in livestock water points and pasture rehabilitation (IFAD, 2026; IFAD, n.d.). Simple environmental sensors — water-level and water-quality probes at communal troughs, soil-moisture sensors on rehabilitated rangeland — could feed the same gateway infrastructure proposed for animal monitoring, giving cooperatives early warning of a failing water point during drought rather than discovering it once animals are already showing distress.

Market and value-chain linkage is a longer-term opportunity, but a consistent theme in the World Bank's assessment of Afghan agriculture, which identifies weak market connectivity as one of the central constraints on livestock-based income (World Bank, 2018). Aggregated, anonymised herd and productivity data collected through an IoT system could, over time, feed price-information services or cooperative bargaining, echoing how conversational and low-bandwidth digital platforms have supported smallholders in other lo- and middle-income farming systems (“Kissan-Dost,” 2026).

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The barrier model in Figure 3 groups the obstacles to realising these opportunities into four layers, nd it is worth being explicit that they compound rather than operate independently.

Infrastructural barriers are the most fundamental. Large parts of rural Afghanistan have no reliable grid electricity, which is precisely why the architecture proposed in the Method section assumes solar-powered gateways rather than mains-fed base stations. Mountainous terrain also degrades radio line-of-sight, meaning that even a long-range technology such as LoRaWAN would need a denser network of relay points in valley terrain than the same technology requires on open plains (Raza et al., 2017). Physical access for installation and maintenance is itself constrained by the same lack of roads and bridges that limits MAIL's own field presence (FAO, 2018).

Economic barriers follow directly from the country's overall investment picture: agriculture, including livestock, has historically received a strikingly small share of total business investment relative to services and industry (Diplomat, 2016), and individual herding households typically operate on very thin margins with limited access to credit (ESRJ, 2025). Even sensor hardware that is inexpensive by the standards of commercial dairy operations in North America or Europe may be unaffordable without some form of subsidy, cooperative purchasing or micro-finance mechanism, a pattern also documented in reviews of IoT adoption barriers in other resource-constrained farming systems (“IoT and AI for Smart Agriculture,” 2025).

Socio-institutional barriers include limited digital literacy and, in many communities, unequal access to technology and decision-making between men and women despite women's substantial role in small-livestock care (World Bank, 2018; ESRJ, 2025). Weak agricultural-extension services compound this: a sensor system is only useful if someone can interpret its output and act on it, and that interpretive layer — traditionally provided by extension agents and veterinarians — is itself under-resourced (FAO, 2018; ESRJ, 2025).

Governance and policy barriers are the least technical but arguably the hardest to resolve. Afghanistan's 2018 e-agriculture strategy explicitly recognised the need for ICT-based solutions in agriculture (FAO, 2018), but a strategy document is not the same as a functioning spectrum policy, data-protection rules, or a regulatory environment that gives private telecom and technology providers confidence to invest in rural coverage. Security conditions in many districts add a further layer of difficulty, since neither government field staff nor private technicians can reliably operate there at all (FAO, 2018). Table 3 summarises the principal barrier facing each opportunity identified above, together with a suggested near-term mitigation.

Table 3. Opportunity–Barrier–Mitigation Matrix for IoT-Enabled Livestock Farming in Afghanistan

Opportunity	Principal barrier	Suggested near-term mitigation
Early disease detection (PPR, FMD)	Weak veterinary/extension reach	SMS alert routed to nearest cooperative and MAIL contact
Anti-theft / geofencing	Connectivity gaps in insecure districts	Store-and-forward data buffering on the gateway during outages
Water-point / pasture monitoring	Limited electricity access	Solar-powered gateway and sensor nodes
Market / value-chain linkage	Weak market infrastructure	Aggregate anonymised data via cooperative before wider scaling

Lessons from Comparable Settings

None of these barriers is unique to Afghanistan, and design choices that have worked in other resource-constrained agricultural settings are informative even where the local literature is thin. Systems built around voice or conversational interfaces rather than text- or app-based dashboards have shown promise for reaching farmers with limited literacy or smartphone access, an approach demonstrated for smallholder precision agriculture more broadly (“Kissan-Dost,” 2026). Low-cost, locally repairable hardware rather than the premium wearables sold into commercial dairy markets has proven more sustainable in pilot deployments across other low-income farming systems (Kamilaris et al., 2017; “IoT and AI for Smart Agriculture,” 2025). Cooperative or community ownership of shared infrastructure, such as a village gateway, also tends to outperform individual-household purchase, both financially and in terms of long-term maintenance, a pattern consistent with how IFAD-supported livestock initiatives in Afghanistan already organise shared water points and other community assets (IFAD, 2026).

Future Directions

Bringing the opportunities and constraints together, IoT adoption in Afghan livestock farming seems more likely to succeed as a staged, cooperative-anchored process than as a single large deployment. A first stage might place one solar LoRaWAN gateway and a small number of wearable tags with one cooperative or community in a relatively accessible and secure district, deliberately choosing SMS-based alerts over a smartphone app so that the pilot does not depend on device ownership. A second stage would extend coverage to neighbouring villages once the gateway and backhaul model has been tested across a full winter and a full grazing season, and would begin layering in water-point and pasture sensors alongside the animal-health use case. Only in a third stage, once basic connectivity and institutional trust are established, does it make sense to invest in the market-linkage and analytics functions that depend on richer data and broader participation.

Realising even the first of these stages will require alignment across several actors that do not automatically coordinate today: MAIL and the existing e-agriculture strategy (FAO, 2018), donor programmes already investing in livestock water infrastructure such as IFAD's Crisis Response Initiative Supplementary Financing (IFAD, 2026), mobile network operators who control the backhaul layer, and local cooperatives who would need to own and maintain the gateway. Framing IoT adoption explicitly as an extension of existing livestock-resilience investment, rather than as a separate "digital" initiative, may be the most realistic way to secure that alignment.

Conclusion

Livestock remains one of the few assets many Afghan rural households can rely on in an otherwise difficult agricultural economy, yet it is still managed almost entirely through direct observation and word of mouth. The IoT literature reviewed in this paper shows that wearable sensing, low-power wireless networking and cloud-based analytics have matured to the point where early disease detection, geofencing and environmental monitoring are technically realistic even outside well-resourced commercial farms. What is missing is not the technology itself but a deployment model that takes Afghanistan's specific constraints — weak electrification, difficult terrain, thin household budgets, limited digital literacy and, in places, active insecurity — as its starting assumptions rather than treating them as implementation details to be solved later.

The three-tier architecture, connectivity comparison and barrier model presented here are offered as a starting point for that kind of design work. The most promising path forward is not a single ambitious system but a small, solar-powered, cooperative-owned pilot, built around SMS-level accessibility, that can be evaluated over a real grazing season before any wider investment is committed. Future work should move from this conceptual stage to a genuine field pilot, ideally in partnership with MAIL, a livestock cooperative and a mobile network operator, so that the assumptions made in this paper can be tested against actual herd, network and cost data.

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The authors declare no conflict of interest.

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