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Impact of Agricultural Practices on Tick Population Ecology and Tick-Borne Disease Transmission

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Abstract: Ticks and tick-borne diseases represent a growing threat to livestock productivity, rural livelihoods, public health, and agricultural sustainability. Farming practices modify vegetation, microclimatic conditions, host availability, and wildlife–livestock interactions, thereby influencing tick survival, distribution, and pathogen transmission. However, conventional control programmes primarily depend on repeated acaricide application and often overlook ecological drivers, seasonal variation, farm-management conditions, and emerging chemical resistance. This study investigates the impact of livestock density, grazing patterns, pasture rotation, irrigation, vegetation management, land-use change, animal movement, and wildlife accessibility on tick populations and associated diseases. An integrated ecological assessment framework was developed by combining field-based tick sampling, livestock examination, pathogen detection, acaricide-resistance assessment, environmental monitoring, farm-management surveys, statistical analysis, remote sensing, and GIS-based risk mapping. A model-based comparative evaluation was conducted across intensive, extensive, mixed crop–livestock, rotational grazing, and silvopastoral systems. Extensive grazing recorded the highest mean tick burden of 24.8 ticks per animal, while rotational grazing recorded the lowest burden of 8.7. Compared with conventional management, the proposed integrated approach reduced mean tick burden by 59.4%, livestock infestation by 49.3%, pathogen-positive ticks by 51.9%, and disease incidence by 57.1%. It also reduced acaricide applications by 48.5%, treatment failure by 62.3%, and relative control costs by 24%. The findings demonstrate that combining pasture management, herd biosecurity, targeted chemical treatment, resistance monitoring, environmental surveillance, and One Health coordination provides better ecological, epidemiological, and economic performance than conventional chemical-dependent control. The framework supports adaptive and location-specific strategies for sustainable management of ticks and tick-borne diseases in diverse agricultural landscapes.

Keywords: acaricide resistance, agricultural practices, ecological assessment, integrated tick management, livestock health, One Health, tick-borne diseases, tick ecology.

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I. Introduction

Ticks are among the most important arthropod vectors affecting both animal and human health worldwide. As obligate hematophagous ectoparasites, ticks feed on the blood of vertebrate hosts throughout different stages of their life cycle and serve as efficient vectors for a wide variety of bacterial, viral, and protozoan pathogens. Their remarkable adaptability to diverse environmental conditions, broad host range, and long survival under adverse climatic conditions have contributed to their global distribution across tropical, subtropical, and temperate ecosystems. During the last two decades, the geographical expansion of tick populations and the increasing incidence of tick-borne diseases have become major concerns for veterinary medicine, livestock production, biodiversity conservation, and public health. Climate change, agricultural intensification, land-use modification, wildlife movement, and increasing human–animal interactions have collectively accelerated the spread of ticks into previously unaffected regions. Consequently, tick-borne diseases are now recognized among the fastest-growing vector-borne diseases worldwide, creating significant socioeconomic and ecological challenges.

Ticks and tick-borne diseases represent a growing challenge to livestock production, public health, and the sustainability of agricultural ecosystems worldwide. Farmers in tropical, subtropical, and temperate regions experience substantial economic losses from tick infestations in cattle, sheep, goats, buffaloes, horses, and other domesticated animals. Tick infestations directly impair animal health through continuous blood feeding, skin lesions, irritation, stress, reduced feed intake, anemia, decreased body weight, and lowered reproductive efficiency. Heavy infestations frequently reduce milk production, meat quality, wool yield, leather quality, and overall livestock productivity, thereby affecting farm profitability and food security. More importantly, ticks transmit numerous pathogenic microorganisms responsible for economically important diseases including babesiosis, anaplasmosis, theileriosis, ehrlichiosis, Lyme disease, Rocky Mountain spotted fever, tick-borne encephalitis, and Crimean–Congo hemorrhagic fever. These infections increase morbidity and mortality among livestock populations, elevate veterinary treatment costs, reduce reproductive performance, and impose substantial financial burdens on farmers and national agricultural economies [1], [2].

The public health significance of tick-borne diseases has also increased considerably over recent decades. Agricultural workers, veterinarians, livestock handlers, wildlife professionals, forestry personnel, and rural communities frequently encounter infected ticks while handling animals or working in agricultural landscapes. Human infections occur through direct tick bites or through increased exposure to infected livestock and wildlife reservoirs. Several zoonotic pathogens transmitted by ticks have emerged as important causes of febrile illness, neurological disorders, hemorrhagic fever, and chronic inflammatory diseases in humans. The expansion of agriculture into forested landscapes, combined with increased recreational activities in rural environments, has further increased opportunities for human exposure to infected ticks. Consequently, tick-borne diseases should no longer be considered exclusively veterinary problems but rather complex One Health issues involving interconnected relationships among humans, domestic animals, wildlife, vectors, pathogens, and environmental systems [3].

The ecology of tick populations is highly dynamic and influenced by numerous biological and environmental factors. Unlike many insect vectors, ticks spend a significant proportion of their life cycle in the external environment, where temperature, humidity, vegetation structure, soil moisture, and host availability determine their survival and reproductive success. Agricultural ecosystems provide diverse habitats that may either promote or suppress tick populations depending on management practices. Farming activities modify vegetation composition, alter microclimatic conditions, influence host density, and reshape ecological interactions among livestock, wildlife, and pathogens. Consequently, agricultural management has emerged as one of the most influential determinants of tick population ecology and disease transmission dynamics.

Irrigation practices represent another important agricultural factor influencing tick ecology. Increased irrigation enhances soil moisture, stimulates vegetation growth, and creates humid microhabitats favorable for tick survival during vulnerable developmental stages. Moist environments reduce desiccation stress experienced by eggs, larvae, nymphs, and adult ticks, thereby increasing survival rates and extending seasonal activity periods. Conversely, poorly managed irrigation systems may create environmental conditions that facilitate rapid expansion of tick populations into previously unsuitable habitats. Seasonal rainfall patterns further interact with irrigation practices by modifying vegetation productivity, pasture quality, and host movement, ultimately influencing disease transmission risk within agricultural landscapes.

Vegetation management also plays a significant role in determining tick habitat suitability. Tall grasses, shrubs, forest edges, leaf litter, and dense vegetation provide ideal questing sites where ticks attach to passing hosts. Agricultural practices such as

mowing, controlled burning, pasture renovation, mechanical vegetation removal, and herbicide application alter vegetation structure and consequently affect tick survival. Proper pasture management can reduce shaded humid habitats required by ticks, whereas neglected vegetation often supports higher tick densities. However, excessive vegetation removal may simultaneously reduce biodiversity and disrupt ecological interactions that naturally regulate tick populations. Therefore, balancing vegetation management with ecological sustainability remains an important consideration in integrated tick control programs.

Land-use change associated with agricultural expansion has profoundly transformed tick ecology worldwide. Conversion of forests into cropland, grazing land, or plantations alters wildlife communities, host diversity, and landscape connectivity. Habitat fragmentation frequently increases interactions among wildlife reservoirs, livestock, humans, and tick vectors. Many wildlife species, including deer, rodents, wild boars, and birds, serve as competent hosts for immature ticks and reservoirs for various pathogens. Agricultural encroachment into natural habitats therefore creates ecological interfaces where pathogen transmission among wildlife, domestic animals, and humans becomes increasingly likely. Such environmental changes contribute not only to increased tick abundance but also to the emergence of novel disease transmission cycles.

Climate variability further complicates the relationship between agricultural practices and tick population ecology. Rising global temperatures, altered rainfall patterns, prolonged droughts, changing humidity levels, and increasing frequency of extreme weather events directly influence tick development, survival, seasonal activity, and geographic distribution. Warmer temperatures accelerate developmental rates and expand suitable habitats toward higher altitudes and latitudes, whereas adequate humidity remains essential for preventing tick desiccation. Agricultural management practices interact with climatic conditions by modifying local microclimates through irrigation, vegetation cover, soil management, and landscape configuration. Consequently, agricultural landscapes should be understood as dynamic ecological systems where environmental conditions and management decisions jointly determine tick population dynamics and disease transmission potential [6].

The extensive use of chemical acaricides has historically represented the primary approach for controlling tick infestations in livestock. While acaricides can rapidly reduce tick populations, their long-term effectiveness has been compromised by the widespread emergence of acaricide-resistant tick populations. Repeated and indiscriminate application of chemical treatments exerts strong selective pressure, enabling resistant individuals to survive and reproduce. Additionally, chemical residues may contaminate soil, water, and agricultural products, affecting environmental quality and non-target organisms. Increasing concerns regarding resistance development, environmental contamination, and food safety have stimulated interest in integrated tick management approaches that combine biological control, pasture management, host resistance, vaccination, and precision livestock farming technologies.

Despite growing awareness of tick-borne diseases, significant research gaps remain regarding the combined influence of agricultural practices on tick ecology and pathogen transmission. Existing investigations frequently examine livestock density, climate change, wildlife abundance, land-use change, or acaricide application as independent variables. However, tick populations emerge from complex interactions among environmental conditions, host communities, pathogen ecology, farm-management decisions, and socioeconomic factors. The relative contribution of each agricultural practice often varies according to geographical region, farming system, climatic conditions, and tick species. Consequently, isolated analyses may fail to capture the multidimensional ecological processes governing tick abundance and disease emergence [6].

Current evidence also demonstrates considerable geographical imbalance. Most ecological studies have focused on commercial livestock enterprises and well-resourced farming systems in developed countries, whereas relatively limited information exists for smallholder farms, mixed crop–livestock systems, pastoral communities, and resource-constrained agricultural environments. This limitation is particularly important in developing countries such as India, where climatic diversity, fragmented landholdings, seasonal livestock migration, inadequate veterinary infrastructure, inconsistent surveillance systems, and heterogeneous farm-management practices complicate effective tick control. Indigenous livestock breeds, traditional grazing systems, and close interactions between domestic animals and wildlife further increase ecological complexity. Comprehensive region-specific investigations are therefore essential for designing sustainable disease-control strategies suitable for local agricultural conditions [7].

II. Review of Literature

Ticks are obligate blood-feeding ectoparasites whose geographical distribution and seasonal activity depend on temperature, humidity, vegetation, host availability, and land-use patterns. Agricultural activities alter these ecological

conditions by changing vegetation structure, soil moisture, wildlife habitats, and livestock density. Irrigation and dense vegetation can provide humid microhabitats that protect ticks from desiccation, while intensive grazing ensures the regular availability of animal hosts. Tick host-seeking behaviour is additionally regulated by chemosensory mechanisms that allow ticks to detect carbon dioxide, odours, body heat, and other host-related signals [9]. Understanding these behavioural and ecological mechanisms is important for explaining why tick populations become concentrated in particular grazing areas, vegetation types, and livestock-production systems. Climate and land-use changes can also expand the geographical range and seasonal activity of ticks. Such changes may expose livestock and human populations to tick species and pathogens that were previously absent or uncommon. Ye et al. explained that the emergence and transmission of tick-borne viruses are influenced by climatic conditions, host movement, ecological disturbance, vector distribution, and interactions among wildlife, livestock, and humans [10]. Therefore, monitoring tick populations in agricultural landscapes is necessary for both veterinary disease prevention and the early detection of emerging zoonotic threats.

Ticks transmit a wide range of viral, bacterial, and protozoan pathogens. Important tick-borne diseases include babesiosis, theileriosis, anaplasmosis, ehrlichiosis, Lyme disease, rickettsiosis, tick-borne encephalitis, and Crimean–Congo hemorrhagic fever. Tick-borne viruses are of particular concern because several can cause severe neurological or haemorrhagic disease, while limited vaccines and therapeutic options are available for many infections [11]. Their transmission involves complex relationships among tick species, wildlife reservoirs, domesticated animals, humans, and environmental conditions. Agricultural workers, veterinarians, animal handlers, and rural communities face elevated exposure because of their frequent contact with livestock and tick-infested habitats. Livestock can serve as hosts for ticks and may transport them between farms, pastures, markets, and human settlements. However, the detection of emerging tick-borne diseases is often delayed by nonspecific clinical symptoms, inadequate diagnostic capacity, and fragmented reporting systems. Ye et al. emphasized the need to combine viral discovery, clinical surveillance, ecological investigation, and vector-control research to understand and manage emerging tick-borne viruses [12].

Conventional tick surveillance usually concentrates on either human disease, animal infections, or environmental vector distribution. This separation can prevent the timely identification of connections among infected ticks, wildlife reservoirs, livestock cases, and human exposure. A One Health approach addresses this limitation by integrating medical, veterinary, entomological, ecological, and public-health information. Johnson et al. demonstrated the value of collaborative surveillance for identifying tick species and tick-borne pathogens and for improving communication among animal-health and public-health stakeholders [9]. One Health surveillance may incorporate tick samples collected from humans, livestock, companion animals, wildlife, and vegetation. The resulting data can be combined with climatic, land-use, and animal-movement information to identify emerging hotspots and changing disease risks. Community reporting and participation by veterinarians, farmers, healthcare workers, and diagnostic laboratories can expand the spatial coverage of surveillance programmes [13]. Nevertheless, differences in sampling protocols, diagnostic techniques, data ownership, and reporting standards continue to limit integration. Long-term surveillance is therefore required to distinguish persistent ecological changes from temporary seasonal fluctuations.

Biological control methods use natural enemies, pathogenic fungi, bacteria, plant-derived compounds, or other biologically active agents to suppress tick populations. These methods can reduce chemical dependence, although their field performance may be affected by temperature, humidity, formulation stability, and application procedures [14]. Physical methods include manual removal, pasture modification, habitat cleaning, fencing, and controlled grazing. While environmentally safer, they can be labour-intensive and may be insufficient when applied independently in areas with heavy infestation. The relative effectiveness of each strategy therefore depends on the agricultural system, target tick species, climate, cost, and farmer capacity. Integrated tick management combines compatible chemical, biological, physical, genetic, ecological, and managerial interventions. Its purpose is not necessarily to eliminate every tick but to maintain infestation and pathogen-transmission risks below economically and epidemiologically damaging levels. Makwarela et al. emphasized that integrated management can improve control effectiveness while reducing selection pressure for acaricide resistance [15]. Relevant measures include strategic acaricide treatment, pasture rotation, resistant livestock breeds, biological agents, animal inspection, quarantine, farmer education, and regular surveillance [16].

III. Research Methodology and Ecological Assessment Framework

The study adopts a multidisciplinary methodology to evaluate how agricultural practices influence tick abundance, ecological distribution, and tick-borne disease transmission. The proposed framework integrates field-based tick surveillance, livestock

examination, pathogen detection, environmental monitoring, farm-management surveys, and spatial analysis. Agricultural systems are compared across seasons to identify the management and environmental factors associated with increased or reduced tick-related risks.

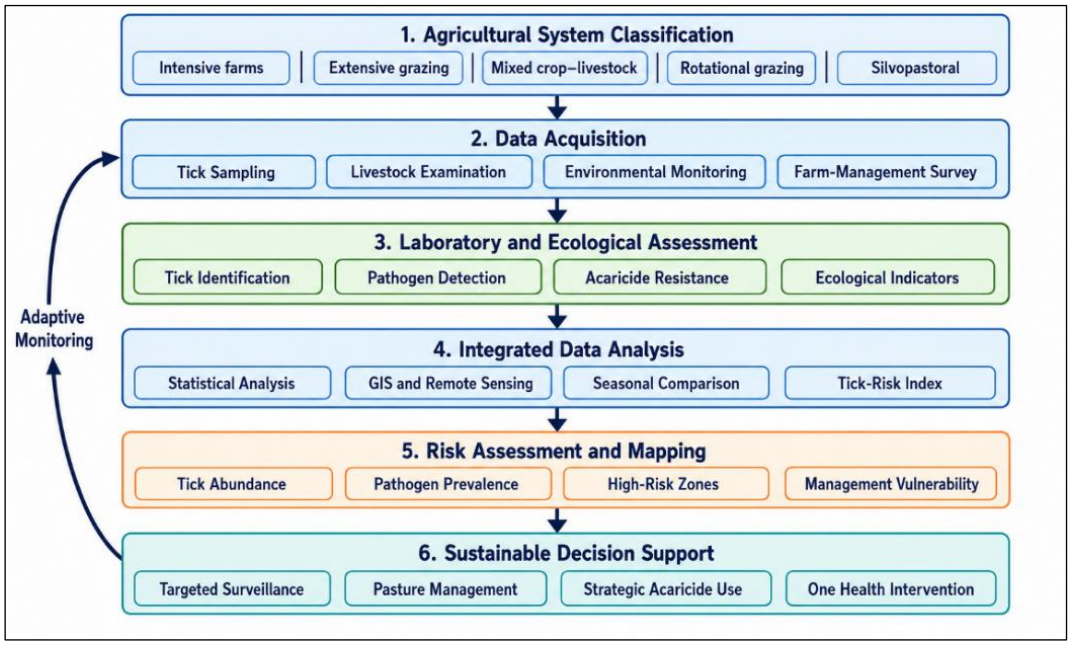


Figure 1. Integrated Ecological Assessment Framework

Figure 1 shows the framework that connects agricultural-system classification, field data acquisition, laboratory assessment, integrated analysis, risk mapping, and sustainable decision support. Adaptive monitoring provides continuous feedback for improving surveillance and management strategies.

A. Study-Area Selection and Agricultural-System Classification

Representative study locations are selected from regions with documented livestock farming and seasonal tick activity. The selected farms are classified according to production type, including intensive livestock farms, extensive grazing systems, mixed crop–livestock farms, rotational grazing systems, and silvopastoral farms. Farms are further categorized according to herd size, livestock density, grazing duration, pasture-rest period, vegetation cover, irrigation intensity, animal movement, wildlife accessibility, and acaricide-use frequency. Sampling locations include grazing fields, livestock shelters, watering points, feeding areas, field margins, irrigated zones, woodland boundaries, and wildlife–livestock contact sites. Geographic coordinates are recorded for each sampling point. Data are collected during pre-monsoon, monsoon, post-monsoon, and dry seasons to account for temporal variation in temperature, humidity, rainfall, vegetation, and tick activity.

B. Tick Sampling, Identification, and Population Assessment

Ticks are collected from both livestock and the surrounding environment. Animal-based sampling involves the systematic examination of major attachment sites, including the ears, neck, dewlap, udder, groin, tail, and spaces between the legs. The number of ticks per animal is recorded according to species, life stage, sex, and degree of engorgement. Environmental sampling is performed using drag-cloth and flagging techniques across predefined transects. Additional collections are conducted around sheds, fences, pasture edges, water sources, and shaded vegetation. Collected specimens are preserved, labelled, and transported to the laboratory. Tick species are identified using morphological keys and, where required, molecular markers. Population characteristics are measured using tick prevalence, mean tick burden, tick density, species richness, and seasonal abundance. Tick prevalence is calculated as

$$TP = \frac{N_i}{N_e} \times 100,$$

where $N_i$represents the number of infested animals and $N_e$represents the total number of examined animals. Mean tick burden is calculated by dividing the total number of ticks collected by the number of examined animals.

C. Detection of Tick-Borne Pathogens

Ticks are grouped into pools according to species, life stage, host, farm, and sampling location. DNA or RNA is extracted from individual ticks or pooled samples using standardized laboratory procedures. Polymerase chain reaction, quantitative PCR,

reverse-transcription PCR, and sequencing techniques are employed to detect bacterial, protozoan, and viral pathogens. Target pathogens may include Anaplasma, Babesia, Theileria, Ehrlichia, Rickettsia, Borrelia, and regionally relevant tick-borne viruses. Blood samples from selected livestock are also analysed to determine active or previous infections. Pathogen prevalence is estimated as

$$PP = \frac{N_p}{N_t} \times 100,$$

where $N_p$is the number of pathogen-positive samples and $N_t$is the total number of samples tested. The results are compared with tick burden, disease symptoms, farming practices, and environmental conditions to identify potential transmission relationships.

D. Agricultural, Environmental, and Management Data Collection

Farm-management information is collected using structured questionnaires, direct observation, and farm records. Variables include livestock species, breed, herd size, stocking density, grazing system, grazing duration, pasture rotation, irrigation, vegetation management, animal introduction, quarantine, acaricide type, treatment frequency, dosage, and reported treatment failure. Environmental variables include temperature, relative humidity, rainfall, soil moisture, vegetation height, canopy cover, distance from livestock sheds, proximity to water, and surrounding land use. Portable sensors and nearby meteorological records are used for climatic monitoring. Satellite imagery and remote-sensing data are employed to estimate vegetation indices, surface temperature, moisture conditions, and landscape fragmentation.

E. Ecological and Epidemiological Performance Indicators

The framework evaluates farms using ecological, epidemiological, management, and sustainability indicators. Ecological indicators include tick density, species diversity, seasonal persistence, vegetation suitability, and wildlife-host accessibility. Epidemiological indicators include pathogen prevalence, livestock disease incidence, human-exposure potential, and the frequency of co-infection. Management indicators include acaricide-use intensity, pasture-rest duration, quarantine compliance, surveillance frequency, and farmer awareness.

A composite tick-risk index is calculated as

$$TRI = w_1 T_d + w_2 P_p + w_3 H_d + w_4 E_s + w_5 M_v,$$

where $T_d$is normalized tick density, $P_p$is pathogen prevalence, $H_d$is host density, $E_s$is environmental suitability, and $M_v$represents management vulnerability. The weights $w_1$to $w_5$are assigned using expert judgement or a multi-criteria decision-making method, with their sum equal to one. Higher index values indicate greater ecological and epidemiological risk.

IV. Results, Comparative Analysis, and Discussion

Comparative analysis was conducted to provide a clear visual interpretation of the relationships among agricultural practices, tick abundance, pathogen prevalence, ecological risk factors, and management performance. The graphs transform the numerical results into comparative visual patterns, allowing differences among farming systems and control strategies to be identified more effectively. Figure 2 compares tick burden, livestock infestation, and pathogen-positive ticks across different agricultural systems. Figure 3 illustrates the prevalence of major tick-borne pathogens in tick and livestock samples. Figure 4 presents the direction and strength of associations between selected agricultural variables and tick abundance. Figure 5 compares the performance of conventional and integrated tick-management approaches across epidemiological, operational, and economic indicators.

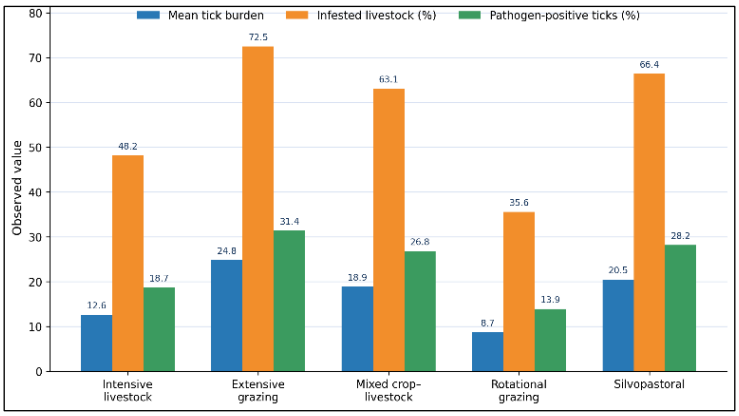


Figure 2: Tick Distribution Across Agricultural Systems

Figure 2 shows extensive grazing recorded the highest tick burden, livestock infestation, and pathogen-positive ticks. Rotational grazing showed the lowest values, indicating that suitable pasture-rest periods can effectively reduce tick populations and disease risk.

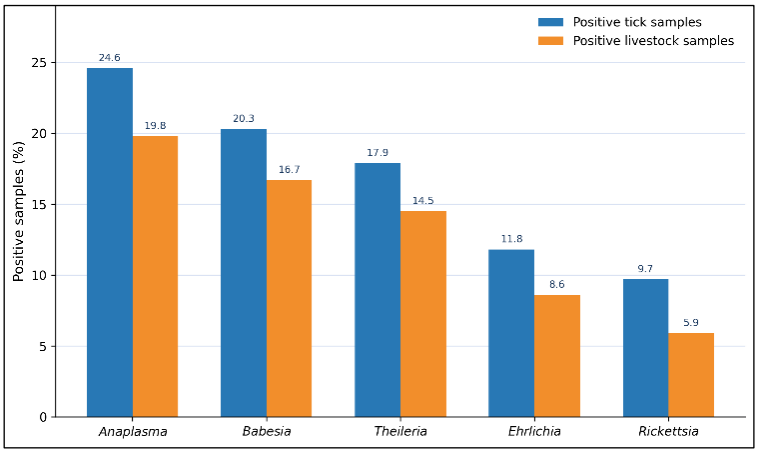


Figure 3: Prevalence of Major Tick-Borne Pathogens

Figure 3 shows that the Anaplasma showed the highest prevalence in both ticks and livestock, followed by Babesia and Theileria. Tick samples consistently recorded higher positivity than livestock samples, indicating potential exposure without confirmed host infection in every case.

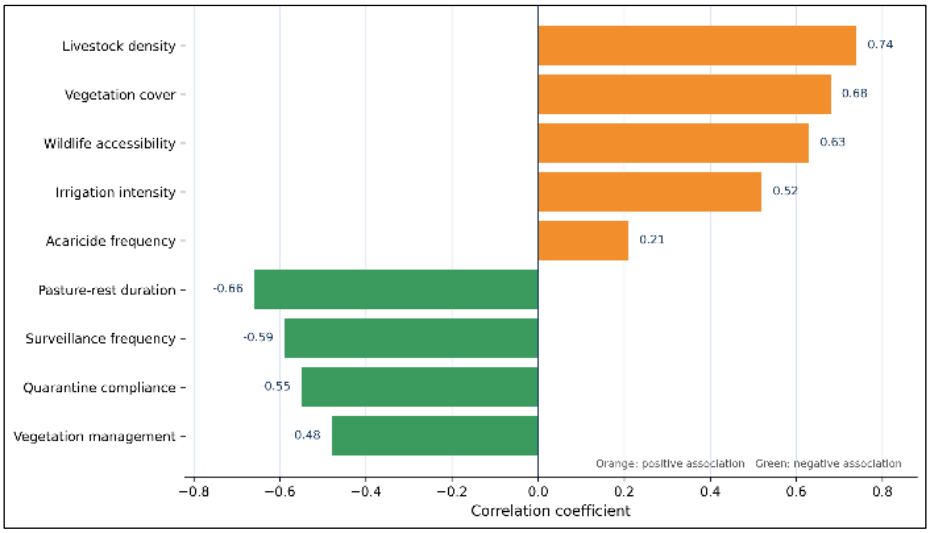


Figure 4: Farming Variables Associated With Tick Abundance

Figure 4 shows that the Livestock density had the strongest positive association with tick abundance, followed by vegetation cover and wildlife accessibility. Pasture-rest duration showed the strongest negative association, suggesting that longer resting periods can substantially suppress tick populations.

V. Conclusion

This study establishes that agricultural practices strongly influence tick ecology and the transmission of tick-borne diseases. High livestock density, continuous grazing, unrestricted animal movement, irrigation, dense vegetation, and wildlife accessibility create favourable conditions for tick survival, reproduction, and pathogen circulation. Conversely, extended pasture-rest periods, livestock quarantine, habitat management, continuous surveillance, and resistance-informed acaricide application can substantially reduce infestation and disease risk. The comparative evaluation demonstrated that integrated tick management reduced mean tick burden by 59.4%, livestock infestation by 49.3%, pathogen-positive ticks by 51.9%, disease incidence by 57.1%, and acaricide applications by 48.5% compared with conventional management. Treatment failure decreased by 62.3%, while relative control costs declined by 24%. These results highlight the ecological, epidemiological, and economic advantages of combining pasture management, strategic chemical treatment, biosecurity, environmental monitoring, and One Health surveillance.

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