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Farmers and veterinarians' perceptions and adaptive management of tick-borne disease risk on endemic dairy farms

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Tick-borne diseases are an increasing challenge for UK livestock farming, yet decision-making processes and risk perceptions surrounding them are not well understood. This study explores how dairy farmers and veterinarians perceive and manage tick-borne disease risk, and how these perceptions guide farm-level actions. Using a constructivist framework and reflexive thematic analysis, we analysed focus group discussions with eight farmers and seven veterinarians. Four themes were constructed: (1) risk perception as a characteristic of the farming landscape, (2) navigating uncertainty through experiential knowledge, (3) negotiating exposure, immunity, and production pressures, and (4) the hidden burden of endemic disease. Risk was understood as embedded in the physical and ecological features of farms, with disease management guided more by experience than evidence. Emotional strain, economic loss, and herd disruption emerged as substantial, under-recognised costs. Participants also voiced concern that Environmental Land Management Schemes may inadvertently expand tick habitat and increase disease risk. These findings highlight the need for greater integration of ecological, epidemiological, and social science research to support evidence-based management of tick-borne diseases in changing agricultural landscapes.

Tick-borne diseases are considered an emerging significant threat to livestock health by the World Organisation for Animal Health[1]. Across Europe, the distributions of ticks, their hosts and pathogens are shifting in response to climatic, ecological and landscape change[2,3]. These changes coincide with profound transitions in agricultural and land management priorities. Farmers are under increasing political and societal pressure to adopt sustainable, environmentally responsible agricultural practices while simultaneously improving animal health and welfare[4,5]. In England, the replacement of the Common Agricultural Policy with the Environmental Land Management (ELM) Schemes has redirected farm support towards the principle of "public money for public goods", rewarding actions that enhance biodiversity and encourage nature-friendly farming practices[6]. These reforms are anchored in ambitious environmental commitments, including large-scale woodland creation to support net-zero goals and major expansion of wildlife-rich habitats beyond protected areas, with farmers expected to deliver a substantial share of this effort[7]. Evidence suggests public opinion similarly favours multifunctional farm landscapes characterised by semi-natural habitats, trees, and low-intensity livestock systems[8].

These policy and societal drivers are expected to change farmland composition and structure, with potential consequences for livestock disease risk. The highest densities of *Ixodes ricinus*, the most widespread vector of livestock tick pathogens in the UK[9], are typically found in areas that are unsuitable for crops, so are commonly used for extensive livestock grazing land. In the UK, dairy production remains closely associated with grassland-based systems in which cattle graze for at least part of the year[10], making dairy farms an important setting in which to examine livestock exposure to ticks and tick-borne pathogens. Expansion of woodland and biodiversity-focused management is likely to increase suitable habitat for ticks[11], alter host densities and movement patterns, and changing farm management practices may change patterns of exposure to tick pathogens and risk of disease in livestock[12].

Tick-borne diseases rank among the top three health priorities for extensively grazed livestock in the UK, characterised as "high-impact, low-

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prevalence" conditions[13,14]. Bovine babesiosis, commonly known as "red-water", is caused by *Babesia divergens* and can result in haemolytic anaemia and death within a few days in naive adult cattle[15,16]. Tick-borne fever caused by *Anaplasma phagocytophilum* can cause fever, loss of milk production and abortion, as well as decreasing host immune function, which can result in secondary infections[17]. Despite these clinical impacts, little is known about their burden in the UK, reflecting the historically sporadic nature of outbreaks and the absence of coordinated livestock-focused surveillance for tick-borne pathogens. Limited case reports, including from mainland Europe, suggest outbreaks can cause severe production losses, substantial veterinary costs, and mortality, particularly in naïve herds[12,16,18]. Compared with directly transmitted livestock diseases, vector-borne infections are more difficult to monitor and predict because their transmission depends on multiple complex factors, including environmental conditions, vector populations, and multiple host species, that are not routinely captured by livestock disease surveillance systems[19,20]. In the UK, as in much of Europe, tick surveillance has largely been conducted through research projects and public health initiatives[21], with monitoring efforts primarily focused on pathogens affecting humans and companion animals rather than livestock[20]. As a result, the prevalence, distribution, and temporal dynamics of bovine babesiosis and tick-borne fever remain poorly characterised across Europe, limiting the ability to anticipate how disease risk may respond to changing landscapes and agricultural management. By contrast, in regions where tick-borne diseases represent major constraints on livestock production, particularly in tropical and subtropical systems, these infections have received substantially greater research attention, including studies on vector ecology, host immunity, and control strategies such as vaccines and acaricide management[22,23].

In recognition that human behaviour plays a pivotal role in the transmission of infectious diseases, research has increasingly examined the factors shaping farmer decision-making about livestock disease control[24]. In the UK cattle sector, studies have shown that decisions are influenced by multiple factors, including attitudes and motivation, moral and societal pressures, economic considerations, and levels of trust in advisors and authorities[25–28]. Collectively, these findings illustrate the multifaceted nature of farmer decision-making. However, as Hidano et al.[29] note, much of this research has concentrated on determinants shaping a single prescribed course of action. By contrast, many livestock diseases present farmers with multiple possible interventions, creating a more complex decision-making environment. Tick-borne diseases exemplify this challenge: a number of control measures are suggested, yet unlike directly transmitted infections, their transmission involves an arthropod vector and multiple potential wildlife and livestock hosts, adding additional complexity and uncertainty to design of management options.

In the UK, responsibility for tick-borne disease control rests at the farm level, with only limited guidance available. Current recommendations include exposing youngstock to infection in endemic areas to build immunity to tick-borne infections, selective purchasing of replacements, use of acaricides, and pasture management[30–32]. However, there is no empirical evidence from UK pasture-based systems to inform how these measures should be implemented in practice. Only one licensed product is available for the treatment of bovine babesiosis in the UK, imidocarb dipropionate (Imizol®)[33], however it has a notable withdrawal period and restrictions on repeated use. Vaccines are only available via import[30]. Additionally, decisions about grazing management, land use, and acaricide application occur within a complex system where actions taken to protect livestock health may also influence biodiversity, soil and water quality, and the development of acaricide resistance[34,35]. While farmer decisions have the potential to influence both livestock health and the environment, little is known about the approaches farmers currently adopt, or the factors shaping those choices in UK pasture-based systems. Understanding these perspectives is critical for co-design of contextualised environmental interventions that optimise multiple benefits from farmed landscapes whilst minimising the risk of tick-borne diseases. The aim of this study was to explore how dairy farmers and veterinarians make sense of tick-borne disease risk within UK pasture-based dairy systems, and how these interpretations shape approaches to disease management within the ecological and practical constraints of farm environments. Specifically, the study sought to understand how farmers and veterinarians interpret tick-borne disease risk within farm environments, how decisions about disease management are made in practice, how uncertainty and knowledge gaps influence these decisions, and how broader environmental changes may affect perceptions of future risk.

Results

Analysis generated four interrelated themes capturing how farmers and veterinarians interpreted and responded to tick-borne disease risk within pasture-based dairy systems: (1) risk perception as a characteristic of the farming landscape, (2) navigating uncertainty through experiential knowledge, (3) negotiating exposure, immunity, and production pressures, and (4) the hidden burden of endemic disease. Rather than representing separate topics, the themes capture interconnected ways in which farmers and veterinarians conceptualised risk, adapted management strategies, and experienced the consequences of tick-borne disease within the ecological and production contexts of their farms. Figure 1 summarises the relationships between these themes and the broader ecological and knowledge contexts in which they were discussed.

Risk perception as a characteristic of the farming landscape

Participants framed tick-borne disease risk not solely in terms of biological transmission or pathogen presence, but as something embedded within the geography, ecology, and history of their farms. Risk was therefore interpreted less as a discrete biological hazard and more as a feature of the landscape that farmers had to manage and adapt to over time. These perceptions were shaped by long-term familiarity with the land, local wildlife populations, and previous disease experience. Risk was frequently associated with particular landscapes, such as valleys, woodland edges, or steep, unmanaged areas. These environmental features were often seen as inherent and largely beyond the control of farmers or veterinarians.

Veterinarian: "So I used to work in Cumbria and there was like just this one valley, yeah, all the farms at that valley would get redwater and no other farm that we went to".

Woodland and wild, unmanaged areas were commonly linked to increased tick presence. Both farmers and vets emphasized that these features were permanent parts of the landscape, and therefore difficult, if not impossible, to eliminate, necessitating adaptive management rather than removal.

Farmer: "You're never going to change the woodland around you, are you? That's always going to be there, so you've got to work with what is around you. You've got to change what you do because that's, that environment's never going to change"

These accounts illustrate how participants interpreted tick-borne disease risk as structurally embedded within landscape features that were largely beyond direct control, reinforcing the need to adapt management rather than attempt environmental elimination. Participants also linked tick presence to particular field characteristics, especially marginal or difficult-to-manage land. Specific fields were often described as consistently high-risk for disease, linked to long-standing features such as difficult-to-manage vegetation or topography:

Farmer: "Yeah, but there is so many pockets on our farm, which it's steep. That they will go to, that you'll never be able to plough anyway, so you're never going to stop it [redwater]"

Veterinarian: "As vets, I'd say we definitely see it on the farms that say they've got that land that they can't really do anything with it and so the grass gets, the grass just gets old."

Wildlife was consistently mentioned as a factor contributing to tick burden and disease pressure, especially where wild animals moved from the surrounding landscape into grazing land. These accounts highlight how participants interpreted tick-borne disease risk as extending beyond farm

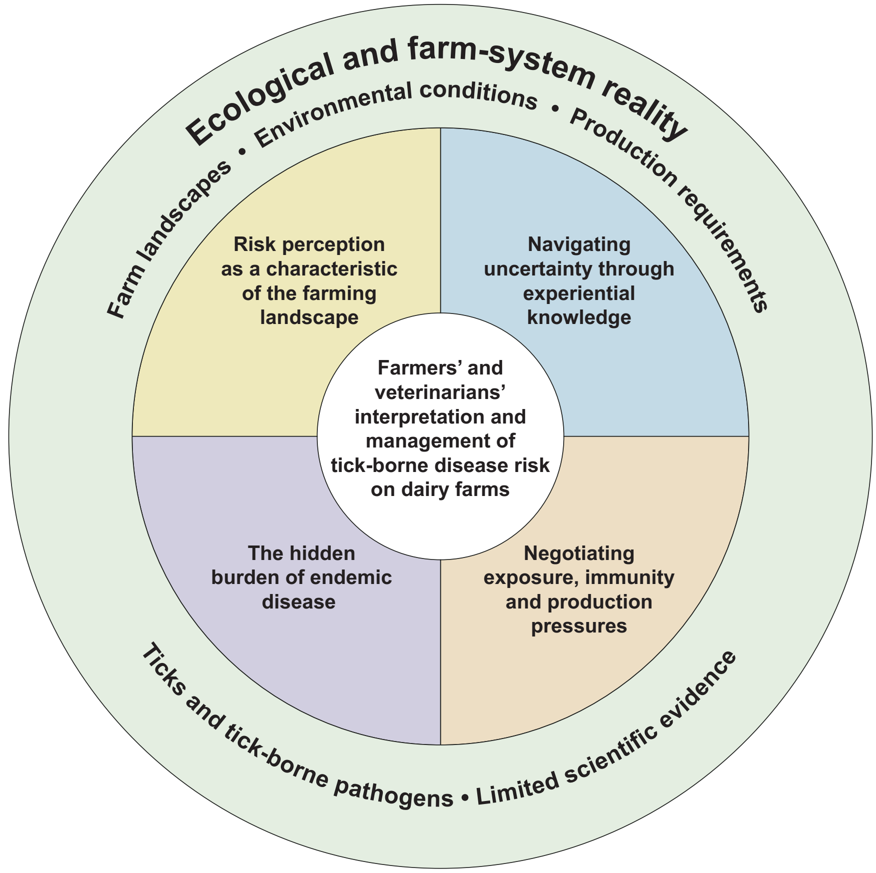

Fig. 1 | Conceptual framework illustrating how farmers and veterinarians interpret tick-borne disease risk within pasture-based dairy systems. The framework summarises the interpretive structure developed through reflexive thematic analysis. Interpretations of tick-borne disease risk at the farm level were shaped by four interconnected themes: risk perception as a characteristic of the farming landscape, navigating uncertainty through experiential knowledge, negotiating exposure, immunity, and production pressures, and the hidden burden of endemic disease. These interpretations were situated within the ecological and farm-system realities shaping pasture-based dairy systems, including farm landscapes, environmental conditions, production requirements, tick and pathogen presence, and limited scientific evidence on disease dynamics and control in UK livestock systems.

boundaries and shaped by wider landscape ecology, particularly wildlife movement between unmanaged habitats and grazing areas.

Farmer: "I do think wildlife burden has something to do with it as well. If there's a lot of rabbit and deer about we do see more ticks. Simple as that… just having wild areas…it's the animals that move from those areas to our grazing fields"

However, some participants emphasised that location could override field management history.

Farmer: "You can say about your fields and that but ours were good fields. They'd been ploughed, we'd had rape in there for the sheep. They'd been ploughed, they are good fields. But it's in the area."

Participants interpreted findings from the parallel ecological field study as largely confirming patterns they had already observed through experience.

Veterinarian: "It might be a perfectly lovely grazing field, but if it has hedgerows or woods…that's where you find the ticks"

Weather was also perceived as influencing tick activity, although participants emphasised that these patterns were unpredictable.

Farmer: "weather is a huge you know you get wet years, we get a lot more ticks and it's almost like they are further out in the field kind of thing like when we had the, a couple of years ago when we had that drought when it got really hot and dry, didn't see a single tick anywhere it just must have just burned them all, you know, which was brilliant".

In addition to existing landscape features, participants also considered how future land-use changes might alter tick risk. Participants expressed concern that environmental land-use policies such as ELM schemes could increase tick habitat. Veterinarians in particular worried that farms newly engaging in habitat diversification might be unprepared for emerging disease risks.

Veterinarian: "Tick-borne disease wasn't even, wasn't a consideration, which is fair enough because it's not in their sphere of work. But, you know, for some people who might not know that they really have an issue, it might just blow up into a really big thing if they …drastically change the habitats of the fields that these cattle are grazing."

Veterinarian: "You're going to start seeing it on people that haven't seen it before and they're just totally unprepared".

These concerns illustrate how environmental land-use policies were interpreted through the lens of livestock disease risk.

Overall, these accounts illustrate how tick-borne disease risk was interpreted through a place-based understanding of farm environments, drawing on familiarity with landscape features, land management histories, wildlife presence, and prior disease experience. Rather than relying primarily on formalised epidemiological evidence or standardised disease – control guidance, participants interpreted risk through locally embedded and experience-based understandings of their farm environment. In this sense, risk was not perceived as a discrete or fully controllable biological hazard but as an enduring characteristic of particular farm landscapes that farmers and veterinarians learned to manage through local ecological knowledge.

Navigating uncertainty through experiential knowledge

Uncertainty about transmission dynamics, immunity and pathogen persistence strongly shaped how both farmers and veterinarians interpreted disease risk and constrained their ability to make confident management decisions. In the absence of clear scientific guidance, participants relied heavily on experiential knowledge and practical assumptions to guide disease management. Participants described particular uncertainty around how best to manage exposure to tick-borne infection in a way that promotes protective immunity without triggering clinical disease. Both veterinarians and farmers referred to a shared belief that controlled exposure of youngstock to infected ticks may facilitate the development of immunity and reduce the risk of severe disease later in life, however, participants consistently highlighted the lack of clear evidence to guide implementation of such exposure strategies in practice.

Farmer: "If we could find out how long they need to be exposed for on this ground, you could just give them a blast."

Farmer: "The dangerous thing is not to have them infected, you know, you want, you want them to have the immunity, because otherwise they're always at risk…We almost need to learn how to infect them rather than how not to infect them"

These comments illustrate how management strategies were often built around practical assumptions about immunity in the absence of robust evidence.

Participants also expressed a need for greater spatial resolution in understanding where infected ticks are located on farms, farmers often using the terms *disease* and *infection* interchangeably, referring both to clinical illness and to the presence of pathogens. It was widely acknowledged that not all ticks carry all pathogens and that certain areas may harbour ticks without transmitting specific diseases.

Farmer: "I'm sure in in [site a] I think we've probably not got infection [B. divergens]. Whereas three miles up the road, there is infection [redwater]. And we know that at [site a] we've still got ticks because they get tick fevers. We're just not getting redwaters. So I think you'd need to know that the whether you've got the infection [B. divergens] there or not."

Both farmers and veterinarians described how improved knowledge of pathogen distribution could help target grazing strategies more effectively.

Veterinarian: "The ideal for these guys if they knew exactly where infected ticks were on their farm at a given time but. Yeah, I don't know. You'd be a very clever person to be able to tell them that."

Beliefs regarding the persistence and durability of immunity were inconsistent and often based on anecdotal evidence rather than diagnostic testing. While some participants assumed that once exposed, cattle would retain lifelong immunity, others reported suspected waning immunity with age, further complicating management decisions.

Farmer: "Well, what we found at home is actually, they'll lose that immunity as they get old"

Participants further questioned how infections circulated within herds, including whether certain animals might act as carriers. These concerns reflect a lack of empirical data on the natural history of tick-borne disease pathogens within herds and underscore the difficulty of distinguishing new infections from recrudescence or transmission events.

Veterinarian: "I'd like to take [your] herd and go through the summer and sample them…and see what you got, and see whether it stays in the same cow the whole time or whether it went around, or whether it just went away"

Veterinarians also described marked variation in epidemiological patterns of tick-borne diseases between farms, even in similar environments.

Veterinarian: "I've got a case of redwater and you come and sort it and it kind of trickles on. And then some farms where you just get a really horrible outbreak in one year, and it's just really horrible, then it sort of goes away and doesn't come back again the next year. That seems to be how it works, doesn't it?"

Veterinarians expressed a mix of surprise and pragmatic acceptance of the apparent unpredictability, reflecting the limited scientific understanding of the ecological and epidemiological drivers of livestock tick-borne diseases. Farmers described relying heavily on observational knowledge to recognise cases, often drawing on subtle signs such as changes in appetite, milk yield or demeanour. While some felt confident identifying cases based on experience, others reported difficulty recognising early-stage disease, particularly in the absence of dramatic clinical signs. Diagnosis was therefore often based on subjective judgement rather than laboratory confirmation.

Farmer: "Yeah, I know and you're like but how off are you? Because you look a bit off and then we'll get the vet out to give it the Imizol. And then like sometimes we'll be like, oh, it was that bad. It was like they'll take the blood. And we did try, its trying to catch them if it was a really good cow to do the blood transfusion."

The concept of modifying seasonal grazing patterns as an approach to managing tick-borne disease risk was explored hypothetically, with widespread agreement that the unpredictability of tick emergence limited its practical viability. Tick abundance and pathogen transmission were perceived to be highly influenced by environmental variables, particularly temperature and moisture, which vary substantially across seasons and years. This variability was seen as a major obstacle to planning or standardising turnout periods as part of a preventive management strategy.

Farmer: "So you could say well, I'm going to turn them out in May, all of May."

Farmer: " Then you go and you have a real dry May or something."

Farmer: "And then there's nothing in May. But there will be hell of a lot in August and it's too late."

These accounts illustrate how assumptions about immunity became central organising principles for management decisions, despite participants recognising that the underlying biological processes remained poorly understood. In this context, experiential reasoning emerged as a practical framework for navigating uncertainty, with farmers and veterinarians drawing on observation, prior experience, and locally derived assumptions to guide decisions about exposure, grazing, and treatment. This reliance on experiential knowledge reflects the practical realities of managing vector-borne disease in pasture-based systems where surveillance, diagnostic certainty, and formal guidance remain limited, often resulting in adaptive trial-and-error approaches that can produce inconsistent outcomes and contribute to stress in herd health management.

Negotiating exposure, immunity and production pressures

Strategies for disease management reflected the need to balance disease risk with the practical and economic constraints of pasture-based dairy systems. Rather than implementing standardised protocols, participants described management as an ongoing process of experimentation and adjustment shaped by the practical realities of pasture-based farming systems. Management strategies were highly farm-specific, shaped by the characteristics of individual farms and the practical constraints of grazing systems.

Participants were reluctant to avoid perceived high-risk land completely and instead described pragmatic approaches to managing essential grazing ground. Total avoidance of tick habitats was rarely considered a feasible or economically viable solution, particularly because farmers prized immunity and therefore wanted their animals to experience some level of exposure. Instead, grazing decisions were framed as strategic trade-offs between production needs and disease risk, with farmers adjusting grazing patterns according to animal type, value, and timing.

Farmer: "The problem with it is of course you losing production because you're just not getting any yield of that part of the field. So, so [avoiding the use of grazing pasture].. it's not a great answer from that point of view, which is what I would, why I would be pretty against doing it."

Pasture management practices included ploughing and reseeding to reduce suspected tick habitats, though farmers reported mixed results. Some were confident their efforts had made a difference, others remained uncertain.

Farmer: "The year which we had the real outbreak we think it was one certain field they were getting it and we did actually plough that field. So in our mind, we think that's how we solved it, but perhaps it had nothing to do with it, I don't know."

Some farms altered calving patterns or breeds in response to tick-borne disease pressure, aiming to align risk periods with more resilient stock.

Farmer: "Changed like everybody, we've got Holsteins, we've gone to cross breds and we've gone to block calving, as opposed to all year round calving, it was difficult to point your finger."

Farmer: "We pushed it back a bit. So it's a bit more manageable now. And this was a, better year. And we do other few things like pour on's and stuff like that, which I think helps a bit."

A common goal was balancing exposure with immunity while avoiding clinical cases. Farmers described actively encouraging regular tick exposure in an effort to maintain immunity, adjusting grazing patterns accordingly.

Farmer: "We still want the ticks to bite them to hopefully keep this level of immunity that they have, so we let them go into those places and almost try to do it so that they're regularly bitten, not say if we know there's a field that's got them, they'll go in there for a prolonged period and then not see the ticks again for a prolonged period, you know what I mean. Sort of. Keep that constant exposure to it."

In more severe cases, farms had altered their milking systems or stopped grazing their cattle entirely, in response to disease pressure. On one farm, the changes were particularly striking: after recently investing in an automated robotic milking system, the farmer chose to replace it with a conventional parlour to enable seasonal calving. This change allowed home-bred replacements to be grazed during peak tick season while still considered protected by age-related resistance, as part of a strategy to promote immunity and manage disease.

Veterinarian: "You were in robots, now you're not. So you guys put a parlour back in didn't you so you could home breed enough replacements at the right time of year to get them grazed to get immunity… And we have had a client in the last year or so at work that has had their milk contract changed so they don't have to graze because of ticks, but they've only got a two or three-year like leeway on that."

Acaricide use was widespread, with participants often rotating products and balancing tick control with other parasite management needs and perceived effectiveness of products.

Farmer: "We've used all sorts…of different things, and we tried doing with different active ingredients, didn't we? Each month. Different active ingredients."

*Farmer: "And then the other thing we had to do is like, which again could be interfering with our immunity was we give our heifers Cydectin LA [*a long acting parasite treatment*] in the ear because they were also the first year we thought we don't want to try and kill off any ticks. So we just then have the ticky ground, not give them any, like very little wormer, which obviously how they get immunity I don't know, but like. And we had real bad worms. Yeah, so we so we now go back to this."*

Veterinary input was valued, but typically reactive, focusing on outbreaks and treatment of clinical cases rather than prevention or land management. Collaboration between vets and farmers was common, drawing on farmers' detailed knowledge of their land and livestock.

Veterinarian: "It's quite farm to farm isn't it. Because the farmer has the knowledge about their farm so we use that knowledge and work with them. Because they know the fields, they know what signs they normally have. They're really good at spotting them early…. the ones that know about it, yeah, it's we kind of manage it with everyone's knowledge put together"

Preventative strategies were farmer-driven, developed through trial and error, historical knowledge of the farm, and iterative adjustment over years in response to outcomes. Some farmers sought information from online or overseas sources to inform their approaches.

Farmer: "I tried when I was like, googling like ticks like and you see like in South Africa and Australia they were dipping them.. I think it's an Australian like journal like I read, was saying about using Cydectin which is a like a slightly longer acting wormer, but it doesn't say on the bottle much about ticks, but we used a combination again, it probably was like not licenced to be using on such a short rotation…"

Some farmers had normalised their approaches and considered them to be effective, even when cases or outbreaks occurred.

Farmer: "So and since we've been doing that, the last four or five years, we've seen no increase in redwater, apart from that one spate of dry cows, which is just really weird, you know, and they'd all been treated with spot on and everything, and they still all got it…I more see redwater a failing of me not controlling it with spot on opposed to anything else."

Others, who had been confident in their control measures, were surprised by study results indicating sub-clinical infection within their herds.

Farmer: "See like I thought we cracked it. We went from having 8 or 10 cases there and to preventing the all the others. Then doing Dysect [a topical acaricide used on cattle to control flies and lice] *there every four weeks, like religiously. And then we didn't have any redwater and we thought beauty we cracked this job and then turns out half of those have had tick fever"*

There was no evidence of farmers discussing tick control or seeking advice from peers. Participants noted that, more broadly, such discussions might be limited by stigma, with tick-borne disease sometimes perceived as being associated with lower-quality pasture, and a reluctance among farmers to admit having a problem.

Farmer: "But the biggest problem is that farmer initially saying I've got a problem, can you help"

Farmer: "And ticks associated with more rubbish farming, farming worse ground, isn't it…"

Veterinarian: "Yeah, I think you're right. There's a little bit of stigma".

The hidden burden of endemic disease

Tick-borne diseases were described as having significant, multifaceted, and often long-lasting impacts on dairy farms. These effects were not limited to individual animal health but extended to productivity, herd management, farm economics, and farmer wellbeing. The effects of outbreaks could become normalised by farmers in the absence of more severe clinical signs, even when clinically important outcomes such as premature calving and reduced milk yield were evident.

Farmer: "As soon as they got that temperature, they were chucking the calf out. Calf was alive. All you got was like a small, like, slightly weedy calf, and a cow that had no udder at all. And when its, so, it's like nothing's dying. So, you know, we weren't like, oh my goodness this is horrendous. Just because it wasn't a crazy outbreak, it was just niggling, it's just frustrating. We've got all these cows calving early, you have no, you're trying to get their dry cow ration right"

Veterinarian: "And then they don't milk like they should either"

The word "disaster" was frequently used by both veterinarians and farmers when describing outbreaks, underscoring the severity and consequences of the outbreaks that farms have experienced.

Veterinarian: "Yeah, but you, your cows, were so immunocompromised for so, like after that big disaster, and then we had massive problems in the calves, cause the colostrum was crap, then massive pneumonia in the calves, it just like, it just led onto other disasters, didn't it?"

The impact of limited treatment options and withdrawal periods of licensed products influenced decisions around tick-borne disease control. Farmers expressed concern about treating cattle with Imizol because the associated milk and meat withdrawal periods reduced saleable output, creating difficult trade-offs between treating animals and protecting income.

Farmer: "but sometimes you think oh, they're not that bad, so you think is it worth giving [Imizol] to them, to have the meat withdrawal"

An additional layer of complexity arose when farms faced multiple concurrent infections, where even the shorter withdrawal periods of more commonly used antibiotics had a cumulative impact. In such situations, the need to manage multiple diseases while avoiding the impact of excessive loss of saleable milk could prevent farmers from treating clinically affected animals, despite recognising the potential benefits of doing so, or suffering significant production losses. These scenarios reflect the complexity of decision-making within a production system.

Farmer: "the milk completely dried up or they scoured and they scoured and looked like Johnes but you could not get them to test positive and then the salmonella came and I think that was the salmonella was the start of it. Yeah, but those cows didn't get Imizol and were clinically really poorly with the tick-borne fever, whereas I think if you the engemycin was I think if you can treat them you minimise that but you just couldn't do it because you'd have had no cows in the tank,"

Veterinarian: "they'd lost a load of, they'd had a load of TB reactors and then they got redwater like that same, like within a month after the TB and then I don't know if they lost any, but they have a lot of cows out the tank because they'd all been Imizol'd and it was, it was awful wasn't. It was really hard."

The emotional toll of tick-borne diseases was striking. Participants described feelings of stress, worry, and helplessness, particularly during high-risk periods such as spring turnout or following prior outbreaks. The mental burden was compounded by the limited options for control in an outbreak situation. More than once vets described farmers as *coming out the other side*, highlighting how profoundly such episodes affected their herds, workload, and morale. Emotional exhaustion compounded the already heavy workload of managing disease, and this sense of overwhelm was intensified by the lack of clear solutions.

Farmer: "You start questioning yourself then don't you"

Veterinarian: "They were rock bottom, weren't they. Thinking about giving up. Yeah. They've come out of it, now on the other side, but"

Farmer: "like I say things to have improved to a level where we're not terrified now"

Veterinarian: "And that's like it's just awful, isn't it, when you like, when you're in that position".

Farmer: "Well, it's when you can't stop it. That's the problem. It's everyday you're going and you get these spells and it's you can't stop it and once"

Veterinarian: "It's so helpless."

Despite these challenges, many participants had come to see tick-borne diseases as an unavoidable part of farming in certain landscapes, focusing instead on coping and mitigation. This normalisation of disease did not reflect indifference but rather a form of pragmatic acceptance. Farmers did not expect to eradicate the problem but aimed to live with it as best they could.

Across themes, participants described tick-borne disease as shaped by the interaction between ecological context, uncertainty about disease processes and the practical constraints of pasture-based farming. Risk was interpreted through long-term familiarity with landscapes and wildlife, while gaps in scientific knowledge reinforced reliance on experiential judgement and adaptive management strategies.

Discussion

This study shows how dairy farmers and veterinarians interpret and manage tick-borne disease risk within complex ecological, production and policy landscapes. The findings highlight the substantial uncertainty surrounding tick-borne disease dynamics in pasture-based systems, particularly regarding how farm-level environmental risk translates into disease outcomes in individual animals. Rather than approaching disease control through standardised protocols, participants described navigating uncertainty through experiential knowledge, adaptive management strategies and ongoing adjustment to local conditions.

A central challenge was the need to balance deliberate exposure of cattle to ticks to maintain immunity, with the risk of clinical disease. This created a persistent risk-management dilemma in which farmers sought to manage, rather than eliminate, exposure amid limited evidence on transmission dynamics, pathogen distribution, and the duration of protective immunity. Localised knowledge often informed practical decisions, with farmers adapting grazing rotations and altering access to specific fields to expose certain cattle to infected ticks and encourage immunity. These experiential, trial and error strategies mirror wider findings from farm biosecurity and disease-risk research, where producers routinely navigate uncertainty by combining previous experience, perceived efficacy of approaches and pragmatic adjustment[28,36,37]. The emphasis on practical, field-derived knowledge was also reflected in veterinary accounts. Research has similarly highlighted the role of experiential knowledge gained through everyday veterinary practice and fieldwork in shaping professional expertise (Proctor et al., 2011). Similar place-based reasoning has been reported for bovine tuberculosis, where farmers categorised fields as "safe" or "dodgy" based on landscape features[38], though in contrast to the fatalism described in that context, farmers here adopted adaptive, iterative strategies despite substantial uncertainty. Tick control was integrated within wider parasite management, with acaricide choices influenced by multiple parasite pressures. Off-license use was widespread, and product schedules driven by perceived effectiveness. While these adaptive approaches are understandable in the absence of licensed products and context-specific guidance, frequent switching between products, repeated exposures, and off-label timing may contribute to the broader problem of antiparasitic resistance across grazing systems[39–41]. This reflects a structural, system-wide gap in sustainable solutions rather than shortcomings at farm level. The Food and Agriculture Organisation has identified essential research and development priorities to mitigate acaricide resistance, highlighting the wider implications for livestock production, environmental integrity, and public health unless sustainable solutions are found[35].

Concerns were voiced that ELM-driven habitat diversification could inadvertently enhance tick suitability, posing emerging risks for farms in areas with little prior exposure. UK environmental policies are primarily shaped by biodiversity and climate goals and give little consideration to livestock disease risk, reflecting gaps in both policy integration and evidence on how environmental objectives may trade off with animal health[42]. Existing research indicates that certain forms of habitat creation and agri-environment management, including woodland expansion and wildlife conservation may increase tick densities, wildlife-livestock interfaces and tick-borne disease hazard under certain conditions[2,43–45]. Together, these findings highlight the need for targeted research to better understand how environmental land-use changes may influence livestock tick-borne disease risk and to ensure that livestock health considerations are not overlooked in discussions around agri-environment schemes.

Although assessing impacts was not an explicit aim of the study, participants repeatedly described the wider consequences of tick-borne diseases for farm systems and personal wellbeing, suggesting that these effects represent a significant but often under-recognised dimension of endemic livestock disease. Effects extended beyond animal health to productivity, herd management, farm economics and farmer wellbeing. For some farmers, the emotional burden was substantial, characterised by stress, helplessness, and periods of profound demoralisation, accompanied by coping strategies and pragmatic acceptance. Existing UK research on the mental health impact of livestock diseases has largely focused on high-profile, trade-limiting diseases such as bovine tuberculosis and foot and mouth disease[46,47], but our findings show that endemic, non-notifiable diseases can also have significant psychological and economic burdens. This aligns with wider evidence that farmer mental health is a growing concern: studies show that depression rates among farmers are rising, and suicide occurs more frequently in farming than in the general population or any other occupational group[48–50]. These findings highlight the need for support and research that recognise the emotional as well as epidemiological challenges posed by endemic vector-borne disease.

Participants also described reluctance to discuss tick-borne disease openly within farming networks, reflecting concerns that tick-borne diseases are often associated with poorer quality land. In farming cultures where land condition and productivity can function as visible markers of competence, disease problems linked to landscapes may therefore carry a degree of stigma. This aligns with sociological research on the "good farmer" identity, in which farmers' reputations are partly shaped by how their land is perceived and managed[51].

This study has limitations. The purposive sample of dairy farmers and veterinarians from farms with a known history of tick-borne disease, recruited from a prior field study, likely meant participants were more knowledgeable and engaged with the topic than the broader farming and veterinary community. The small sample reflects the depth-oriented nature of qualitative research, but limits the breadth and transferability of findings, particularly to regions of low disease risk. Mixed-professional focus groups encouraged cross-perspective dialogue but may have constrained disclosure of sensitive experiences, such as perceived management failures.

Tick-borne diseases present a complex and often under-recognized challenge for UK dairy farmers operating in increasingly biodiverse and environmentally regulated landscapes. In the absence of formal surveillance or standardised guidance, farm-level responses are pragmatic, context-specific, and frequently adapted through trial and error in the absence of clear epidemiological evidence. While these strategies demonstrate considerable resilience and adaptive capacity among farmers and veterinarians, they also expose systemic gaps in advisory support, research, and policy. Addressing these gaps will require greater integration of ecological, epidemiological, and social science perspectives. Future research should prioritise improved surveillance of livestock tick-borne pathogens, field-based studies on immunity and exposure dynamics under pasture-based grazing systems, and evaluation of management strategies that balance livestock health with environmental objectives. Greater consideration of animal health risks within the design and implementation of agri-environment schemes will also be important to ensure that biodiversity and climate goals can be achieved without unintended consequences for livestock disease risk.

Methods

This research was guided by a constructivist epistemology, informed by Vygotsky's view that knowledge is co-produced through the interaction of social and mental processes, with individuals constructing meaning within their own contexts[52]. Farmers' and veterinarians accounts were understood as shaped by both personal experience and wider socially constructed realities[53]. In parallel, a critical realist perspective acknowledged that these subjective accounts are grounded in the material presence of tick and tick-borne pathogens on farms, and shaped by institutional and structural factors, including economic pressures, environmental conditions, and animal health policies, that influence decision-making. This dual framing supported an analysis that valued lived experience while situating it within its broader structural and contextual conditions[54].

Participant recruitment

Participants were recruited from dairy farms in southwest England that had participated in a parallel ecological field study conducted in the same region[55]. Southwest England was selected because it contains a high density of pasture-based dairy farms and has historically reported cases of livestock tick-borne disease. Farms were eligible for inclusion in the parallel studies if they had a veterinary-diagnosed history of recurrent bovine babesiosis and/or tick-borne fever in the herd, and managed pasture-based dairy herds.

The focus on dairy farmers reflected the sampling frame of the wider programme of work, which was conducted with pasture-based dairy farms and enabled direct integration of the qualitative findings with the accompanying ecological and epidemiological data. Farmer participants were senior decision-makers within their dairy enterprises, responsible for herd management and overall farm management decisions. In one case, day-to-day management had transitioned to the next generation within the family business. Veterinarians included both the practising farm-animal clinicians responsible for these herds and government veterinarians with recognised expertise in tick-borne diseases in livestock. A total of fifteen participants took part: eight farmers and seven veterinarians. This purposive sampling strategy enabled the study to capture diverse experiences of tick-borne disease across farms participating in the wider ecological and epidemiological research programme investigating tick distribution, environmental drivers of tick abundance, and pathogen prevalence in cattle.

Focus group procedure

Focus groups were used to generate rich data through participant interaction[56]. Veterinarians and dairy farmers occupy distinct but interdependent roles in the agricultural system: veterinarians contribute clinical, scientific, and regulatory perspectives, while farmers provide experiential knowledge of management and on-farm challenges. Mixed focus groups that bridge professional boundaries can reveal broader, systemic challenges that might not emerge in homogenous groups, and can help to capture the complexity of real-world decision-making[57,58]. Bringing farmers and veterinarians together in qualitative research can also provide insight into how veterinary advice and farm-level decision-making interact in practice (Chomyn et al., 2023). In this study, farmers and veterinarians were included in mixed groups to explore the interface between veterinary advice and on-farm implementation, recognising that how a participant expresses themselves is influenced by their expectations of how other participants will react to what they say[59]. Group composition was considered during analysis to account for how participants may have shaped or moderated their responses in the presence of others, particularly where existing professional relationships or shared farming experiences may have influenced discussion.

Three focus groups were conducted: two in person (total participants = 12), and one online via Microsoft Teams (participants = 3) to accommodate geographical constraints. Focus Group 1 included three farmers (all of whom knew each other) and two veterinarians; Focus Group 2 included five farmers (two of whom knew each other) and two veterinarians; and Focus Group 3 consisted of three veterinarians. In Focus Groups 1 and 2, the participating veterinarians were practising farm-animal clinicians who provided veterinary services to some of the participating farms. As such, some farmers and veterinarians had existing professional client–veterinarian relationships. In Focus Group 3, which included only government veterinarians, participants were professionally acquainted through their work in livestock disease surveillance and research. These existing professional relationships reflect the structure of veterinary service provision within the livestock sector and were considered during facilitation and analysis as a potential influence on group dynamics. Moderators encouraged contributions from all participants and prompted quieter participants where necessary to minimise the influence of dominant voices and ensure a range of perspectives were represented in the discussion.

Sessions were facilitated by SS together with either TF or a postdoctoral researcher from the University of Liverpool. The presence of two facilitators helped manage discussion flow and ensured that all participants had opportunities to contribute. All sessions were audio-recorded. Written informed consent was obtained from all participants, who were provided with an information sheet in advance and reminded that participation was voluntary. A topic guide, developed from existing literature and preliminary field study findings, structured discussion around farm practices, tick-borne disease burden and control strategies, knowledge gaps, and anticipated impacts of ELM Schemes (supplementary material). The guide was used flexibly to encourage open discussion while ensuring that key topics relevant to the research aims were explored across groups. Key findings from the parallel field study, including findings from cattle sampling and observations on tick presence and environmental risk factors, were presented at the start of each session to prompt reflection and discussion. Transcripts were anonymized to remove any identifying information and were transcribed verbatim by SS.

Analysis

Data were analysed using reflexive thematic analysis following the six-phase process described by Braun and Clarke[60]. This approach supports the identification of patterns across qualitative datasets while acknowledging the active role of the researcher in interpreting meaning. Analysis was consistent with the study's constructivist orientation, recognising that themes are not simply discovered in the data but constructed through a process of interpretation shaped by the researchers' engagement with participant accounts.

Transcripts were read repeatedly by SS to develop familiarity with the data, and initial codes were generated inductively to capture patterns of meaning relevant to the research aims. Coding was conducted manually and iteratively, with early codes revised, merged, or expanded as engagement with the data deepened. This process corresponded with the early phases of reflexive thematic analysis, including familiarisation with the data, generation of initial codes, and exploration of patterns across the dataset.

Codes were then examined for patterns and relationships and grouped into candidate themes that captured broader interpretive concepts within participants' accounts. Conceptual mapping was used to explore relationships between codes, candidate themes, and the broader socio-ecological context of disease management. This process enabled the research team to move iteratively between individual data extracts and developing interpretations of how participants understood tick-borne disease risk, management strategies, and their impacts within farm systems. Theme development was an iterative and reflexive process. Developing interpretations were discussed with TF and JD to explore alternative perspectives and refine the developing thematic structure. Through this process, candidate themes were reviewed, defined, and named to represent shared interpretive patterns across the dataset rather than simple summaries of participant statements. Illustrative quotations were then selected to demonstrate how these meanings were expressed within participant accounts. The analysis therefore, involved continual movement between data, codes, and themes to develop an interpretive account of how participants understood tick-borne disease risk within pasture-based dairy systems.

Reporting was guided by the Standards for Reporting Qualitative Research (SRQR)[61], to support transparency in qualitative reporting. Given the small number of participants within a closely connected regional farming and veterinary community, reporting additional demographic characteristics or assigning individual participant identifiers risked deductive identification of individuals or farms. Quotations are therefore attributed only by participant role (farmer or veterinarian). This work was carried out under the approval of the University of Liverpool Veterinary Research Ethics Committee: VREC1558.

Reflexivity

The first author (SS) is a veterinarian and researcher who previously led a field study on tick-borne diseases involving the farms and veterinarians recruited for this project. This prior relationship may have influenced participant responses by fostering trust or by shaping expectations of the study. The author's veterinary background provided technical knowledge that supported the discussion but may also have influenced interpretation. Reflexive practices, including critical discussion with co-authors and efforts to create an open environment in which participants could share diverse perspectives, were used to mitigate potential bias.

Data Availability

The data supporting the conclusions of this article are included within the article.

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Author contributions

S.S. Data collection, wrote the first draft; B.P. Supervision; N.J. Funding acquisition, supervision; J.D. Supervision; C.M. Funding acquisition; T.F. Supervision. All authors edited the manuscript and approved the final version.

Competing interests

The authors declare no competing interests.

Additional information

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