

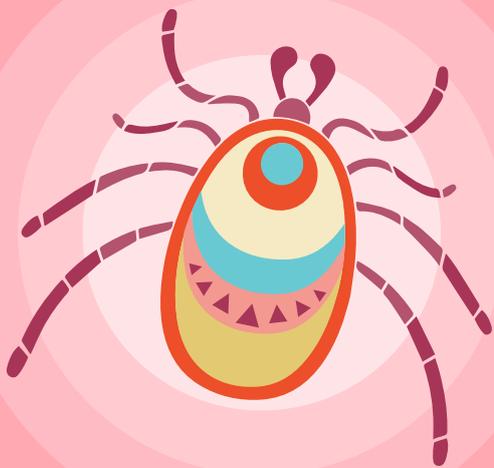


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Guidelines for sustainable tick control and acaricide resistance management in livestock

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Guidelines for sustainable tick control and acaricide resistance management in livestock

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A [Technical documentation](#) providing complementary technical and practical information is included as a supplement.

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Foreword

Parasitism is one of the barriers to achieving profitable and sustainable livestock production. While the global cattle population was estimated to be 1.5 billion in 2022, with the production of cattle meat and milk showing regular and steady growth (Food and Agriculture Organization of the United Nations [FAO], 2023), parasitic diseases continue to impair the health and welfare of livestock and influence the economy and trade of animals and food products.

Among these parasites are ticks. These cause significant losses to livestock production in several ways. Most importantly, ticks transmit pathogens that cause acute and subclinical diseases, which can cause mortality, reduced milk and meat production, depressed manure production and reduced animal draft power. Ticks and tick-borne diseases are found worldwide, especially in tropical and subtropical regions, where they particularly impact the livelihoods of small-scale producers. Models predict that the burden of ticks will increase globally over the coming decades because of climate change, making the issue more pressing (Cumming and Van Vuuren, 2006; Marques *et al.*, 2020; Olwoch *et al.*, 2008).

Most livestock production is supported by antiparasitic drugs, which represent the second-largest global market segment in the animal health industry after vaccines (Selzer and Epe, 2021). Tick control almost entirely depends on commercial synthetic acaricides, with a limited number of compound classes used in various forms on infested animals. The widespread exposure to acaricides aggravated by malpractices in the application, use of substandard products and the lack of implemented strategies to mitigate acaricide resistance have selected resistant strains in tick populations. As a result, the livestock sector is facing a surge in ticks and tick-borne diseases in areas where resistant ticks occur. Resistance in cattle ticks has been reported against almost all acaricidal classes, leading to global economic losses for cattle producers. Along with animal welfare, health risks and production losses, other potential associated effects include food safety concerns related to potential residues, the rising use of antimicrobials, pathogen transmission to humans, user exposure to toxicity, and pollution that impacts ecosystem health and biodiversity. To ensure the effective and sustainable prevention and control of ticks, tick-borne diseases and acaricide resistance, while also securing sustainable livestock production and its potential need for adaptation, a One Health approach is needed.

The current situation is critical. Developing new veterinary pharmaceutical products for animal production is lengthy and costly. In this context, a collective pathway including effective stewardship programmes to reduce overuse and misuse and therefore slow the emergence of resistance is even more essential.

FAO's involvement in the issue of resistance to antiparasitic agents dates back to 1984. In 1997, a permanent FAO working group of experts was established to advise on resistance management and integrated parasite control. In 2004, FAO published guidelines on resistance management and integrated parasite control in ruminants. Since 2004, the number of scientific papers on antiparasitic drug resistance, especially in ticks, has sharply increased, indicating growing interest in and importance of the issue. FAO organized a virtual expert consultation from 9 to 10 November 2021 (FAO, 2022a; FAO 2022b) on the sustainable management of parasites in livestock challenged by the global emergence of resistance. This highlighted the worrying situation and the need to consider this issue a priority area of work. Following the recommendations from this virtual expert consultation, a core group of international experts was set up to develop updated guidelines for sustainable tick control and acaricide resistance management in livestock with the aim of globally aligning recommendations. Similarly, the World Health Organization (WHO) and World Organisation for Animal Health (WOAH) published recommendations in combating insecticide and anthelmintic resistance, respectively. As well, a FAO community of practice on acaricide resistance management for livestock ticks was established in 2023. This is an inclusive, international community that brings together relevant stakeholders across sectors and disciplines to build consensus and promote a shared vision through a One Health approach. It contributes to implementing integrated tick and acaricide resistance management in livestock and supporting the development of these guidelines.

We hope these guidelines will be useful to as many stakeholders as possible to support farmers and communities affected by cattle ticks. They should especially support the work of consultants, veterinarians, animal health workers, veterinary pharmaceutical sales and technical staff, and government officers. We trust that these guidelines will guide everyone's work and encourage cooperation between all stakeholders involved to co-develop economically, socially and environmentally sustainable solutions that strengthen the efficiency and resilience of agrifood systems.

Abbreviations

AChE	acetylcholine esterase
ADI	acceptable daily intake
AGR	acarine growth regulator
AIT	adult immersion test
AMT	amitraz
API	active pharmaceutical ingredient
AR	acaricide resistance
BW	bodyweight
CFTEP	Cattle Fever Tick Eradication Program
Codex	Codex Alimentarius
CVMP	Committee for Veterinary Medicinal Products
EC	emulsifiable concentrate
EMA	European Medicines Agency
EPF	entomopathogenic fungi
EPMAR	European public maximum residue limit assessment report
EPN	entomopathogenic nematode
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FIP	fipronil
FLU	fluazuron
GABA	gamma-aminobutyric acid
GluCl	glutamate-gated chloride channel
GST	glutathione S-transferase
IPM or ITM	integrated pest or tick management
IRAC	Insecticide Resistance Action Committee
IZ	isoxazolines
JECFA	Joint FAO/WHO Expert Committee on Food Additives
Kdr	knock-down resistance
LC50	lethal concentration 50 percent
LIT	larval immersion test
LMIC	low and middle-income countries
LPT	larval packet test
LTT	larval tarsal test
LU	livestock unit
MA	marketing authorization
M&E	monitoring and evaluation
ML	macrocyclic lactones
m-LIT	microcentrifuge tubes-larval immersion test
MoA	mode of action
MRL	maximum residue limit
OC	organochlorines
OECD/ISO	Organisation for Economic Co-operation and Development/ International Organization for Standardization
OP	organophosphates
OTC	over the counter
PBO	piperonyl butoxide
PMD	p-menthane-3,8-diol

R&D	Research and development
RIT	resistance intensity test
SIT	syringe immersion test
SP	synthetic pyrethroid
SPC	summary of product characteristics
spp.	species
TBD	tick-borne diseases
TTBD	ticks and tick-borne diseases
USD	United States dollar
VICH	International Cooperation on Harmonisation of Technical Requirements for Registration of Veterinary Medicinal Products
VMP	veterinary medicinal product
WAAVP	World Association for the Advancement of Veterinary Parasitology
WAEMU/UEMOA	West African Economic and Monetary Union/Union Economique et Monétaire Ouest Africaine
WHO	World Health Organization
WOAH	World Organisation for Animal Health
WP	withdrawal period

Glossary

Acaricide

A synthetic chemical compound that kills members of the class Arachnida subclass Acari, which includes ticks and mites.

Acaricide product

An approved commercially available formulation of an acaricide that may be classified as a veterinary medicinal product, veterinary pesticide, ectoparasiticide or insecticide, depending on different regional/national regulations. The terms acaricide and acaricide products will be used interchangeably.

Acaricide class rotation

Rotation or alternation among or between acaricide chemical classes over time intended to delay the development of resistance.

Acaricide efficacy

Efficacy of a product in controlling a pre-existing infestation or the ability of the product to prevent new infestations. The efficacy of an acaricide against ticks is estimated from the reduction of tick infestation *in vivo*, engorged female fecundity and fertility of eggs.

Acaricide residual effect

The period after the application of the acaricide in which there is persistence of the acaricidal effect.

Acaricide resistance

Heritable change in the susceptibility of a tick population that is reflected in the repeated failure of an active ingredient to achieve the expected level of control when used at the recommended dosages as per the label recommendations for its use.

Access

All processes from manufacturing to registration, import, delivery, and product sales to the end user. Market access refers to the ability of a company to access and compete in a specific market as well as the user to reach an acaricide product. It involves the elimination of barriers to trade such as tariffs, quotas and other regulatory and distribution restrictions that limit access to a particular market.

Behavioural barriers

Factors such as beliefs, attitudes or habits that prevent individuals from adopting or adhering to desirable behaviours. These barriers can be conscious or unconscious and may arise from a range of cultural, social or environmental factors.

Behaviour change

A broad concept that includes any effort to change behaviour and often involves giving people the information necessary to modify their attitudes and decisions.

Behavioural insights

Knowledge obtained from applying behavioural science to gain an accurate and evidence-based understanding of how people behave and make decisions.

Behavioural science

The evidence-based study of how people behave, make decisions and respond to context could include programmes, policies, administrative processes, and incentives.

Bio-assay

Experiment in which a living organism is used as a test subject. When a stimulus is applied, the organism responds and the bio-assay provides the means to quantify the response. In the context of acaricide resistance evaluation, bio-assay can be defined as an experiment in which live ticks (adults or immature stages) are exposed to an acaricide to quantify the response: mortality or reproductive performance.

Biocides

Biocides are chemical substances or microorganisms intended to destroy, repel, render harmless, or control any harmful organism, including bacteria, viruses, fungi, algae and arthropods.

Biological control (biocontrol)

Method of controlling pests, such as insects and mites, by using other living organisms (natural enemies).

Biological product

Medicinal product in which the active ingredient is a biological substance: a substance that is produced by or extracted from a biological source. Biological products are diverse, but generally large, complex molecules. These products are derived from plants, nematodes, bacteria, protozoa, fungi and viruses and used to damage, kill or repel veterinary and agricultural pests.

Cognitive biases

These are systematic cognitive patterns of deviation from logic, probability reasoning and plausibility. These intuitive and subconscious tendencies are at the basis of human judgment, decision-making and, ultimately, actions.

Competent authority

A governmental authority of a country having the responsibility in whole or part of the territory for the implementation of specific rules and standards, particularly those set by legislation.

Cross-resistance

Cross-resistance is defined as resistance to one acaricide by a mechanism that also confers resistance to a second acaricide (typically, but not always, in the same chemical group), even when the tick population has not been subject to exposure to the latter.

Discriminating dose

The concentration of a given acaricide used in a bio-assay to discriminate between a resistant and a susceptible population: some individuals from the resistant population will survive exposure to this concentration, but no individuals of the susceptible population are expected to survive this exposure.

Drug manufacturer

A drug/pharmaceutical manufacturer is a company or organization that is involved in the production, development, and sale of pharmaceutical products, including prescription drugs, over-the-counter drugs, and vaccines. Drug manufacturers are responsible for all aspects of drug development, from pre-clinical research and clinical trials to manufacturing and distribution. This definition includes companies that market and distribute pharmaceutical products to veterinarians or end users.

Drug label

A drug/pharmaceutical label is a document attached to an acaricide, usually on the bottle or box, that contains essential information about the proper use, storage and disposal of the drug. It is an essential component of any medication.

Economic threshold

It is the burden of ticks at which the economic losses arising from the infestation are equal to the costs control methods. It implies an acceptable level of tick infestation below which treatment is not profitable.

Education

Education is a process of teaching, training or learning that improves knowledge and critical thinking, fosters skills and promotes proper decision-making. It also refers to the transmission of a society's values and accumulated knowledge.

Endemic stability

Endemic stability refers to the consistent presence of a particular disease or parasite within a population over time without causing significant fluctuations in the prevalence or severity of the infection. This principle mainly applies to cattle challenged by ticks infected by *Babesia* species.

Generic drug/pharmaceutical

Veterinary medicinal product that is identical or of the same pharmaceutical form and demonstrated to be bioequivalent as an already marketed reference products.

Genomics

The branch of biotechnology concerned with the structure, function, evolution and mapping of genomes.

Good manufacturing practice

A production and testing practice recognized by a competent authority to ensure the quality of a product: a set of guidelines and regulations designed to ensure that pharmaceutical products, including drugs, vaccines, and medical devices, are manufactured, packaged, labelled and distributed in a consistent and controlled manner.

Good practice

A recommended working method that has been proven to produce reliable results.

Grassland-based system

A system in which more than 10 percent of the dry matter fed to animals is farm-produced and in which annual average stocking rates are less than ten livestock units per hectare of agricultural land.

Guidelines

A document produced by a panel of experts or consortia that recommends methodology and record keeping facilitating authorization/registration or instruct different stakeholders in their decision-making process. These documents may also aim to achieve harmonization across countries.

Implementation

The process of putting a decision or plan into effect.

Implementation barrier

An obstacle that prevents or limits the execution of a decision or plan. Common implementation barriers include lack of awareness and technical capacity to understand or address a problem, lack of an enabling policy environment, and factors related to sustained implementation (i.e. consistent funding mechanisms/technical support).

Immunological veterinary medicinal product

Veterinary medicinal product intended to be administered to an animal to induce active or passive immunity or to assess its state of immunity.

Innovation

The development and translation of novel solutions for existing problems.

Integrated pest or tick management

An approach to managing pests or ticks that uses combinations of complementary control measures to reduce the requirement for conventional synthetic acaricide while sustaining animal health and productivity.

Landless livestock production system

A system in which less than 10 percent of the dry matter fed to animals is farm-produced and in which annual average stocking rates are above ten livestock units per hectare of agricultural land.

Livestock unit

A reference unit that indicates the intensity of land use by grazing herbivores, one livestock unit is the grazing equivalent of one adult dairy cow producing 3,000 kg of milk annually without additional concentrate feeds. One livestock unit is also the grazing equivalent of 10 sheep or goats.

Marketing authorization

This refers to the process by which a government regulatory agency grants permission for a product or service to be sold in the marketplace. This process typically involves a thorough review of the product or service to ensure that it meets safety, quality and efficacy standards and any other regulatory requirements.

Mechanisms of resistance

Resistance to acaricides arises through a natural selection process in a tick population that favours tick survival through the following mechanisms including modifications at the target site, increased detoxification of the acaricide, and/or reduced ability of the acaricide to penetrate and reach its target site.

Minimum effective concentration

Minimum effective concentration is the minimum concentration of a drug required to produce a desired therapeutic effect.

Mitigation

Actions targeted to overcome/control the negative impact of any event or phenomenon.

Multiple resistance

Multiple resistance occurs when ticks develop resistance to two or more compounds from different chemical groups.

Non-chemical control practices

These include any interventions intended to control ticks that do not involve acaricides, such as continuous or rotational grazing strategies and biological control agents.

One Health approach

One Health is an integrated, unifying approach that aims to balance and optimize the health of people, animals and ecosystems in a sustainable manner. It recognizes that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilizes multiple sectors, disciplines, and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for clean water, energy and air, safe and nutritious food, acting on climate change and contributing to sustainable development.

Over the counter

Over-the-counter drugs are medications that can be purchased without a prescription.

On prescription

Prescription drugs are medications that can only be obtained with a prescription from a licensed health-care provider, such as a veterinarian or a veterinary paraprofessional.

Pesticide

Any substance or mixture of substances that prevents, kills or controls an organism that is considered a pest to human interests.

Pharmacovigilance

Science and activities relating to detecting, assessing, understanding, and preventing adverse events or any other medicine/vaccine-related problem (including loss of efficacy). In practice, it refers to a (centralized) monitoring system of the effect of medical drugs after they have been licensed for use, especially to identify and evaluate previously unreported adverse reactions.

Point-of-care testing

Refers to medical diagnostic tests that are performed at or near the patient's location, rather than at a centralized laboratory. These tests are designed to provide rapid results that can be used for immediate clinical decision-making.

Production systems

Any of the methods used in industry to create goods and services from various resources. The cattle production system is the way in which a farmer makes use of available resources to breed new cattle or to grow or finish young cattle.

Refugia

Ticks in refugia are those not exposed to acaricide when cattle are treated. Most ticks in refugia are in the pasture, with those on animals usually representing a tiny proportion of the total farm population. In theory, larger refugia should delay the emergence of resistance to acaricides applied to cattle.

Regulatory authority

A body that carries out regulatory activities relating to medicines, including the processing of marketing authorizations, the monitoring of side effects, inspections, quality testing and monitoring the use of medicines.

Regulatory environment

Regulatory environment refers to the set of laws, regulations and policies that govern the activities of individuals and organizations in a particular industry or sector. It includes the rules and standards set by government agencies and other regulatory bodies to ensure that businesses operate safely, fairly and consistently with public policy objectives.

Re-handling interval

The re-handling interval (also called restricted handling interval) is the minimum amount of time that must pass between the acaricide application and the time that users can re-handle the animal.

Resistance factors or resistance ratios

Estimation of the relative level of phenotypic resistance in a sample of ticks from a field population compared with a fully susceptible reference population. The commonly used RR_{50} is the ratio obtained by dividing the LC_{50} (lethal concentration that kills 50 percent of the population) of the tested populations by the LC_{50} of a susceptible reference strain.

Stakeholders

A stakeholder is any party (person, group or organization) that is directly or indirectly involved in tick control.

Standard operating procedures

Established or prescribed methods to be followed routinely for performance of designated operations or in designated situations, hence in the context of acaricide resistance it can refer to a set of procedures for detection and tactical management of acaricide resistance of field tick population.

Stockists

Include agro and vet dealers, and other local distribution dealers of acaricide products.

Structural barriers

External factors, such as policies, rules, limited access to resources or physical environments, which interfere with or obstruct effective communication and make it difficult for individuals to adopt or adhere to certain behaviours.

Surveillance

Surveillance is the systematic, ongoing collection, collation and analysis of data, and the timely dissemination of information to relevant stakeholders. It can be either active or passive.

Tick control

Reduction of tick burden to an acceptable level because of deliberate efforts; continued interventions are required to maintain the reduction.

Tick elimination/eradication

The elimination of ticks is the complete elimination of all ticks of a targeted species in a defined geographical area because of deliberate efforts; continued interventions and/or biosecurity are required.

The eradication of ticks is the permanent reduction to zero of the worldwide incidence of ticks of a targeted species because of deliberate efforts; intervention measures are no longer needed.

Unauthorized products

Products that do not hold a market authorization.

Veterinary medicinal product

Any substance or combination of substances (human, animal, vegetal, chemical origin) which fulfils at least one of the following conditions:

- (a) It is presented as having properties for treating or preventing disease in animals.
- (b) Its purpose is to be used in, or administered to, animals to restore, correct or modify physiological functions by exerting a pharmacological, immunological or metabolic action.
- (c) Its purpose is to be used in animals to make a medical diagnosis.
- (d) Its purpose is to be used for the euthanasia of animals.

Part 1

Tick infestations in cattle

BIOLOGY OF TICKS

Ticks are obligate, blood-feeding arthropods that parasitize terrestrial vertebrates. Close to 900 tick species have been documented, with approximately 10 percent of those being of veterinary or medical importance. All tick species except one (*Nuttalliella namaqua*) are classified within two families: the Ixodidae (hard ticks) and the Argasidae (soft ticks), based on the outer body shield. The Ixodidae is the most significant numerically (762 species) and as vectors of disease-causing microorganisms (Guglielmone, Nava and Robbins, 2023). Ticks follow a 4-stage life cycle, including an egg and three active stages (larva, nymph, and adult), with sexual dimorphism being discernible only in the adult stage. Depending on the number of hosts required to complete the life cycle, ticks are further classified as 1-host, 2-host, 3-host tick species. Hard ticks complete a single blood meal per stage while soft ticks feed several times on several hosts.

BURDEN OF TICKS, TICK-BORNE DISEASES AND ACARICIDE RESISTANCE

Ticks are present worldwide and particularly frequent in tropical and subtropical regions. They cause significant economic losses to cattle production through direct physical effects and indirectly through pathogens (mainly bacteria, or protozoan parasites) transmitted by the tick's bite that can cause diseases, lack of performance, and mortality (Heylen *et al.*, 2023; Kasaija *et al.*, 2021; Rodríguez-Vivas *et al.*, 2021).

Distribution and importance

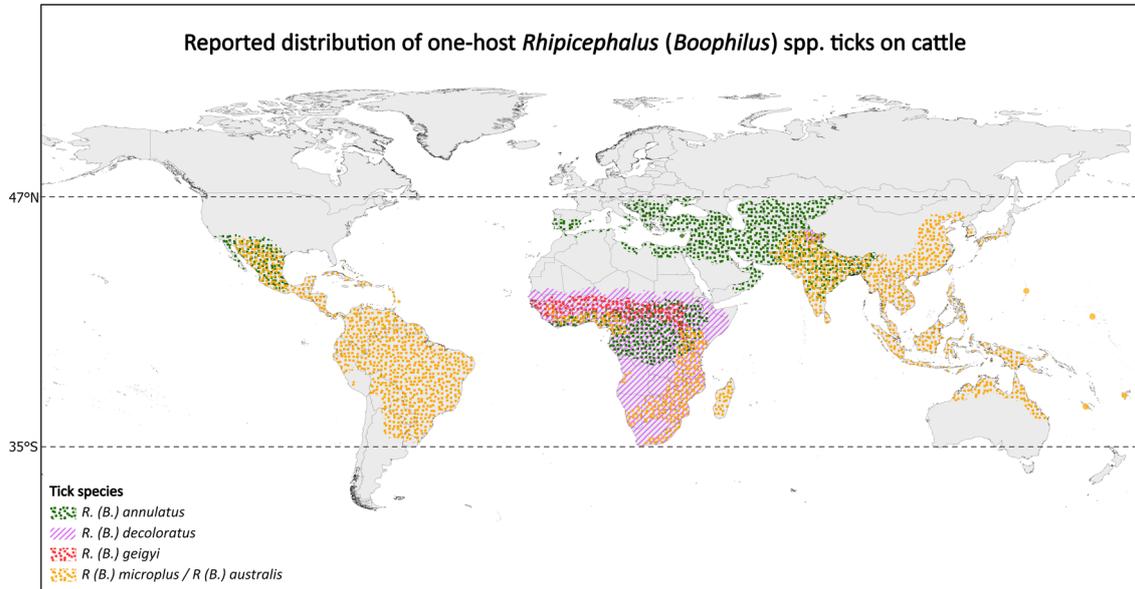
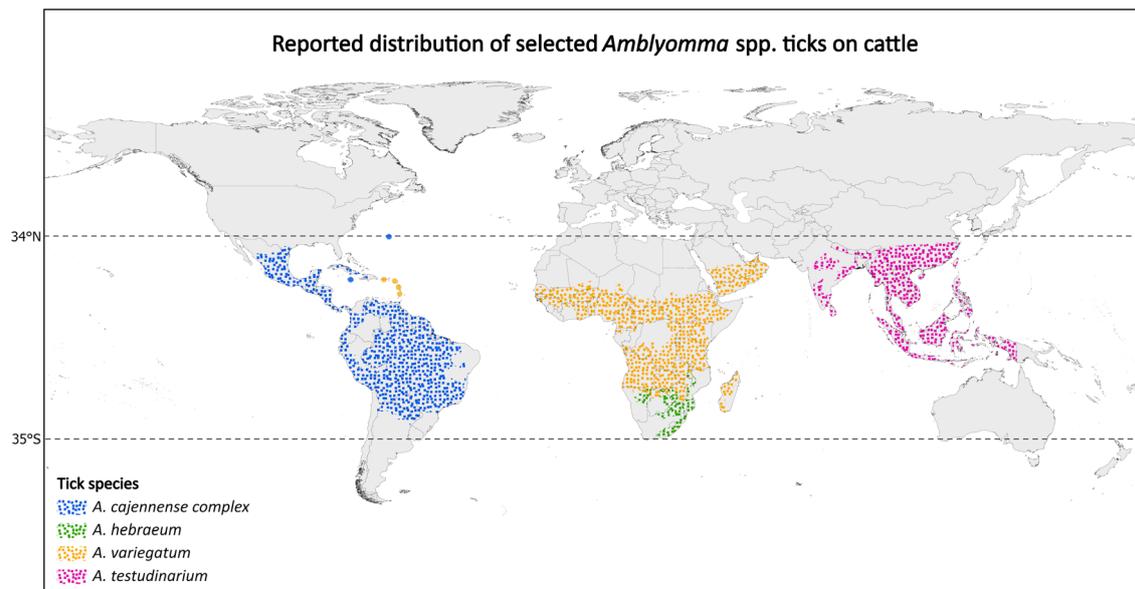
Globally, an estimated 80 percent (i.e. 1.2 billion) of the world's cattle populations are at risk of ticks and tick-borne diseases (TTBD) (de Castro, 1997; Lew-Tabor and Rodriguez Valle, 2016; Nasirian, 2024). Several genera of Ixodidae ticks occur on cattle, including *Amblyomma* spp., *Dermacentor* spp., *Ixodes* spp., *Haemaphysalis* spp., *Hyalomma* spp., one-host *Rhipicephalus* (*Boophilus*) spp., and multi-host *Rhipicephalus* spp. (see Figure 2: Guide for genus level differentiation of major economically important cattle ticks in the [Technical documentation](#), FAO, 2025). The economically most important tick genera are found on cattle worldwide (Figure 1) where distinct tick-pathogen complexes occur (Table 1). Each tick genus and species have a different pattern of distribution and epidemiology and transmit specific disease(s), as well as having variable susceptibility to acaricides.

Global climate change, animal movement and trade and other environmental changes are impacting tick distribution, with a risk of tick species expansion and changes in tick-borne diseases (TBD) epidemiology (Kivaria *et al.*, 2012; Olwoch *et al.*, 2007). The recent introduction of *Rhipicephalus* (*Boophilus*) *microplus* into West Africa, probably by importing live cattle from infested areas (Madder *et al.*, 2007, 2011), and its subsequent rapid expansion, is one example of the threat posed by invasive tick species later favoured by extensive livestock farming systems associated with herd movements (Ouedraogo *et al.*, 2021). The development rates of ticks are governed by temperature and humidity and models predict an increased burden of ticks over the next decades as a result of climate change (Cumming and Van Vuuren, 2006; Marques *et al.*, 2020; Olwoch *et al.*, 2008). *Rhipicephalus* (*B.*) *microplus* is of particular concern because of the suitable environmental conditions for this tick species in most tropical areas worldwide.

FIGURE 1

Distribution mapping of the most economically important tick species in cattle

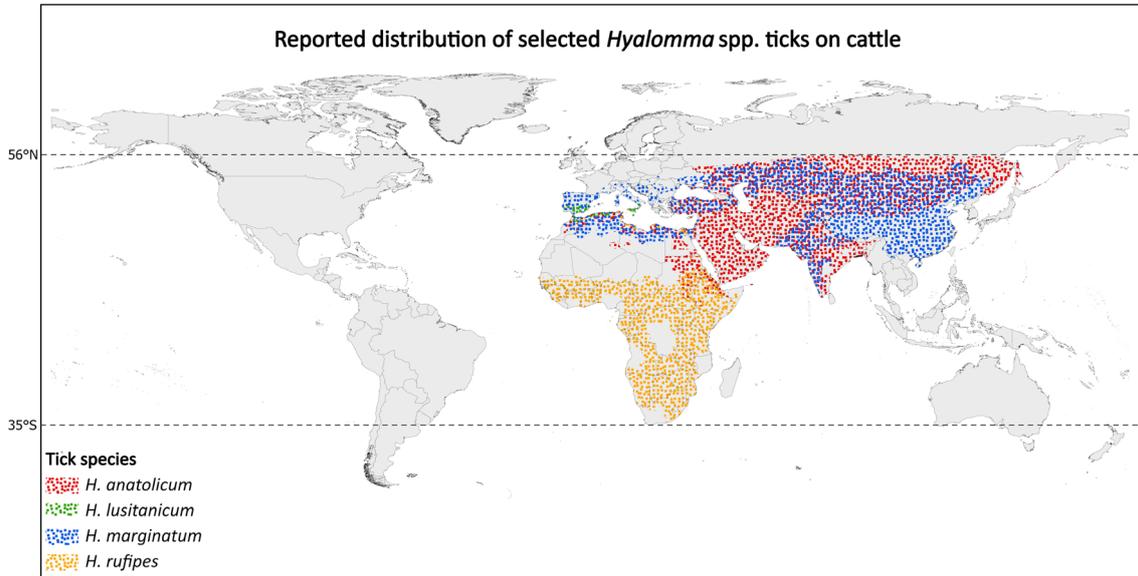
These maps are indicative and do not claim to be exhaustive. The coloured dots do not represent precise locations but are intended to represent the general reported extent of the tick species' distribution.

A) One-host *Rhipicephalus (Boophilus)* spp.**B) *Amblyomma* spp.**

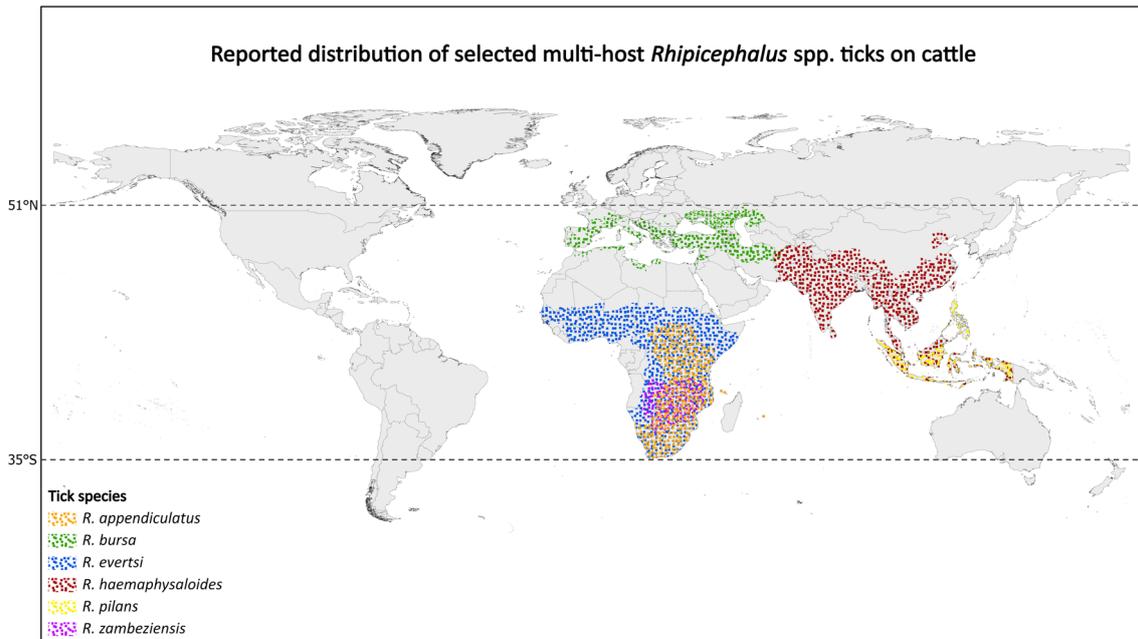
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FIGURE 1 (Continued)
Distribution mapping of the most economically important tick species in cattle

C) *Hyalomma* spp.



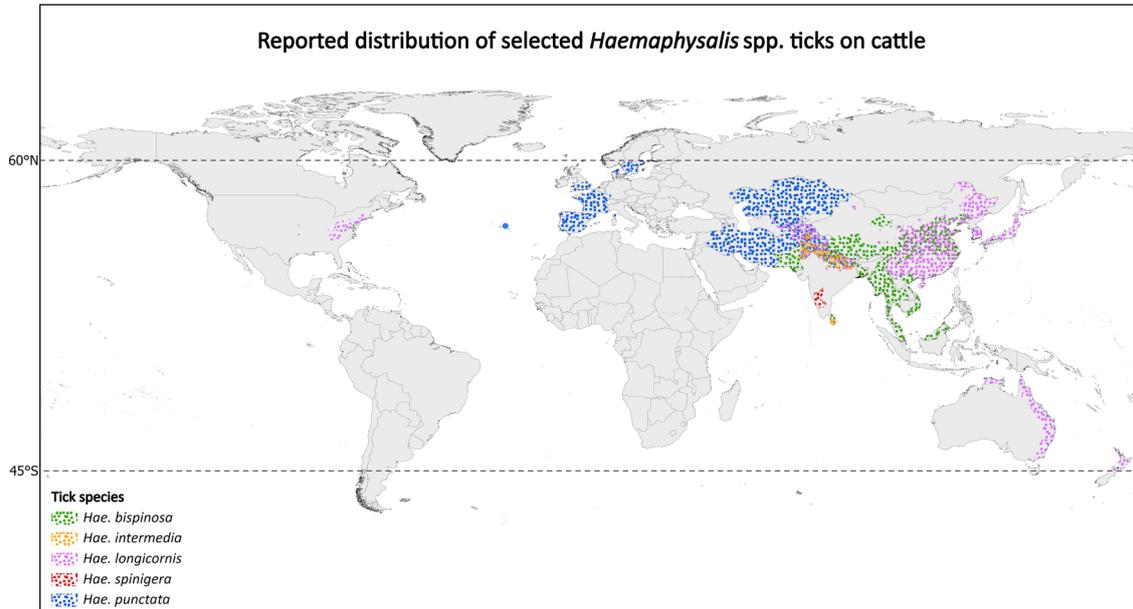
D) Multi-host *Rhipicephalus* spp.



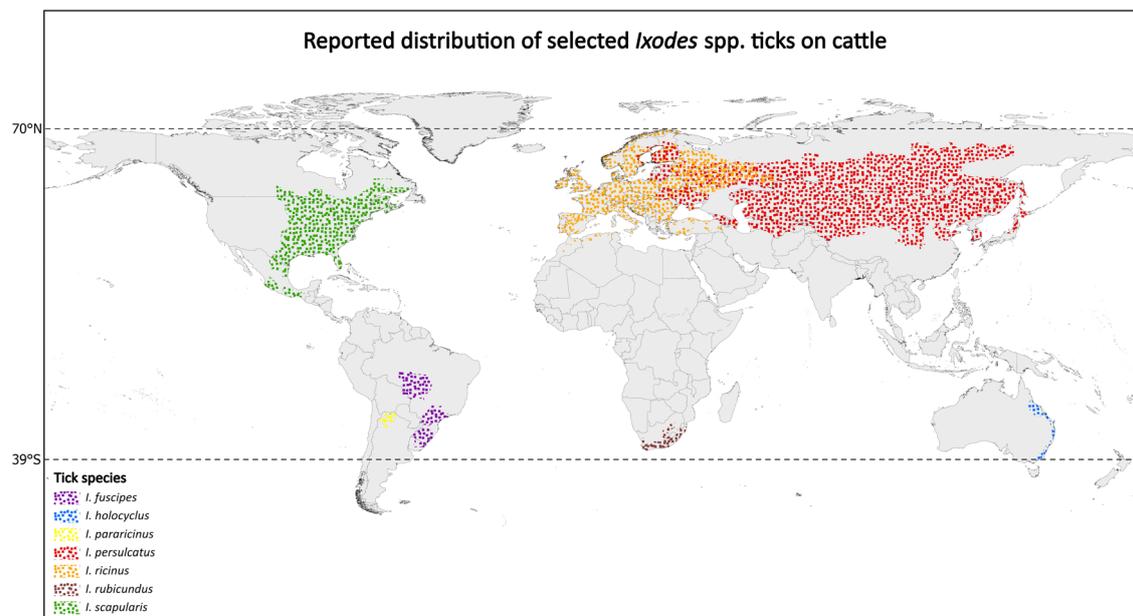
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FIGURE 1 (Continued)
Distribution mapping of the most economically important tick species in cattle

E) *Haemaphysalis* spp.



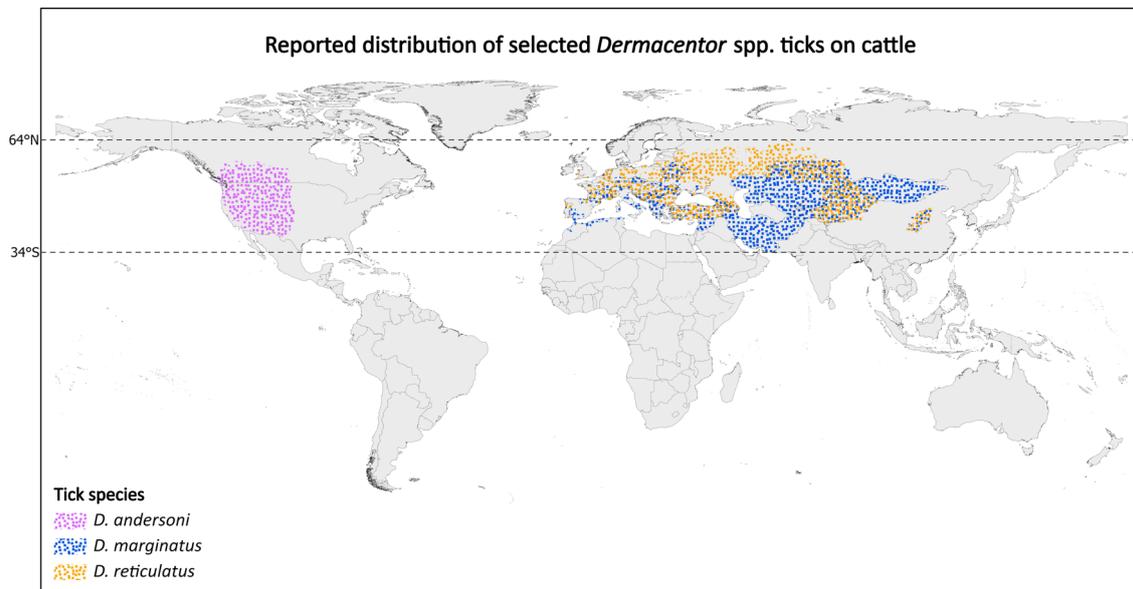
F) *Ixodes* spp.



(Continues)

FIGURE 1 (Continued)
Distribution mapping of the most economically important tick species in cattle

G) *Dermacentor* spp.



Note: Refer to the disclaimer on page ii for the names and boundaries used in this map. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. A dispute exists between the Governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas). Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. Final status of the Abyei area is not yet determined.

Source: Authors' own elaboration based on references obtained according to the methodology described.¹ Country boundaries based on UN Geospatial. 2023. Map of the World. In: *United Nations*. [Cited: 10 October 2024]. <https://www.un.org/geospatial/content/map-world-1>

¹ A combination of a systematic literature search (conducted on 8 February 2024) with expert consultation was used to create tick distribution maps. The systematic literature search used the bibliographic CAB Abstracts database to find articles published between 2003 and 2024. An initial search targeted cattle tick-related literature using terms such as "cattle" and "Metastigmata" as well as variations of "tick control" and "tick infestations", yielding 4,176 results. Subsequently to the systematic review, the search was refined to include only articles with data on tick distribution, employing keywords related to monitoring, surveillance, prevalence and geographical distribution, resulting in 2,132 relevant articles. Data on the spatial distribution of the tick species of interest were extracted and grouped by genus (*Amblyomma*, *Rhipicephalus* [*Boophilus*], *Hyalomma*, and *Rhipicephalus*) using ChatGPT 4.0, followed by a manual check. When data for individual countries were limited, an additional literature search was done, including older articles (published before 2003) and articles with distribution maps for that country. A set of global maps showing the geographical distribution of each of the seven tick genera at the continental, regional and national levels were produced using Arc-GIS Pro 2.7.3 software (ESRI, Redland, California, United States of America). For each tick genus map, a different colour palette was selected, and a colour was assigned to each tick species.

TABLE 1
Economically most important tick species and pathogen (disease) complexes in cattle worldwide

World region	Tick species	Tick-borne pathogen (disease)
Sub-Saharan Africa	<i>Rhipicephalus (Boophilus) microplus</i>	<i>Babesia bovis</i> , <i>Babesia bigemina</i> (Babesiosis); <i>Anaplasma marginale</i> (Anaplasmosis)
	<i>Rhipicephalus (Boophilus) spp.</i>	<i>Babesia bigemina</i> (Babesiosis); <i>Anaplasma marginale, centrale</i> (Anaplasmosis)
	<i>Rhipicephalus appendiculatus</i>	<i>Theileria parva</i> (Theileriosis, East Coast fever)
	<i>Rhipicephalus spp.</i>	/
	<i>Amblyomma variegatum</i> , <i>A. hebraeum</i> , <i>A. lepidum</i>	<i>Ehrlichia ruminantium</i> (Heartwater or cowdriosis)
Near East and North Africa	<i>Hyalomma spp.</i>	<i>Theileria annulata</i> (Tropical theileriosis)
	<i>Rhipicephalus (Boophilus) annulatus</i>	<i>Babesia bigemina</i> (Babesiosis); <i>Anaplasma marginale, centrale</i> (Anaplasmosis)
Europe and North America	<i>Ixodes spp.</i>	<i>Babesia divergens</i> (Babesiosis); <i>Anaplasma phagocytophilum</i> (Anaplasmosis)
Asia and United States of America	<i>Haemaphysalis longicornis</i>	<i>Theileria orientalis</i> (Theileriosis)
Americas	<i>Rhipicephalus (Boophilus) microplus</i> , <i>R. (B.) annulatus</i>	<i>Babesia bovis</i> , <i>Babesia bigemina</i> (Babesiosis); <i>Anaplasma marginale</i> (Anaplasmosis)
	<i>Amblyomma mixtum</i> (included in <i>A. cajennense</i> complex)	/
Caribbean islands	<i>Amblyomma variegatum</i>	<i>Ehrlichia ruminantium</i> (Heartwater or cowdriosis)
	<i>Rhipicephalus (Boophilus) microplus</i>	<i>Babesia bovis</i> , <i>Babesia bigemina</i> (Babesiosis); <i>Anaplasma marginale</i> (Anaplasmosis)
Asia	<i>Rhipicephalus (Boophilus) microplus</i> , <i>R. (B.) annulatus</i>	<i>Babesia bovis</i> , <i>Babesia bigemina</i> (Babesiosis); <i>Anaplasma marginale, centrale</i> (Anaplasmosis)
	<i>Hyalomma spp.</i>	<i>Theileria annulata</i> (Tropical theileriosis)
Oceania	<i>Rhipicephalus (Boophilus) australis</i>	<i>Babesia bovis</i> , <i>Babesia bigemina</i> (Babesiosis); <i>Anaplasma marginale</i> (Anaplasmosis)
	<i>Haemaphysalis longicornis</i>	<i>Theileria orientalis</i> (Theileriosis)
	<i>Ixodes holocyclus</i>	Toxicosis causing paralysis

Source: Authors' own elaboration.

Economic burden

Cattle production is an important economic activity worldwide. The economic burden caused by ticks is associated with decreased livestock productivity such as reduced milk and beef production, depressed manure production and reduced animal draft power. On average, each engorging *R. (B.) microplus* female tick is responsible for the loss of 1 g of body weight per day and 1 ml of milk production in *Bos taurus*, *B. indicus* cattle and their crosses. Tick burdens can range to 1000–2000 ticks per cattle, with expected losses up to 2 litres of milk per day and 600 litres over a standard 300 days of lactation (Jonsson, 2006; Jonsson *et al.*, 1998).

The economic burden is even more important when the impacts of TBD are considered. Economic losses resulting from TTBD have been estimated in some countries (Betancourt, 2017; Grisi *et al.*, 2014; Kivaria, 2006; Rodríguez-Vivas, Jonsson and Bhushan, 2018; Shephard *et al.*, 2022; Singh *et al.*, 2022). A re-estimation of the economic losses caused by TTBD in 2016 based on updated global cattle

numbers (1.5 billion) and the algorithms of de Castro (1997) was to be between **USD 22–30 billion per annum globally** (Lew-Tabor and Rodríguez Valle, 2016). While these estimates reveal the considerable economic impact of TTBD, they also show the complexity of making correct economic estimations when most regions lack analytical data for recent global estimations. In the context of return on investment for farmers to treat infested cattle, few evaluation studies include the cost of acaricide resistance or the potential economic benefits of other interventions (Paucar-Quishpe *et al.*, 2023), such as the integrated tick management approach (see Part 3). The additional costs associated with acaricide resistance correspond to the increased frequency of treatments, use of more expensive products, increased workload, increased loss of productivity and the costs associated with risks to users, food safety and environmental impacts. Although the complexity of calculating the costs and benefits of diseases and interventions is real, estimations are needed to guide resource allocation at the farm, national and regional levels (Lopes *et al.*, 2016).

Part 2

Synthetic acaricides and the threat of acaricide resistance

The control of parasites, including ticks, has changed tremendously over the past 100 years. Before the 1960s, the use of chemotherapeutic agents for improving animal production and welfare was almost non-existent. Livestock producers largely relied on the genetic resistance or resilience of their animals to maintain growth, milk production, and reproduction, often at a significant cost to the animals' welfare and performance. From the first use of arsenic dips, chemotherapy developed in the twentieth century enabled the routine treatment and prevention of parasite infections with effective drugs. The easy and cost-effective productivity gains from parasiticide treatments led to the widespread adoption of chemotherapy. Additionally, the challenge of developing non-chemical methods of parasite control with comparable efficacy has further increased reliance on these drugs. Globally, parasiticides represent the second biggest segment in the animal health industry after vaccine, accounting for 23 percent of veterinary pharmaceutical sales, around USD 8 billion in 2019, of which one-third was for livestock (Selzer and Epe, 2021). The spread of drug resistance and the risks to the user and environment have raised new concerns since the turn of the twenty-first century (Molento, 2009; Sangster, 2001).

The development of new veterinary products is long and costly. The direct cost of bringing a new product for production animals to market is estimated to be up to USD 75 million in 2015 (Health for Animals, 2015) and it takes an average of 8 to 15 years. Those values are the highest range of animal health R&D and estimated to be higher than for vaccine development. This is related to the stringency of the user and environmental safety requirements, which corresponds to the One Health aspect of pharmaceutical drug development. The authorization process for new acaricides in most regions requires extensive data to demonstrate the product's quality, safety and efficacy (Geary, Conder and Bishop, 2004). In this context, effective stewardship programmes are needed to encourage the reasonable use and reduction of misuse, and to slow the emergence of drug resistance (Rodríguez-Vivas, Jonsen and Bhushan, 2018); as expected for the novel class of acaricides (isoxazolines) that recently reached the livestock sector in Latin America, where it could make a difference if adequately used.

SYNTHETIC ACARICIDE PRODUCTS

Globally, there are seven classes of acaricides as well as one acarine growth regulator (AGR) available on the market in various pharmaceutical forms to manage cattle ticks (Table 2). These acaricides can be classified according to their target sites and modes of action (MoAs). This MoA classification can guide users through the selection of acaricides and represents the basis for effective and sustainable resistance management, as suggested by the Insecticide Resistance Action Committee (IRAC, <https://irac-online.org>). These products are applied to animals in various ways according to the formulation: plunge-dips or baths; sprays; topical application to the backline (pour-on or spot-on – depending on the volume); intramuscular or subcutaneous injection; impregnated ear tags; and dusting on the skin.

The efficacy of acaricides, both in terms of onset and persistence, is determined by the pharmacokinetics of active pharmaceutical ingredient (API) and the pharmaceutical form. These will determine absorption, distribution, metabolism and excretion (ADME) of the product. Therefore, acaricides can be categorized in short-, medium- or long-acting classes.

Non-systemic acaricide products will not be absorbed into the cattle's bloodstream and will typically be applied directly on the skin. Therefore, they will offer a quick knock-down effect, reaching peak efficacy within days post-treatment. However, their efficacy is short-lived, classifying them as short-acting. This will be the case with synthetic pyrethroids (SP), amitraz, and organophosphates (OP). The formulation of these products may influence absorption and diffusion in the skin and therefore modifying the persistence of their activity. Products applied by spray and dipping are typically lasting only 7–10 days (Davey and Ahrens, 1984; Roy-Smith, 1975), whereas pour-on formulation are lasting 14–42 days (Bhushan *et al.*, 1999; Mehlhorn *et al.*, 2011; Mekonnen, 2000).

Systemic acaricides are absorbed and enter the cattle's bloodstream, subsequently being taken up by the parasite. The shorter the time it takes to reach the maximum concentration in the blood (T_{max}), the faster the product will produce its effects. The slower the elimination, the longer the concentration will remain above the minimum effective concentration and therefore longer the effects will persist.

This will be the case with macrocyclic lactones (ML), fluazuron and isoxazolines which are typically applied using pour-on or injectable formulation. Therefore, medium-acting acaricides include injectable and pour-on formulations of 0.5 to 1.0 percent macrocyclic lactones (ML) and injectable fluazuron. These products can protect the animals for 2 to 4 weeks (George, Pound and Davey, 2004). The long-acting category, which provides protection for 5 to 10 weeks, includes isoxazolines, injectable high concentration (> 3.0 percent) ML, and the pour-on formulation of fipronil and fluazuron (George, Pound and Davey, 2004).

Synthetic acaricide products are usually effective against a broader spectrum of ectoparasites and may be used for other indications than tick control. The macrocyclic lactone (ML) family has the widest spectrum of activity, being effective not only against arthropods (acarids and insects) but also effective against helminths (nematodes). Therefore, in most cases, it is difficult to develop and implement specific tick control measures without affecting the control of other parasites.

TABLE 2
Characteristics of common active pharmaceutical ingredients (API) currently authorized to control cattle ticks

Physiological target	Site and mode of action	MoA classification group ^a	Acaricide class	API used for tick control in cattle (in bold the most frequently encountered API)	Typical commercially available dosage forms	Summary of market status (region where it's used, non-authorized, accessible)	Main characteristics (Indication, pharmacokinetics, user, animal and environmental safety/toxicity, ADI)
Nerve and muscle	Site of action: Acetylcholinesterase (AChE) Mode of action: Inhibiting the action of AChE, causing hyperexcitation. (AChE is the enzyme that terminates the action of the excitatory neurotransmitter acetylcholine at nerve synapses)	1B	Organophosphates (OP)	chlorfenvinphos, chlorpyrifos,^d coumaphos, diazinon, dichlorvos, ethion, phoxim, malathion, phosmet	Emulsifiable concentrate for spray and dip and eartag (diazinon). Often in combination with other API.	OP are not authorized as veterinary products for use in cattle in the EU and United States of America (except for the CFTEP in the United States of America). They are widely used in Africa, Latin America, Australia and India. Where OP is available, it is authorized for use on cattle-producing milk for human consumption.	<p>According to the API, OP have non-systemic broad spectrum of activity against nematodes, insects and acarids. OP are active against larvae and adult flies, lice, ticks and mites on domestic livestock, although activity varies between compounds and the different formulations.</p> <p>OP compounds irreversibly block AChE, with a bioaccumulation potential and high toxicity risk for insects, plants, animals and humans.</p> <p>WHO toxicity class^e Ib: coumaphos, chlorfenvinphos, dichlorvos II: chlorpyrifos, diazinon, ethion, phoxim, phosmet III: malathion ADI: diazinon: 0–0.003 mg/kg bw chlorpyrifos: 0–0.01 mg/kg bw chlorfenvinphos: 0–0.0005 mg/kg bw ethion: 0–0.002 mg/kg bw phoxim: 0–0.004 mg/kg bw</p>
		1A	Carbamates	carbaryl, propoxur	Pour-on, dust.	Veterinary use of carbamates for tick control in livestock has always been uncommon.	<p>Carbamates are non-systemic insecticides and acaricides.</p> <p>Carbamates are reversible inhibitors of AChE and therefore are less toxic than OP.</p> <p>WHO toxicity class II ADI: Propoxur: 0–0.02 mg/kg bw</p>

(Continues)

TABLE 2
 Characteristics of common active pharmaceutical ingredients (API) currently authorized to control cattle ticks (Continued)

Physiological target	Site and mode of action	MoA classification group ^a	Acaricide class	API used for tick control in cattle (in bold the most frequently encountered API)	Typical commercially available dosage forms	Summary of market status (region where it's used, non-authorized, accessible)	Main characteristics (Indication, pharmacokinetics, user, animal and environmental safety/toxicity, ADI)
Nerve and muscle	<p>Site of action: Voltage-gated sodium channel</p> <p>Mode of action: Modulating sodium channels by keeping them open, causing hyperexcitation, permanent depolarization and the disruption of the propagation of action potentials along nerve axons</p>	3A	Synthetic Pyrethroids (SP)	cyfluthrin, cypermethrin (=alpha-cypermethrin), deltamethrin , flumethrin , permethrin, lambda-cyhalothrin	Pour-on, spray, dip and eartag. Often in combination with other API.	SP are widely used worldwide for tick and other ectoparasite control in cattle. Most pyrethroids leave little or no residues in meat and milk and are often approved for use on cattle-producing milk for human consumption.	<p>SP are non-systemic insecticides and acaricides with contact efficacy. They have a broad spectrum of activity against external parasites, although the spectrum of activity varies among the molecules. SP have a limited dermal absorption and are rapidly metabolized. However, pyrethroids are irritant for the skin, the eyes and the respiratory tract of mammals. Pyrethroids are highly toxic to fish.</p> <p>WHO toxicity class Ib: cyfluthrin II: cypermethrin, cyhalothrin, deltamethrin, permethrin ADI: cypermethrin: 0–0.02 mg/kg bw cyfluthrin: 0–0.02 mg/kg bw lambda-cyhalothrin: 0–0.02 mg/kg bw deltamethrin: 0–0.01 mg/kg bw flumethrin: 0–0.004 mg/kg bw</p>
	<p>Site of action: GABA-gated chloride channel</p> <p>Mode of action: Block the GABA-activated chloride channel, causing hyperexcitation and convulsions (GABA is the major inhibitory neurotransmitter in insects)</p>	2B	Phenylpyrazoles	fipronil	Pour-on.	Fipronil is used on beef cattle in some Latin American countries and South Africa. It is not authorized for use on dairy cows producing milk for human consumption.	<p>Fipronil is used for the treatment and control of ectoparasite infestations on cattle. Fipronil is highly toxic to terrestrial and aquatic invertebrates.</p> <p>WHO toxicity class II ADI: 0–0.0002 mg/kg bw</p>
	<p>Site of action: Glutamate-gated chloride channel</p> <p>Mode of action: Glutamate-gated chloride channel (GluCl) allosteric modulators. Allosterically activate GluCl, causing paralysis (Glutamate is an important inhibitory neurotransmitter in insects)</p>	6	Macrocyclic lactones (ML)	Subgroup of Avermectin: abamectin , doramectin , eprinomectin , ivermectin Subgroup of Milbemycins: moxidectin	Injectable, drenches, pour-on.	ML are widely used to control endo- and ectoparasites. Some ML are authorized for use in cattle-producing milk for human consumption.	<p>ML are broad-spectrum antiparasitic drugs. Activity extends to insects, acarids and nematodes. All ML have a systemic MoA. Efficacy against ectoparasites varies depending on the compound. Acaricide efficacy reaches the standard threshold only against one-host ticks. Residues from ML-treated animals have potential toxic effects to non-target organisms in pasture and soil environments (i.e. diptera, earthworms, springtails, mites, nematodes and dung beetles).</p> <p>WHO toxicity class Ib: abamectin ADI: eprinomectin, ivermectin: 0–0.01 mg/kg bw abamectin, doramectin: 0.001 mg/kg bw moxidectin: 0–0.002 mg/kg bw</p>

(Continues)

TABLE 2
 Characteristics of common active pharmaceutical ingredients (API) currently authorized to control cattle ticks (Continued)

Physiological target	Site and mode of action	MoA classification group ^a	Acaricide class	API used for tick control in cattle (in bold the most frequently encountered API) ^b	Typical commercially available dosage forms	Summary of market status (region where it's used, non-authorized, accessible)	Main characteristics (Indication, pharmacokinetics, user, animal and environmental safety/toxicity, ADI)
Nerve and muscle	Site of action: GABA-gated chloride channels and glutamate-gated chloride channels Mode of action: Allosteric modulators which inhibit GABA-gated chloride channels and glutamate-gated chloride channels	30	Isoxazolines	fluralaner umifoxolaner ^f	Pour-on, injectable.	Only currently available in some countries in Latin America for cattle tick control. No MRL in milk is available and not intended to be used in cattle-producing milk for human consumption.	Isoxazolines have insecticide and acaricide efficacy and are currently registered against ticks, mites and flies. ADI: Fluralaner: 0–0.01 mg/kg bw ^g
	Site of action: Octopamine receptors Mode of action: Octopamine receptor agonists decrease intracellular Ca ²⁺ and activation of K ⁺ efflux, interrupting nervous transmission and death	19	Formamidines	amitraz cymiazole	EC for dipping and spraying. Often in combination with other API.	Amitraz is widely used for tick and other acarids control in cattle, although it is almost no longer used in the European Union. It is authorized in dairy and beef cattle.	Amitraz is effective against mites and ticks in domestic livestock. Formamidines have central α_2 -adrenergic agonist activity, leading to sedative effect and neurotoxicity in mammals. Horses do not tolerate formamidines, which are also toxic to cats and rodents. WHO toxicity class II: amitraz ADI: amitraz: 0–0.01mg/kg
Growth	Site of action: Chitin Synthase 1 (CHS1) Mode of action: Inhibits chitin biosynthesis. It inhibits the enzyme that catalyses the polymerization of chitin	15	Benzoylphenyl urea	fluazuron	Pour-on, injectable.	It is used only in cattle against cattle ticks (<i>Rhipicephalus</i> (<i>B.</i>) spp.). No formulations are authorized for use on cattle-producing milk for human consumption.	AGRs constitute a group of chemical compounds that interfere with the growth and development of the parasite. Fluazuron does not affect insects at the usual dosage but is highly effective against tick larvae. The adverse consequences for ticks are the reduction of the fecundity and fertility of engorged females to near zero as well as the mortality of immature ticks as they are unable to moult to the next instar. Because of their action on development, they will not display a knock-down effect on adult ticks on animals. WHO toxicity class IV ADI: 0–0.04 mg/kg bw

Notes:

- ^a Mode of action (MoA) classification group: <https://irac-online.org/mode-of-action/classification-online>.
- ^b Most frequently commercially available API encountered based on a survey of regulators and veterinary services (see section on “Access and use of acaricides in the field”). Veterinary medicinal products authorized in countries are listed in national database (see [Technical documentation](#) – Regulatory requirements).
- ^c Acceptable daily intake (ADI) is used to calculate further maximum residues limits (MRL) in the different edible tissues. ADI presented in this table are the last available values elaborated by the Joint [FAO/WHO Expert Committee on Food Additives \(JECFA\)](#) or the [Joint FAO/WHO Meeting on Pesticide Residues \(JMPR\)](#). ADI for some products are no longer relevant, as they are banned in some regions.
- ^d No longer has Codex MRLs pesticide residues in food.
- ^e [The WHO Recommended Classification of Pesticides by Hazard and guidelines to classification, 2019 edition](#).
- ^f This product will be marketed in the months following this publication.
- ^g ADI for fluralaner calculated in European public MRL assessment report (EPMAR) Fluralaner (poultry) 15 February 2017 EMA/CVMP/567262/2016 Committee for Medicinal Products for Veterinary Use.

Sources: Adapted from Junquera, P. 2021. Ectoparasitocides. In: *PARASITIPEDIA*. [Cited 7 March 2024]. <https://parasitipedia.net>; Rodríguez-Vivas, R.I., Pérez-Cogollo, L.C., Rosado-Aguilar, J.A., Ojeda-Chi, M.M., Trinidad-Martinez, I., Miller, R.J., Li, A.Y. et al. 2014. *Rhipicephalus* (*Boophilus*) *microplus* resistant to acaricides and ivermectin in cattle farms of Mexico. *Brazilian Journal of Veterinary Parasitology*, 23(2): 113–122; Rodríguez-Vivas, R.I., Jonsson, N.N. & Bhushan, C. 2018. Strategies for the control of *Rhipicephalus microplus* ticks in a world of conventional acaricide and macrocyclic lactone resistance. *Parasitology Research*, 117: 3–29.

Contraindications may be present and potential adverse events may occur during or after animal treatment. An adverse drug reaction (also known as an adverse drug event) is defined as unexpected or unintended effects associated with use of drug including sensitivity reactions, lack of efficacy and injury (Hsu, 2013). Adverse events can manifest in various ways depending on the acaricide used and the animal's response. It is therefore essential to follow the instructions given in the product leaflet before use and to report any adverse reactions to the pharmacovigilance system in place.

It is recommended to use only veterinary products authorized for the species indicated. Even if non-veterinary products contain the same active ingredient (e.g. agrochemical), differences in formulation, concentration or intended use can render them ineffective or even toxic to animals. Additionally, the improper use of non-veterinary products can contribute to acaricide resistance, diminishing their overall efficacy in combating parasites. It is also recommended that acaricide products approved only for application to animals should not be applied to the environment, either on pasture or in buildings.

REGULATORY FRAMEWORK

The regulatory framework for products registered to control ticks in cattle differs across countries and regions. Acaricides can be classified as veterinary medical products (VMP) or as pesticides, and nomenclature and the associated regulation vary considerably. Most countries have legislation to ensure that acaricides are authorized only after manufacturers or distributors have provided evidence of quality, safety and efficacy. However, the specific approval processes can vary widely from one country to another (for detailed regional descriptions, refer to [Technical documentation](#) – Regulatory requirements [FAO, 2025]).

A marketing authorization (MA) (also called “registration” or “licence”) is the necessary approval from the competent authority in the country concerned for the sale and use of a product. This authorization is granted by the national or regional competent authorities to the applicant based on information on quality, safety and efficacy (International Cooperation on Harmonisation of Technical Requirements for Registration of Veterinary Medicinal Products [VICH], 2016). The objective is to demonstrate a positive balance between risks and benefits of the product.

The applicant must provide a comprehensive data package addressing the above elements to allow this evaluation. This data package is often referred to as the “dossier.” It should detail the product specificities (such as the name of the active substance, target species, indications for use, dose, and duration of treatment), usage conditions (including storage conditions, shelf life, withdrawal period, instructions for safe use, and instructions for safe disposal of waste), and any precautions or warnings for safe use,

including potential contraindications and adverse events. This information and the instructions for product use are included on the label and package leaflet of the product when it is marketed (European Medicines Agency [EMA], 2021a; VICH, 2016).

The data gathered in the dossier must follow specific technical guidance on quality, safety and efficacy as determined by the competent authorities. One of the reference programmes for the registration of veterinary products is the Veterinary International Conference on Harmonization (VICH), a trilateral (European Union–Japan–United States of America) programme aimed at harmonizing technical requirements for veterinary product registration. Other guidance may exist such as those from OECD.

Ultimately, the MA process will depend on the regulations in the country concerned.

Regulatory requirements for the evaluation of acaricide quality

Quality is a key attribute of a veterinary acaricide, along with safety and efficacy. Chemistry, manufacturing and control are the main characteristics evaluated to assess a drug's quality. The objective is to guarantee that a product is appropriately manufactured to ensure that the resulting medicinal product complies consistently with the required standards. Specific manufacturing processes, product characteristics, and product testing must be defined, and their consistency over time must be proven. The registration dossier includes descriptions of qualitative and quantitative composition, the preparation method, and controls on raw materials, checks during manufacture and on the finished product, as well as stability testing. The legislation in countries that follow VICH guidelines requires certification that the product is manufactured in compliance with good manufacturing practice.

Following MA, products should be monitored by regular inspections of manufacturing sites. Systems must be established to ensure ongoing monitoring once the product is on the market. Quality requirements may differ between regulatory authorities.

Regulatory requirements for the evaluation of acaricide safety

The safety part of the registration dossier includes data on the product's safety profile obtained from various pre-clinical and clinical studies. It is an extensive evaluation of the potential hazards related to the product under development and the exposure risk for the environment, treated animal and user – including the consumer of the food from the treated animal (such as meat and milk) – and defines the measures to be taken to mitigate those effects (for detailed description of the evaluation of acaricide safety, refer to [Technical documentation](#) – Regulatory requirements [FAO, 2025]).

The safety of the target animal assesses the toxicity, pharmacokinetics, pharmacodynamics and identifies any potential adverse effects of the product in the treated animal.

The safety of user evaluates the human health exposure hazard and risk. Users may also be exposed to an acaricide when handling the product, treating animals and handling animals that have been treated previously with an acaricide. A re-handling interval may need to be established to allow the acaricide to degrade to levels that do not pose an unacceptable risk to users.

The safety of consumer is guaranteed by compliance with the withdrawal period (WP) which gives the interval of time that must be respected after treatment before meat, offal or milk can be collected for human consumption. It is calculated based on the determination of the maximum residue limit (MRL) at which no adverse effect would be expected on product consumers, given regionally predictable intakes of food types. Therefore, it means that after the WP, the concentrations of API, in meat or milk, are all under MRL. Determining the MRL and related WP follows a complex calculation and may vary from one agency to another, as regulatory authorities do not follow the same safety standards everywhere. The competent authorities are responsible for establishing the MRL and maintaining the MRL list. They may defer to Codex or the Joint FAO/WHO Expert Committee on Food Additives (JECFA) if national MRLs are not established. JECFA is an international scientific expert committee that governs the procedure used for determining MRL values. For “pesticide” which includes acaricides used in animals, the [CODEX Alimentarius](#) is responsible for establishing MRL for pesticide residues in specific food items or in groups of food or feed that move in international trade also advised by the FAO/WHO Joint Meeting on Pesticide Residues (JMPR).

The safety for the environment evaluates the potential environmental impacts of the product, including its potential to accumulate in the environment and toxicity to non-target organisms. Products for livestock and production animals require varying types and amounts of data depending on the toxicity profile of the compound to various flora and fauna, as well as the expected levels of usage and excretion into the environment. A phased approach is used so that high-risk values from early-phase calculations trigger the need for additional testing and evaluations.

One significant element is that most of the currently used acaricides are generic products that have been registered based on bioequivalence to sometimes very old products. The safety part of the dossier is not fully re-evaluated for authorization renewals in all jurisdictions, and some of the standards for environmental safety have evolved relatively recently, therefore, the requirements described above may not always be met for all currently used products.

Regulatory requirements for the evaluation of acaricide efficacy

(Adapted from EMA, 2021b, 2023a; Holdsworth et al., 2022.)

Since no VICH guidelines exist offering direction to support the conduct of efficacy studies relating to investigational ectoparasiticide products, different guidelines are currently used. The 2022 edition of the World Association for the Advancement of Veterinary Parasitology (WAAVP) guideline for evaluating the efficacy of parasiticides against ectoparasites of ruminants offers guidance on the data requirements that support product regulatory authorization (and is used as a reference in Australia, for example). European Medicines Agency (EMA) guidelines currently exist supporting ectoparasiticide efficacy evaluation, as well as setting overall efficacy thresholds and methods of calculation. These guidelines are currently being updated, given the changes in regulatory requirements (see [Technical documentation](#) – Regulatory requirements [FAO, 2025]).

Approval for an efficacy claim is based on the results of pharmacokinetics and pharmacodynamics studies, dose determination, dose confirmation obtained in pre-clinical trials and field studies for each of the tick species. Extrapolation to claim for other ticks are based on scientific demonstration.

The comprehensive summary of all quality, safety and efficacy-related data includes a risk-benefit assessment and allows regulatory authorities to make informed decisions regarding the product's approval for marketing and use in animals.

Specific requirements for generic acaricide registration

Most of the current acaricides used in livestock worldwide are registered as generic VMPs. As with other human and animal medicinal products, generic VMPs must comply with regulations and be approved by the local competent authorities. In comparison with new active ingredients, the application process for generic products is often a simplified or abbreviated procedure. A generic veterinary drug should typically have the same API concentration, dosage form and pharmaceutical form as the reference product to obtain authorization.

A generic medicinal product must have similar labelling to the reference product, concerning target species authorized, indications, dosage regime, withdrawal periods, warnings and safety information. National competent authorities may request additional studies, such as residue studies at the injection site. Generic veterinary medicinal product applicants are generally required to demonstrate *in vivo* bioequivalence to the reference product, meaning the generic product must have comparable bioavailability, delivering the same amount of active ingredient to the bloodstream in the same time frame. This is typically shown through pharmacokinetic studies in each species for which

the product is indicated. This does not apply for topically administered acaricides in which the blood concentrations may not be indicative of active ingredient.

New target animal safety data, drug effectiveness data and human food safety data are usually not required for generics, although efficacy studies may be performed for products like acaricides with topical activity. The manufacturing of generic veterinary drugs adheres to the same standards as reference product to ensure product quality, including rigorous methods, processes and quality controls, as well as stability over the product's shelf life. Both reference and generic veterinary products must meet current good manufacturing practice standards, and inspections of their manufacturing facilities are expected to be conducted similarly.

ACCESS AND USE OF ACARICIDES IN THE FIELD

General description

There is great variability in the access to acaricides and their use between regions and within regions.² Some regions have established access to quality animal health products, whereas others face challenges such as limited distribution or the prevalence of substandard and counterfeit products. In many countries, regulatory systems are either weak or not effectively enforced as well as pharmacovigilance systems (WOAH, 2022). The way acaricides are used also differs greatly: in some regions, farmers strictly follow label instructions and withdrawal periods, while in others, misuse and reliance on unlicensed products are common. While continuing education of veterinarians and veterinary paraprofessionals on the choice, use and administration of acaricides varies, all regions report knowledge gaps in diagnosis of resistance; knowledge of current resistance status in the country; knowledge of parasite epidemiology; and knowledge of the prudent use of acaricides.

The following region-specific highlights provide examples from countries, acknowledging the description is not exhaustive. More detailed information on regulations, access and use of acaricide with regional descriptions is also available in [Technical documentation](#) – Regulatory requirements (FAO, 2025).

² A survey was conducted involving regulatory authorities and veterinary services in eight regions, with input from external experts (such as Regulatory affair specialists from pharmaceutical manufacturers and WOAH collaborating centres for veterinary products) to provide a comprehensive overview on acaricides access and use in the field. The questionnaire addressed issues related to availability, usage, pharmacovigilance, disposal management, and knowledge. Responses were collected from Veterinary Medicinal Products Regulatory Authorities of Argentina, Australia, Burundi, Colombia, European Union (EMA), France, India, Kenya, Mexico, Morocco, Rwanda, United Republic of Tanzania, United States of America, West African Economic and Monetary Union (UEMOA) commission, as well as National Veterinary Services from Australia, Austria, Côte d'Ivoire, Croatia, Cyprus, Denmark, Ecuador, Egypt, Finland, Germany, Greece, Kenya, Morocco, Portugal, Romania, Rwanda, Slovakia, Slovenia, Sweden, United Republic of Tanzania, United States of America and Uruguay.

Access and use of acaricides in Central and South America

Access to acaricide products: Brazil and Argentina are important domestic manufacturers of veterinary drugs while local manufacturing of acaricides exists in Uruguay, Ecuador, Colombia and Mexico. Access to acaricides is not a major concern in most of the countries in Latin America, although, barriers to accessing quality drugs are reported in some countries such as Mexico, Colombia or Ecuador. Acaricides are mainly sold over the counter (OTC). However, in some countries (e.g. Colombia, Ecuador, Mexico and Uruguay) specific molecules and/or dosage forms require a prescription. Acaricides are mainly sold by agro-cooperatives and agro-dealers while veterinarians may also play a role in some countries (Figure 2). Sales of acaricides are usually not monitored.

Product usage in the field: Farmers get advice from veterinarians or agro-dealers and sometimes from unauthorized vendors on acaricide selection. Farmers are usually the ones administering the products. Acaricides are used to prevent and treat tick infestation and are generally used according to the label instructions depending on local context and cattle operating system. Small farmers use manual spraying, pour-on formulations and injectable acaricides. In large cattle operations from Brazil, sprinkler nozzles are used to treat the entire herd regularly (every 2–3 months). Acaricide combinations (double or triple chemical families) are often used. Acaricide rotation with different chemical groups is a common practice. Withdrawal periods are usually respected depending on the cattle operating system and methods for regulatory testing of residues of acaricides in food are available and applied in most countries. However, the use of unlicensed products (e.g. agrochemicals or motor oil) to treat tick infestations is also reported where resistance is prevalent (Villar *et al.*, 2020). In Argentina, Colombia and Uruguay, producers must record the use of acaricides on farms.

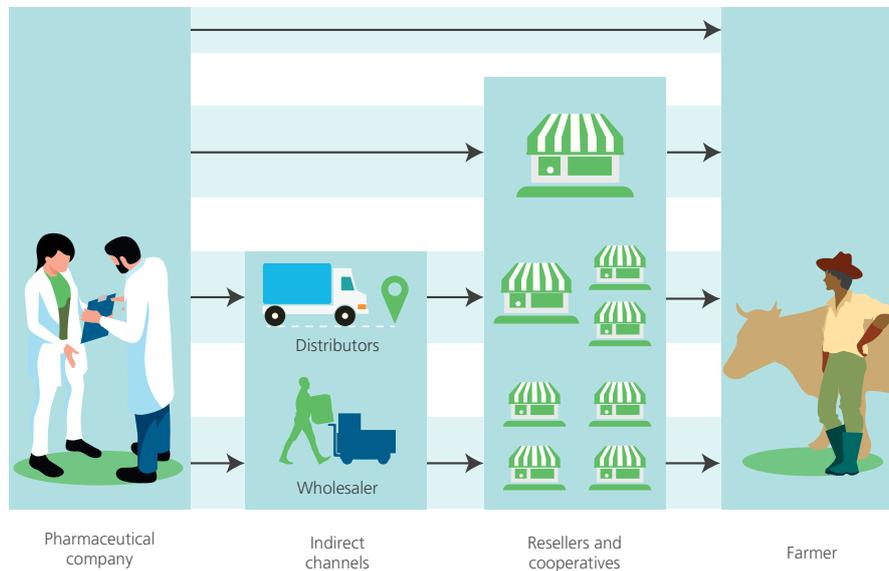
Pharmacovigilance: Centralized pharmacovigilance tracking systems may be absent or not well known by practitioners in some countries.

Collection and disposal of acaricides: Regulated procedures for the collection and disposal or destruction of unused or expired acaricides may exist in Colombia, Mexico and Uruguay, but not in Argentina or Ecuador. In Colombia and Uruguay, there is a collection system in place.

Access and use of acaricides in North America

Access to acaricide products: Local manufacturing of acaricides exists in the United States of America and farmers have sustainable access to quality products. A limited number of authorized acaricides for cattle is reported compared to Central and South America. The Food and Drug Administration (FDA), Environmental Protection Agency (EPA),

FIGURE 2
Access and marketing channels for acaricides in most Latin American countries



Source: Authors' own elaboration.

and/or Department of Homeland Security (DHS)/Customs and Border Protection (CBP) control the unauthorized products that are infrequent in the country. Each competent authority has oversight of imports. Veterinarians, agro-cooperatives or agro-dealers sell the acaricides to farmers, depending on whether a prescription is required.

Product usage in the field: Advice and recommendation on the appropriate use of acaricide products are provided by a wide range of stakeholders from veterinarians to neighbours. Acaricides are generally considered to be administered by the end user or the veterinarian according to the label instructions, withdrawal periods are respected and regulatory testing of residues of acaricides in food is in place.

Pharmacovigilance: Pharmacovigilance breaches and suspicions of acaricide resistance are reported by veterinarians, veterinary paraprofessionals and animal owners. Reasons for not reporting adverse events to a centralized pharmacovigilance tracking system may include lack of awareness about the reporting mechanisms; adverse events in food-producing animals may not be noticeable or animal caretakers may not associate adverse events with the product or may consider adverse events to be a normal part of business operations.

Collection and disposal of acaricides: Procedures exist for the collection and disposal or destruction of unused or expired acaricides. Private companies may offer this service which is not federally regulated.

Access and use of acaricides in Europe

Access to acaricide products: Local manufacturing of acaricides exists in some European Union countries, and importation of VMP is in the remit of each member state. Farmers have access to quality products while the limited number of authorized acaricides in cattle is noticed. The use of unauthorized products is not allowed unless in very specific predeclared conditions and illegal importations are notifiable in the field. The use of counterfeit acaricides or unlicensed products (e.g. agrochemicals) is not reported for tick control. There are currently no acaricides for use in cattle authorized by centralized procedure at European Union level, and therefore they are currently all authorized via decentralized procedures, mutual recognition procedures or national procedures. These products are usually prescription-only medicines and mainly sold by veterinarians and secondarily by pharmacies or retailers.

Product usage in the field: Advice to farmers on acaricide selection is mainly made by veterinarians and less frequently by trained animal health workers and agro-cooperative or agro-dealers. Acaricides are mainly administered by veterinarians and farmers according to the label instructions, and their use on farms is recorded in all responding countries. In the field, withdrawal periods are respected and regulatory testing of residues of acaricides in food is performed.

Pharmacovigilance: A [pharmacovigilance process](#) to allow reporting of adverse events (including lack of efficacy reporting) is in place in all responding countries. However,

the main reasons for non-submission of adverse events to acaricides observed in the field to centralized pharmacovigilance tracking system are lack of time and resources or too complicated/bureaucratic, lack of knowledge about obligation and reporting procedure, difficulty identifying the exact role of the product in the context of a lack of effectiveness or side effect.

Collection and disposal of acaricides: Currently, the majority of the EU countries have adequate procedures for the safe collection and disposal or destruction of unused or expired acaricides and must comply with the [new regulations](#). Pharmacy or specialized establishments are committed to collecting it in almost all countries.

Access and use of acaricides in the West African Economic and Monetary Union (WAEMU/UEMOA)

Access to acaricide products: There is no local manufacturing of acaricides in the countries of West African Economic and Monetary Union (WAEMU/UEMOA) and local competent authorities control acaricides importation and their stock at borders. However, unauthorized products, counterfeit acaricides and illegal imports are reported. Limited distribution coverage is one of the major issues for access to quality products in the region followed by high prices of quality products.

Local drug distributors and informal traders are the main sellers. The distribution flow, illustrated in [Figure 3](#), shows fragmentation among intermediaries, impairing access to quality drugs and recommendations. Although acaricides require prescriptions and OTC sales are prohibited, the lack of veterinarians hampers effective regulation enforcement.

Product usage in the field: Advice to farmers on acaricide selection comes from various stakeholders, including

informal traders. Acaricides, used to prevent and treat tick infestations, are mainly administered by farmers and secondarily veterinarians, veterinary paraprofessionals or trained animal health workers. Acaricides prevent and treat tick infestation and are often not used according to the label instructions with unlicensed products (e.g. agrochemicals) being reported for tick treatment. Although the law requires recording acaricide use on farms, this is mostly ineffective. Withdrawal periods are only partially respected, and there is no process in place for regulatory testing of acaricide residues in food. Common acaricides are based on amitraz and alphacypermethrin and manual tick removal remains common. The use of SP supports also the control of tsetse flies (Adehan *et al.*, 2018; Okello *et al.*, 2021).

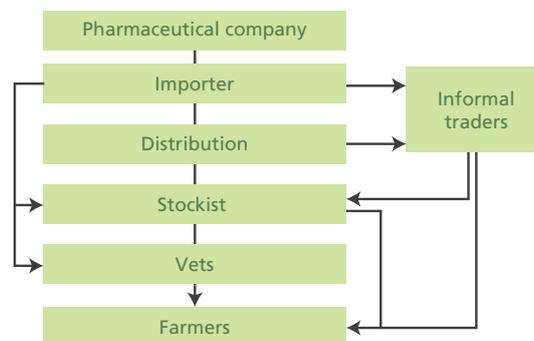
Pharmacovigilance: Veterinarians or veterinary paraprofessionals detect suspicions of acaricide resistance in some countries. However, as the pharmacovigilance system is not operational, submitting adverse events to acaricides observed in the field is extremely difficult.

Collection and disposal of acaricides: There are no regulated procedures for the collection and disposal or destruction of unused or expired acaricides.

Access and use of acaricides in East and Southern Africa

Access to acaricide products: Some acaricides are locally manufactured in East and Southern Africa and their importation and stock are controlled at borders by authorities. Despite this, counterfeit, unlicensed products and illegal imports are frequently reported. Limited distribution coverage and high prices of quality products restrict access to acaricides. The distribution channels are outlined in [Figure 3](#). Farmers obtain acaricides from veterinarians, trained animal health workers, agrovet dealers or non-specialized vendors. Acaricides are

FIGURE 3
Access and marketing channels for acaricides in Africa



Source: Authors' own elaboration.

sold OTC. In the United Republic of Tanzania, the government regulates acaricide distribution and implements zoning for different classes of acaricides. Random sampling of VMPs already authorized are periodically analysed to check the batches released meet the quality specifications.

Product usage in the field: Farmers receive advice on acaricide selection from veterinarians, veterinary paraprofessionals, trained animal health workers, agro-dealers and informal traders. Tick acaricides are applied by spraying, dipping or pouring, though small and medium-sized farms favour spraying because of the high cost of dip tank infrastructure. Handpicking ticks is common in pastoral communities. In South Africa, communal dip tanks were established by the Ministry of Agriculture many years ago to help control tick infestations and populations. Management, structural and financial constraints have led to the disuse of some tanks around the country however, in many other areas, the communal dip tanks are still an integral part of the government's primary animal health-care strategy. As well as parasite control, weekly supervised dipping provide opportunity to assess livestock health and to support the owners with other primary animal healthcare needs such as vaccination and act as sentinel sites for early livestock disease detection.

Acaricides are often misused, mixed with other products, or substituted with crop agrochemicals, and withdrawal periods are inconsistently respected. Regulatory testing for acaricide residues in food is inconsistently applied. Acaricide use must be recorded by farm management, and monitoring of sales is mandatory in some countries like the United Republic of Tanzania but limited.

Pharmacovigilance: Veterinarians or veterinary paraprofessionals detect suspected acaricide resistance in countries, however, lack of pharmacovigilance system limits effective report.

Collection and disposal of acaricides: Regulated procedures and guidelines for the collection and disposal or destruction of unused or expired acaricides exist in several countries but are not implemented (e.g. [guidelines on veterinary medicinal waste management](#) are available in Kenya [Veterinary Medicines Directorate, 2022]).

Access and use of acaricides in North Africa

Access to acaricide products: Local manufacturing of acaricides occurs in Morocco and Egypt, and access to parasiticides is not considered as a major constraint. Excessive price is however the identified limitation to access to quality products in Morocco. OTC sales are not allowed in Morocco; therefore, all acaricides require prescriptions while in Egypt, OTC is allowed. Acaricides are sold by veterinarians and pharmacists in Morocco and, livestock markets and souks are inspected for the presence of unauthorized products including acaricides.

Product usage in the field: Veterinarians advise farmers on acaricide selection. Acaricides are mainly administered by

veterinarians and farmers and are frequently used according to label instructions. Unlicensed products (e.g. agrochemicals) have not been reported to be used to treat tick infestations. Acaricide use on farms is recorded in Morocco by law, but this is not the case in Egypt. However, in practice, implementation of this law is mainly restricted to large farms. There are many small cattle herds which are difficult to inspect. In Morocco, WP are respected mainly in large cattle farms and methods for regulatory testing of residues of acaricides in food are available but are not commonly used.

Pharmacovigilance: Morocco has a pharmacovigilance process that allows reporting of adverse events (including lack of efficacy reporting). However, as the pharmacovigilance system is not operational in Egypt, reporting acaricide-induced adverse events observed in the field is extremely difficult.

Collection and disposal of acaricides: Currently, Morocco has regulated procedures for the safe collection and disposal or destruction of unused or expired acaricides, but they are not yet effective.

Access and use of acaricides in Asia (India)

Access to acaricide products: In India, acaricides are manufactured locally. Acaricides can be purchased OTC. Livestock owners' choice of acaricides is based on the availability of the products and suggestions of veterinary paraprofessionals, shop owners, neighbours and there is limited intervention of veterinarians or other animal health professionals. Because of easy access to acaricide products in the local market under different brand names and pack sizes, actual use of acaricides cannot be monitored. Counterfeit products are sometimes encountered in the field.

Product usage in the field: The product is applied by animal owners and does not always follow label instructions (including respect of the WP). Except in large commercial farms, at village level, use of acaricides on farms is not recorded regularly. SP, ML and amitraz are widely used while the use of OP compounds has reduced (Sharma *et al.*, 2012). Sprays and injectables are mainly used. The strategic use of acaricides for the management of the host stages is almost non-existent and the dose and frequency of use of acaricides is largely decided by the livestock owners, keeping with the manufacturers' instructions as baseline information.

Collection and disposal of acaricides: The labels include procedure for the safe collection disposal of unused and expired products. In practice, procedures are not followed strictly, and there is no monitoring or enforcement in place.

Pharmacovigilance: pharmacovigilance system seems not to be in place specifically for VMP. However, veterinarians are reporting the efficacy status of available acaricides with researchers working on generating acaricide resistance dataset.

Access and use of acaricides in Oceania

Access to acaricide products: Acaricides are locally manufactured, and access is mainly constrained by a limited number of sales points. Acaricides can be bought OTC, without prescription.

Product usage in the field: Veterinarians, agro-dealers, parasite management extension services providers and farmers' neighbours are important sources of advice on acaricide usage. Farmers apply the acaricides which they purchase from agro-dealers. Product is used as per label instructions. Withdrawal periods are observed, and testing is enforced to control residues. Use of unlicensed products is unknown but believed to be limited, as in Australia measures exist to control importation, manufacture and sale of unauthorized acaricides, which are effective. In New Caledonia, cattle are mainly treated by spraying or dipping. A unique acaricide is ordered annually for the whole territory and is used until resistance develops. It is then gradually replaced by a new acaricide. For example, ethion was used from 1973 to 1986, then replaced by deltamethrin between 1982 to 2003, and finally amitraz was ordered in 1996. Today, on farms facing amitraz resistance, long-lasting acaricides (ML and fluzuron) are used once or twice a year as part of an integrated control programme (Thomas Hüe, personal communication, 2024).

Pharmacovigilance: A pharmacovigilance process to allow reporting of adverse events is in place in Australia. Anyone can report a problem with a chemical product. Product holders (pharmaceutical companies) are required to report adverse events to the regulator. Pharmacovigilance reports include lack of efficacy reporting in Australia. Reports of adverse experiences are closely monitored by the regulator.

Competent authorities in Australia conduct random sampling of products to control quality and report adverse drug events.

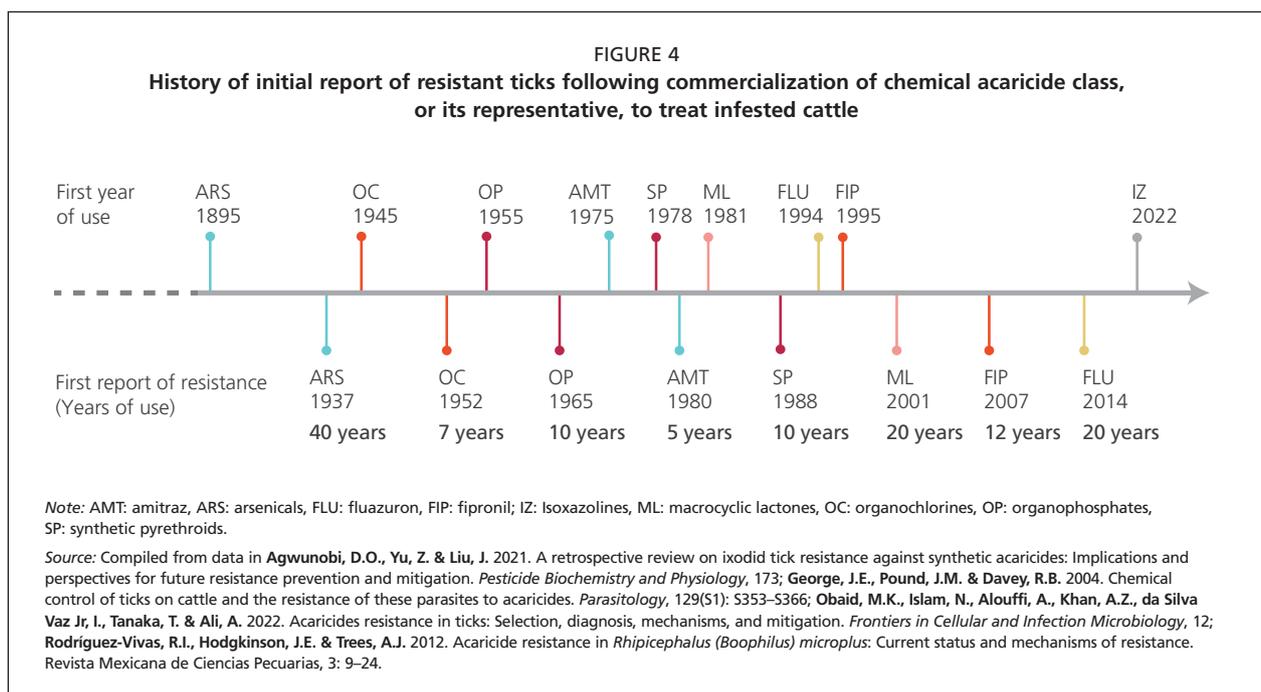
Collection and disposal of acaricides: Stewardship programmes provide Australian agriculture and veterinary chemical users with a recycling pathway for eligible empty agroveter chemical containers and disposing unwanted agroveter chemicals.

ACARICIDE RESISTANCE IN CATTLE TICKS

Acaricide resistance is defined as a heritable change in the susceptibility of a tick population that is reflected in the repeated failure of an active ingredient to achieve the expected level of control when used at the recommended dosages as per label and according to all the recommendations for its use (FAO, 2004). Cross-resistance is defined as resistance to one acaricide by a mechanism that also confers resistance to an acaricide of the same or another chemical class, even where the tick population has not been selected by exposure to the latter. Multiple resistance occurs when ticks develop resistance to two or more compounds by expressing multiple resistance mechanisms in different chemical groups (Rodríguez-Vivas, Jonsson and Bhushan, 2018).

History of acaricide introductions and first reports of resistant ticks

The first acaricide used on cattle was arsenic in 1895. It was widely used throughout the world for 40 years until resistance was observed in 1937 (Newton, 1967). Over time, other classes have been brought to the market, showing resistance over the following 5 to 20 years (Figure 4).



Current situation of acaricide resistance by geographic area

Acaricide resistance is reported in one-host and multi-host cattle ticks in different parts of the world. Information provided below and in [Figure 5](#) reflects currently available data and represents only a partially accurate figure because of the absence or limited monitoring in certain regions. This representation is also highly dynamic, because of the continuous inflow of new data.

- One-host ticks persist in the United States of America inside a narrow tick eradication quarantine area along the Rio Grande, Texas, near the border of Mexico. The resistance status of the tick populations is monitored and controlled in the area. The level of acaricide resistance in multi-host ticks infesting cattle in the United States of America is not recorded.
- In Latin American countries, acaricide resistance of the one-host tick, *R. (B.) microplus*, has been widely described in Central and South America as well as in the Caribbean region with resistance reported across all acaricides classes in southern Brazil, northern Argentina and along the Mexican Atlantic coast.
- In Europe, while resistance in tick populations infesting cattle is not reported. The problem of cattle tick resistance may occur in Mediterranean regions and tropical European territories.³
- In the Near East, data are scarce and currently available from the Islamic Republic of Iran and Iraq where *R. (B.) annulatus* shows resistance to the main acaricide classes used. Resistance to *H. anatolicum* was also reported in Iraq.
- In Asia, resistance reporting is mainly provided from India and Pakistan although also reported in Sri Lanka and the Philippines. Resistance of the one-host tick, *R. (B.) microplus*, to the majority of available acaricides is reported especially in the northern part of India and Pakistan. Resistance to multi-host ticks *H. anatolicum* is also reported. However, because of a limited number of reports, the continent-wide resistance status is still only partially known.
- In North Africa, the status of acaricide resistance is not well documented. *R. (B.) annulatus* is the one-host tick most prevalent in the Mediterranean region and acaricide resistance has been reported so far for that species in Egypt. Resistance has also been reported in multi-host *H. marginatum* in Morocco.
- In West Africa, increasing records of resistance to acaricide are reported in the region, especially since

the introduction of the one-host tick *R. (B.) microplus*. Resistances to all acaricide classes available in the region are described from the coastal regions of Côte d'Ivoire, Ghana, Togo, Benin and Nigeria to south Mali and the Central Plateau of Burkina Faso. The extent of resistance is, however, not extensively monitored.

- In East and Southern Africa, acaricide resistance is widely described and well documented in Uganda, Kenya, United Republic of Tanzania and South Africa. Resistant strains are mainly characterized for the one-host tick species *R. (B.) decoloratus* and the multi-host tick species *R. appendiculatus*.
- In Oceania, resistant populations of the one-host tick *R. (B.) australis*⁴ are present in Queensland and New South Wales (Australia) against the most used acaricides and to a lesser extent in the Northern Territory as well as in New Caledonia. In Queensland, resistant cattle ticks are frequently observed especially in the central highlands and the southeast corner compared to the northern gulf and western regions ([Northern Territory Government, 2022](#)).

Acaricide resistance mechanisms

The drug resistance *genotype* is the genetic composition of the tick, which leads to the expression of the resistance phenotype (Guerrero *et al.*, 2014; Rodríguez-Vivas, Jonsón and Bhushan, 2018). The expression of *phenotypic* resistance is identified by measuring susceptibility of ticks exposed to an acaricide at recommended therapeutic doses or concentrations, *in vivo* or in bioassays.

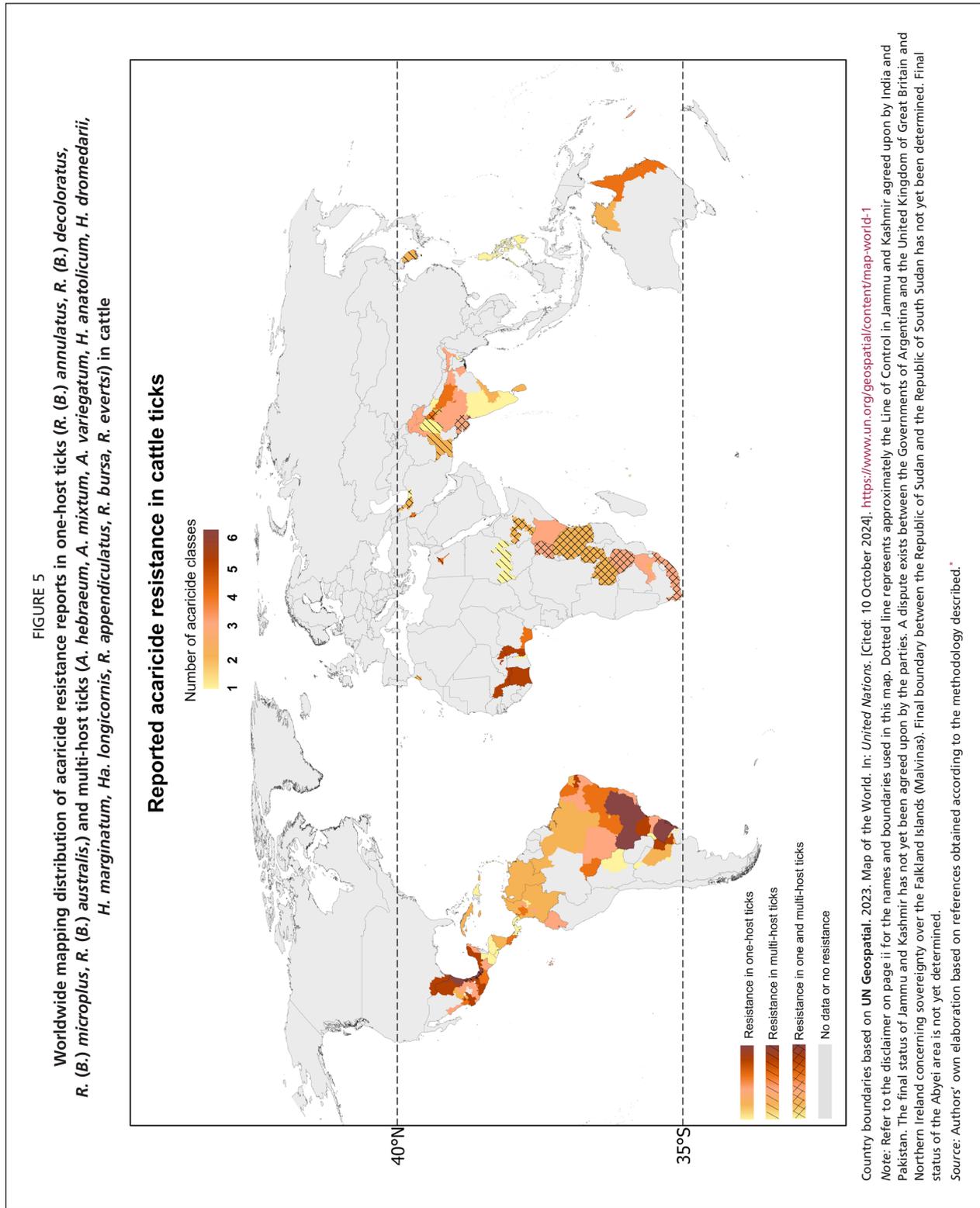
The fundamental mechanisms underlying acaricide resistance are generally classified into three categories: a) target-site mutations (target-site resistance), b) increased metabolic detoxification (metabolic resistance), and c) reduced cuticular penetration (penetration resistance) (Chouaïbou *et al.*, 2014; Guerrero, Lovis and Martins, 2012) ([Table 3](#)).

Target-site resistance occurs when the gene coding for the molecule's target site has a single or multiple nucleotide substitution, leading to amino acid mutations that decrease the acaricide binding (Guerrero *et al.*, 2014).

Metabolic resistance involves increased metabolic detoxification of acaricide mediated by higher expression or activity of detoxification enzymes. Metabolic resistance is usually mediated by families of enzymes, in particular monooxygenases (cytochrome P450s), esterases, glutathione S-transferases (GSTs), and P-glycoprotein ABC transporters (Guerrero *et al.*, 2014; Waldman, Klafke and da Silva, 2023).

³ Although there is currently no reported acaricide resistance in this region, the choice was made to include Europe in this document for the sake of completeness.

⁴ *R. australis* was previously reported as *R. microplus* in literature, before it was reinstated as a separate species in 2012 (Estrada-Peña *et al.*, 2012).



* Acaricide resistance records were obtained from a combination of a systematic literature search with expert consultation. A specific search for drug resistance was performed, identifying 460 articles using terms such as “drug resistance” and relevant acaricides published between 2003 and 2024. To ensure a comprehensive coverage of acaricide resistance data, older articles (14) published between 1978 and 2002 were also included. Data were then organised according to country and region, or specific locations as listed in the literature. Additionally,

our findings were supplemented with unpublished data collected by field experts. All the gathered data were carefully cross-referenced and reviewed by the field experts. Finally, a map showing the reported acaricide resistance was produced at the regional Tier 2 level, which was then combined into a global map. The regions selected for the presence of acaricide resistance were classified and coloured based on the number of acaricide classes reported. Areas where the data are lacking, or resistance were absent are coloured in grey on the map.

TABLE 3
Previously characterized molecular mechanisms of acaricide resistance in livestock ticks

Acaricide	Target site	Described mechanisms of resistance	
		Mechanism	Reference
SP	Voltage-gated sodium channel	Para sodium channel (also known as kdr) mutations (M57T; G72V; L64I; F1550I; F1550L; C190A)	Kumar, Klafke and Miller (2020)
		P450-mediated resistance	Cossío-Bayúgar <i>et al.</i> (2018); Nagar <i>et al.</i> (2021)
		Esterases-mediated resistance	Guerrero, Li and Hernandez (2002)
OP	Acetylcholinesterase	Mutations in acetylcholinesterases	Temeyer, Pruett and Olafson (2010)
Amitraz	Octopamine receptors	Mutations in octopamine / tyramine receptor (T8P; L22S)	Baron <i>et al.</i> (2015); Jyoti <i>et al.</i> (2021)
		Mutations in Beta 2-adrenergic like octopamine receptor (T60P; I61F; I62T; Y88S)	Corley <i>et al.</i> (2013); Jonsson <i>et al.</i> (2018)
		P450-mediated resistance	de La Canal <i>et al.</i> (2021)
Fipronil	GABA-gated chloride channel	Mutations in GABA-gated chloride channels (A286S; A286L)	Castro-Janer <i>et al.</i> (2019)
ML	GluCl-gated chloride channel	ABC transporters mediated resistance	Le Gall, Klafke and Torres (2018); Pohl <i>et al.</i> (2011)
Fluazuron	Chitin synthase	Unknown	-
Isoxazolines	GluCl and GABA-gated chloride channel	Unknown	-

Source: Authors' own elaboration based on references.

Reduced cuticular penetration is considered as a minor contributor to acaricide resistance in cattle ticks (Schnitzlerling, Nolan and Hughes, 1983). There is currently no evidence of any direct association between acaricide resistance and cuticular penetration.

In general, reversion to susceptibility after the emergence of resistance to acaricides is not expected. However, it has been reported in a few instances for amitraz as well as for cypermethrin (Jonsson *et al.*, 2010b; Petermann *et al.*, 2016; Rodríguez-Vivas, 2008; Corley *et al.*, 2013; Foil *et al.*, 2004).

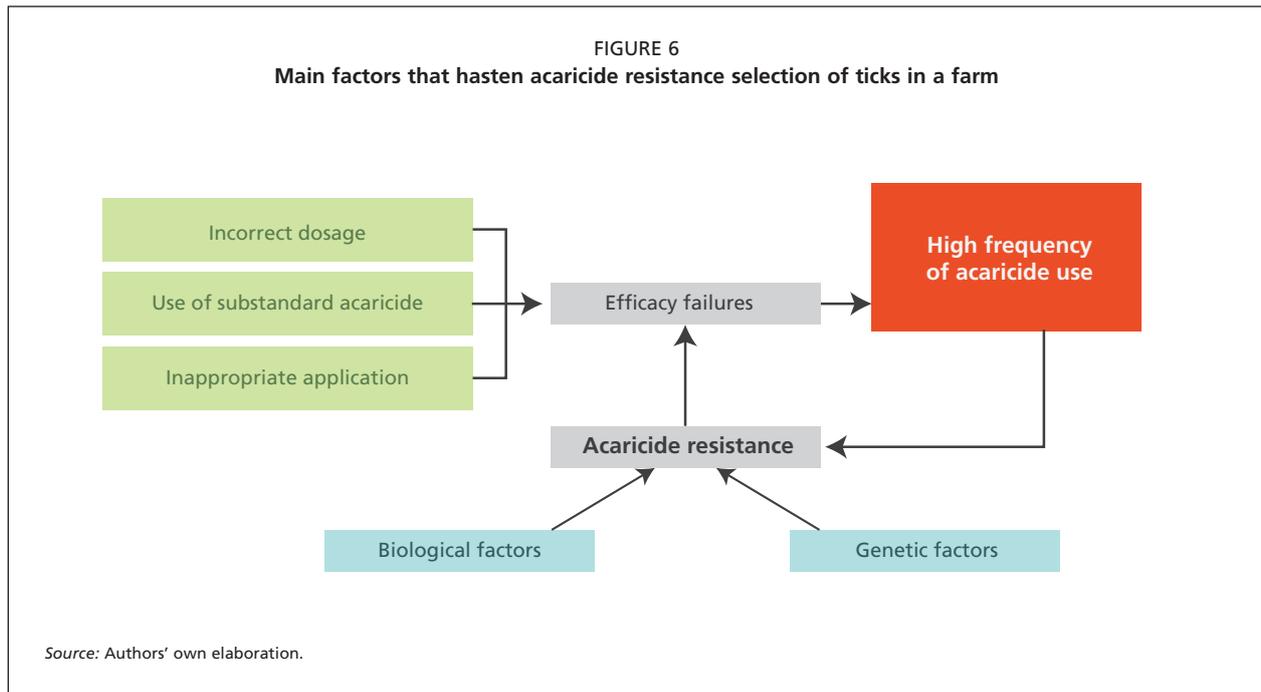
Mode of inheritance of acaricide resistance

Inherited traits such as acaricide resistance are sometimes referred to having a dominant, partially dominant or recessive mode of inheritance. Although the mode of inheritance (determined by the relative fitness of the homozygous resistant, heterozygote, and homozygous susceptible genotypes) is a theoretically important determinant of the rate of resistance emergence, in practice it has not been shown to be useful. The extent to which resistance can be declared dominant or recessive is likely affected by the conditions in the field – *in vitro* resistance profiles do not necessarily correspond exactly with *in vivo* field resistance. Further, there is considerable disagreement in the literature on the mode of inheritance in those cases where it has been examined.

Factors influencing the rate of emergence of resistance to acaricides

The selection of the resistance phenotype is caused by exposure of the resistant tick population to acaricide compounds. Although acaricide resistance is difficult to prevent, the main factor that influences its appearance and increase in a farm is the high frequency of acaricide use, especially with products with the same mode of action. Associated factors are indicated in Figure 6 (Abbas *et al.*, 2014; Aguilar-Tipacamú *et al.*, 2011; Githaka *et al.*, 2022). Selection pressure for acaricide resistance is also strongly driven by the proportion of ticks that will not be exposed when treatments are applied (Kunz and Kemp, 1994), and the proportion of generations over which the treatments are used (Rodríguez-Vivas, Jonsson and Bhushan, 2018).

Ticks in *refugia* are the proportion of ticks in any population that are not exposed to acaricide treatments – those that are in the free-living phase. The larger population of ticks in *refugia* are usually present in the pasture, with those on animals usually being a small proportion of those in the environment. Those ticks in *refugia*, and primarily susceptible at first, will determine how fast resistance will be visible to the farmer. Depending on the species of tick being treated, and the time of year of the acaricide applications, the proportion of *refugia* can vary substantially. In general, multi-host ticks have a much higher proportion of the population in the free-living phase at any time compared with



one-host ticks. With the one-host ticks, the proportion of refugia can be low early in the tick season. This is one of the most likely reasons for the expected more rapid selection for resistance in one-host ticks.

The number of tick generations that are required to generate a resistant tick population varies depending on the chemical class (mode of inheritance of the resistance alleles), frequency of applications, acaricide efficacy, acaricide application errors (Rodríguez-Vivas, Jonsson and Bhushan, 2018).

Operational practices and biological factors promote the selection of naturally occurring resistance traits in tick populations, with human activities exerting selection pressure. Meanwhile, favourable climatic conditions accelerate the emergence of resistant generations because of shorter life cycles (Githaka *et al.*, 2022).

Current methods for diagnosis and monitoring of acaricide resistance

When the recommended treatments do not appear to be effective in the field, the first step is to ascertain that the product is being used correctly. Subsequently, investigation of resistance status using diagnostic tests is recommended. Although we have seen that results of *in vitro* tests do not necessarily correspond exactly with *in vivo* tests, evaluation of *in vitro* resistance profiles using bioassays are recommended first and foremost for the extent of their results on a population scale and a wide range of compounds while remaining realistically feasible.

Acaricide-resistant strains of ticks can be diagnosed with internationally accepted test protocols, and diagnostic

procedures should be standardized to facilitate continuous monitoring and provide a basis for comparing test results overtime and at different locations. Following the advice of experts since 1971, FAO has promoted the use of the larval packet test (LPT) for field investigations of acaricide resistance (FAO, 1971, 1977, 2004). However, other methods have been developed and continue to be used and modified (e.g. larval immersion test [LIT] and adult immersion test [AIT]).⁵

The selection of bio-assay technique depends on several factors, including the quantity of engorged female ticks available, the time between collection and sample arrival at the laboratory, the number of acaricides and concentrations to be tested, and the laboratory's capability to implement specific techniques, considering equipment availability and access to reagents and acaricides. Reliable tick resistance tests are conditional on high-quality field samples. Veterinarians, extension personnel and farmers may require guidance for the proper collection, handling and submission of tick samples to ensure suitable test materials to reach diagnostic laboratories. Barriers to the use of diagnostic tests exist and vary from region to region. These notably includes the lack of access to testing laboratory, the procedure for collecting and sending the ticks and the cost of the test.

⁵ A questionnaire circulated among the FAO Community of Practice on Acaricide Resistance Management in Livestock Ticks in 2023 revealed that the method most widely used in 33 laboratories involved with the diagnosis of acaricide resistance worldwide was the larval packet test (LPT) (48 percent), followed by the adult immersion test (AIT) (33 percent) and the larval immersion test (LIT) (18 percent).

The protocols for tick sampling and available bioassays suitable for detecting acaricide resistance in livestock ticks are described in detail in [Technical documentation](#) – Diagnosis and monitoring of acaricide resistance (FAO, 2025).

Larval packet test (LPT)

The LPT is based on protocols developed and published by Stone and Haydock (1962). It is the most repeatable bio-assay for many of the acaricides in current use, although it is limited by the time it takes. Hence, it remains the test of choice for surveys and resistance diagnosis. The LPT to diagnose resistance in one-host ticks requires approximately six weeks from the collection of the engorged females to the tick larvae to be exposed to chemically impregnated filter papers and their subsequent mortality is quantified after a specified period (depending on the API). Protocols are available for all chemical classes of acaricides except for AGR such as fluzuron because such compounds interfere in the moulting process of ticks, which is not considered in the LPT.

Larval immersion test (LIT)

This larval bio-assay was originally developed by Shaw (1966), and subsequently modified for ML by Sabatini *et al.* (2001), who immersed tick larvae inside microcentrifuge tubes (m-LIT). This technique is more sensitive for the diagnosis of resistance to ML compared to the LPT (Klafke *et al.*, 2006, 2012; Sabatini *et al.*, 2001). The LIT provides a result in approximately six weeks, the same time as the LPT. The inability of the LPT to diagnose potential resistance to fluzuron also applies to LIT.

Adult immersion test (AIT)

The AIT is a bio-assay applied to engorged adult female ticks. The AIT was described by Drummond *et al.* (1973) and used as a screening bio-assay to determine the relative effectiveness of new acaricidal classes against several tick species. In this assay, the *in vitro* efficacy of an acaricide is assessed by evaluating the reproductive performance of treated engorged female ticks, specifically focusing on the reduction in egg production and egg viability. Results are typically obtained two weeks post-test. Acaricides can be applied at laboratory-defined (dose-response assays or discriminating doses assays) or label-recommended concentrations. The AIT requires the collection of a higher number of adult female ticks than for larval tests. It is presently the only method available for diagnosing resistance to the AGR fluzuron.

Other methods for resistance detection

Larval tarsal test

The larval tarsal test (LTT) offers a sensitive and time-efficient way to evaluate a wide range of compounds and

doses, making it particularly useful for studying resistance in field populations (Lovis *et al.*, 2011, 2013). Comparisons with the LPT show that the LTT produces similar resistance ratios but with lethal concentrations up to 150 times lower. This test aims to simplify the process by using multi-well plates and eliminates the need for handling moving larvae.

Syringe immersion test

The syringe immersion test (SIT) is an adaptation of the m-LIT, where the larvae are exposed inside injection syringes covered with a mesh or a piece of cloth. The main advantage of this technique is the minimum manipulation of live larvae required, as aliquots of eggs (10 mg) are allowed to hatch inside the syringes. The syringe test was first proposed to evaluate the activity of acaricides (de Souza *et al.*, 2008) and later adapted for testing plant extracts against *R. (B.) microplus* ticks (Sindhu, Jonsson and Iqbal, 2012). A direct comparison of the LPT, m-LIT and the SIT showed that, at least for amitraz, the LPT is more reliable for acaricide resistance diagnosis (Santos *et al.*, 2013). The technique is as reliable as the m-LIT for determining the toxicity of ML in *R. (B.) microplus* (Robaina, Caballero and Suárez, 2023).

In vivo testing

In vivo efficacy trials are helpful for confirmation studies of resistance detected with bioassays (Evans *et al.*, 2024; Torrents *et al.*, 2020). Also, applied with *in vitro* tests, they are fundamental for describing and characterizing resistance to acaricidal compounds when it manifests for the first time for a specific acaricide (Reck *et al.*, 2014). The test involves directly counting ticks on infested animals before and after acaricide treatment. This method can provide a measurement of the products' efficacy, at its therapeutic dose.

The practical implementation of the test in the field involves selecting representative animals with similar tick infestations for each test group, followed by administering the acaricides according to the manufacturer's instructions, considering the appropriate dosage for the animal's weight and species. After treatment, the number of ticks present on each treated animal is counted. The difference between the number of ticks of control animals and treated animals will determine the product's efficacy. For comprehensive protocols on assessing *in vivo* efficacy in controlled studies such as pen-trials or barn-trials, detailed procedures are available in the WAAVP guidelines (Holdsworth *et al.*, 2006).

Interpretation of results

Acaricide bioassays on ticks can be used to estimate the frequency of resistant ticks in a population. Two forms of analysis can be performed:

- a) In dose-response tests, the response to treatment (usually expressed as the LC_{50}) of a suspected resistant population is compared with the response of a susceptible reference strain. The ratio of the LC_{50} of the test sample to the LC_{50} of the susceptible reference strain provides the resistance factor (RF) or resistance ratio (RR).
- b) In discriminating dose tests, the tick mortality (if using the LPT or LIT) or the reduction in the fertility of adult females (if using the AIT) is quantified at a predetermined critical concentration (determined experimentally) at which 100 percent mortality of a susceptible population would be expected. Further details on interpreting the results of a bio-assay can be found in [Technical documentation](#) (FAO, 2025).

Future approaches for diagnosis and monitoring of acaricide resistance

Other approaches for diagnosis are being developed, such as:

Resistance intensity test

The resistance intensity test is a modification of the LPT and uses filter papers impregnated with commercial formulations at the concentration recommended by manufacturers, plus 5x and 10x higher concentrations. This approach is adapted from the resistance intensity protocol from the latest WHO guidelines for resistance detection in malaria vectors, which uses 1x, 5x and 10x concentrations, revealing a low, moderate and high resistance intensity, respectively (Bagi *et al.*, 2015; Jongejan *et al.*, 2024).

Molecular assays

Some single nucleotide polymorphisms (SNPs) associated with acaricide resistance have been identified in genes coding for acaricide target sites of ticks. These markers have been reported on the voltage-gated sodium channel (for SP), acetylcholinesterases (for OP), β -adrenergic octopamine receptor and octopamine/tyramine receptors (for amitraz), and GABA-gated chloride channels (for fipronil) (Castro-Janer *et al.*, 2021; Corley *et al.*, 2013; Fular *et al.*, 2018; He *et al.*, 1999; Heylen *et al.*, 2024; Jonsson *et al.*, 2010a; Jyoti *et al.*, 2016; Kumar *et al.*, 2013; Nagar *et al.*, 2016; Rodríguez-Vivas *et al.*, 2012; Vudriko *et al.*, 2022).

As an example of usefulness of genotyping using these markers, the presence of mutations in the Na-channel gene (*kdr* mutations) allows for the early detection of pyrethroid resistance-associated genes in low frequencies in *R. (B.) microplus* tick populations (Guerrero, Li and Hernandez, 2002; Stone *et al.*, 2014) or when the number or life-stage of collected ticks is inadequate to run bioassays (Thomas *et al.*, 2020).

However, correlation between the frequency of resistance-conferring alleles (molecular assay) in samples of ticks

and their resistance phenotype (bio-assay-*in vivo* testing) is not always present, limiting the practical relevance for diagnosis of current molecular assays.

THE THREAT OF ACARICIDES TO ANIMAL HEALTH AND WELFARE, PUBLIC HEALTH, AND THE ENVIRONMENT

The regulations in place in most countries and the instructions for acaricide use on labels and leaflets are designed to minimize risks to animal health and welfare, users' safety and the environment. However, despite the existence and tightening of regulations and controls, non-compliance with regulations and instructions as well as intense acaricide use can have harmful implications for food safety, toxic effects to the host-species, non-target animals and public health. There may also be negative environmental consequences of water and soil pollution (Bolognesi and Morasso, 2000; Molento and Brandão, 2022; Obaid *et al.*, 2022; Silva *et al.*, 2019; Songa and Okonkwo, 2016). Although there is no data available to assess the use of acaricides in the cattle sector nor the proportion ending up in the environment, some estimates have been made in Brazil. It has been pointed out that 15 tons of ivermectin (ML) is eliminated per year in the faeces of cattle and around 200 million litres of topical acaricide (OP and SP) are eliminated in the environment every year (Molento, 2020).

The lack of acaricide efficacy has impacted tick control towards using products at higher frequency, concentrations as well as drug combinations, and non-authorized agrochemical products, worsening these scenarios.

An overview of the potential hazards and impacts that acaricides could have on public health, animals and the environment is presented in this section. Practical measures to minimize the unintended consequences of acaricides are described in the [Technical documentation](#) – Best practice for acaricide use and application (FAO, 2025).

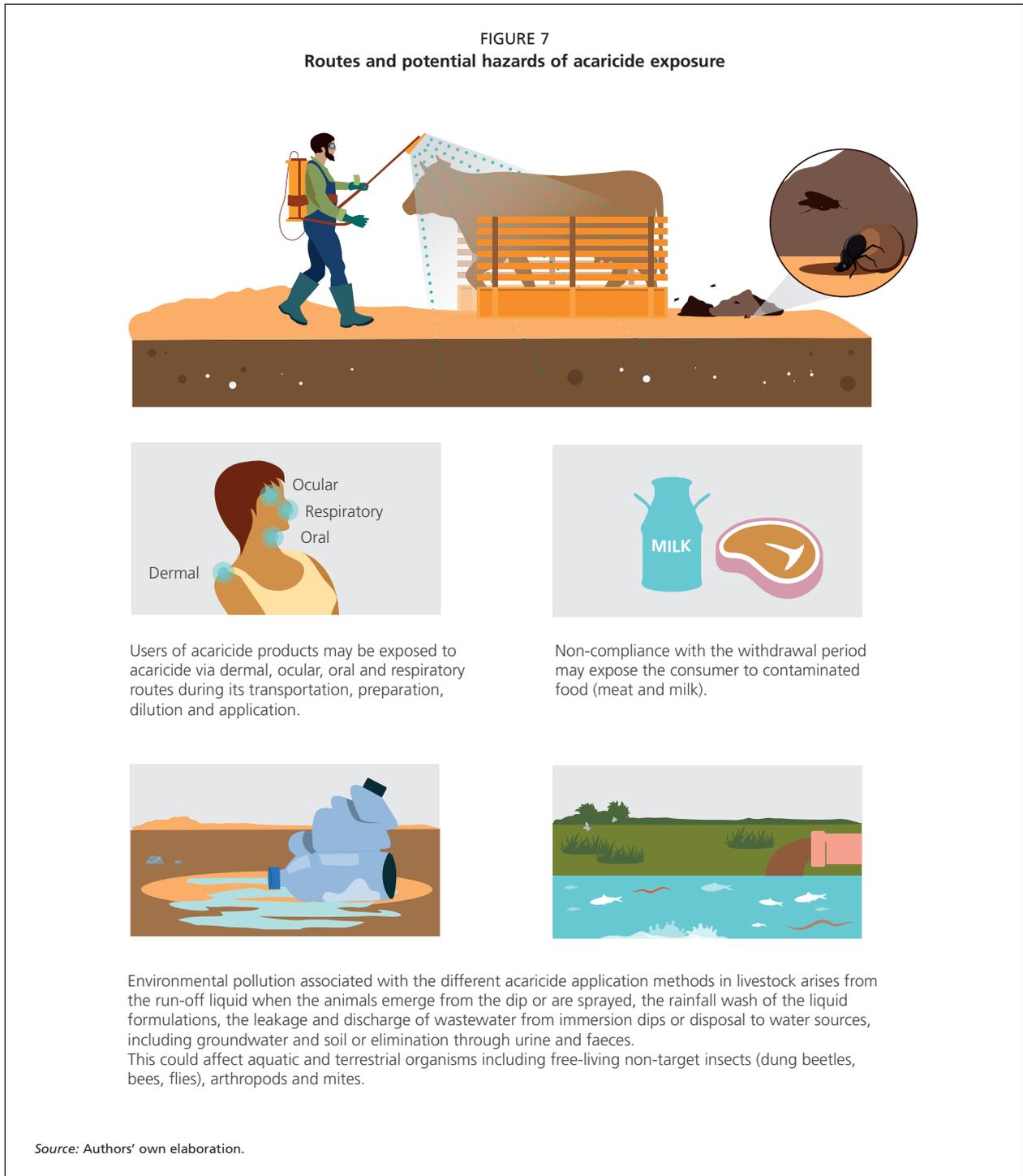
Routes and potential hazards of acaricide exposure

Personal protective equipment and general safety measures are recommended to limit the risks to the user and are adapted according to the products used. Failure to comply with these protective measures may expose people to acaricide via dermal, ocular, oral, and respiratory routes during its transportation, preparation, dilution, and during application (Siriwat *et al.*, 2021; Tudi *et al.*, 2022). WP for milk and meat is adopted to limit risk of consumer exposure to possible drug residues. Non-compliance with the WP may expose the consumer to contaminated food.

The growing awareness of environmental impact and the regulations introduced are reducing the risks that acaricide products can cause to our ecosystems and biodiversity. However, environmental regulations do not exist

everywhere and risks of environmental pollution impacting the natural resources (rivers, ponds, soil) and non-target fauna are existing especially when products are used intensively. Environmental pollution associated with the different acaricide application methods in livestock arises from the

run-off liquid when the animals emerge from the dip or are sprayed, the rainfall wash of the liquid formulations, the leakage and discharge of wastewater from immersion dips or disposal to water sources, including groundwater and soil or elimination through urine and faeces (Figure 7).



Hazards and toxicity of acaricides in human health

Acaricide toxicity is the capacity of an acaricide to produce acute or chronic illness or death, whereas risk (hazard) is a combination of the toxicity and the exposure of humans (or animals). The risk of toxicity from an acaricide depends on the mechanism of action, the duration of exposure, and the exposure dose (Avsarogullari *et al.*, 2006; Sarwar, 2015).

Unintentional acute pesticide poisoning occurs within a few minutes to several hours after poisoning by pesticides. At present, the label warnings use the WHO classification (2019) based on the acute toxicity of the commercial products, that is, extremely (Ia), highly (Ib), moderately (II), slightly (III) and unlikely to present acute hazard (IV) (see Table 2). However, long-term exposure to acaricides is usually observed in workers in places where intensive farming practices are followed (Mathews, 2016), and can be detrimental to human health (Villar and Schaeffer, 2022). Many cases of intoxication occur among farmers, rural workers, and their families especially in low and middle-income countries (LMIC) where they are unable to meet the safety requirements for the most highly hazardous products. These poisoning cases are strongly related to the intense and inappropriate use of acaricides, unsafe practices, absence of protective measures and minimum knowledge about the use of acaricides (Graf *et al.*, 2004).

Animal health and welfare

Acaricides can adversely affect cattle health and welfare when used incorrectly, or in excessive dosage. The more recently developed acaricides are generally safer than the older acaricides although some of the older acaricides are still widely used in LMIC. Potential adverse effects may include skin irritation, salivation, convulsions and death of animals. However, the main risks for animals and their welfare are those linked to the use of prohibited products in animals, such as agrochemicals only authorized for agricultural use. This is more the case in the context of multi-acaricide resistance, where farmers are forced to look for alternatives in the absence of effective registered products or other options.

Impacts on the environment

All acaricide products are biocides by definition and therefore have potential toxic effects in the environment. Use of acaricides inevitably results in some environmental contamination, which can affect aquatic and terrestrial organisms including free-living non-target insects, arthropods and

mites. This risk will depend on the degree of exposure and the properties of the acaricide products used, and the characteristics of their metabolites (toxicity, accumulation, degradation). Various factors such as climatic conditions, especially temperature and humidity, light intensity, pH and microbiological factors will influence the survival time, degradation and the possibility of distribution of the acaricide product in soil and water.

The main characteristics and known effects of acaricide products are listed in Table 2.

Particular attention may be paid to the effects on non-target organisms notably because of the extensive use of ML, which have been documented to negatively impact non-target organisms in pasture and soil environments. Residues in faeces from ML-treated animals (such as ivermectin, doramectin, etc.) have the potential to harm dung-breeding organisms (i.e. diptera, earthworms, spring-tails, mites, nematodes and dung beetles) (Lumaret *et al.*, 2012; Pérez-Cogollo *et al.*, 2018; Rodríguez-Vivas *et al.*, 2020) which are essential for the pasture and soil ecosystem (Ambrožová *et al.*, 2021). It is therefore recommended to use ML to control endo- and ectoparasites (i.e. one-host ticks) with caution especially in their long-acting formulations to minimize the impact of non-target organisms. Recommendations could be to treat during dry seasons that are periods of low dung beetle activity or that the treatment is applied to only a portion of animals in the herd at a time, and to keep animals in small paddocks for at least two weeks after the treatment. Fipronil is another acaricide widely used in agriculture, domestic animals (Villar and Schaeffer, 2022) and livestock. The detrimental effects on terrestrial and aquatic invertebrates, and indirect impacts on food chains, have led to bans or severe restrictions on its use in the European Union, China, India and the United States of America. Species highly susceptible to fipronil, such as crayfish, brown shrimp and bees, hold significant economic and ecological value (Holder *et al.*, 2018).

Although regulatory risk assessment measures adopted and the growing knowledge of the potential consequences of the use of acaricides in livestock, there is still a lack of knowledge that would allow a proper assessment of the risk to the environment. Lack of data (on acaricide use, environmental fate and effects) and models for assessing environmental exposure seriously limits the possibility of this risk assessment (EMA, 2023b). This should be considered when future regulations are being drawn up.

Part 3

Sustainable tick management

Sustainable tick management undoubtedly involves effective stewardship programmes to ensure the reasonable use and reduction of misuse of acaricide, together with good production management (i.e. nutrition, genetics, biosecurity) as a prerequisite.

Moreover, sustainable tick control in livestock can only be achieved by combining different techniques adapted to the environmental, production, economic, social, cultural and individual context.

OBJECTIVES OF TICK MANAGEMENT

Elimination and control refer to two epidemiological strategies to manage tick populations with distinct objectives and consequences.

Control of ticks is the reduction of the burden of ticks on cattle to levels of infestation at which animal health, welfare and production are not unacceptably affected; continued interventions, including biosecurity, are required to achieve those goals. The *elimination of ticks* is the complete elimination of all stages of the targeted species in a defined geographical area because of deliberate efforts. Following elimination, heightened biosecurity must be maintained through active quarantine measures on the boundaries, and surveillance within the designated area, but there is theoretically no need for continued treatments against ticks in the defined area. The term *eradication of ticks* refers to the complete and permanent elimination of the worldwide incidence of ticks of a specific species through intentional efforts, after which no further intervention measures are required. This term has frequently been and continues to be used to describe elimination programmes in specific regions. To avoid any confusion, we will retain the original names given to these programmes.

Several regional elimination programmes have been conducted for *R. (B.) microplus*, including those in Argentina, Australia, Colombia, Mexico, Puerto Rico and the United States of America. The Caribbean *Amblyomma* Program (CAP) that ran from 1994–2006 is one of the very few regional attempt to eliminate a multi-host tick (Pegram, Wilson and Hansen, 2000). These elimination programmes notably required a combination of the following: I) application of systematic fully effective treatments to 100 percent of the animals, II) restrictions on animal movement, III) review and updating the livestock inventory, IV) sampling and monitoring of cattle infestation, diagnostic of haemoparasitic diseases

and the testing for acaricide resistance, V) very strong legislation and government support, VI) farmer cooperation and VII) adequate training for personnel. While achieving and maintaining the elimination of the cattle tick from an area is challenging and costly, the long-term benefits typically outweigh the initial investment.

However, in most other parts of the world, control is the most suitable and achievable approach to manage tick populations for sustainable cattle production taking into consideration user safety, social, economic and environmental dimensions.

The potential consequences of tick reduction for the epidemiology of TBDs such as babesiosis must also be considered. Once ticks have been eliminated from an area, the population immunity to tick-borne pathogens is expected to wane and eventually disappear, meaning that a population that might have had a high level of resistance to TBDs can become vulnerable to high mortalities if the ticks are re-introduced to the area. **The objectives of tick reduction will therefore depend on the geographical location, the epidemiological situation, available resources, and farmers' needs and willingness to participate.**

CATTLE PRODUCTION SYSTEMS

The risk of tick infestation and how it is controlled will depend not only on environmental factors driven by the local geographical context but also on the production systems in place.

Cattle production systems are defined by the purpose of livestock production, the external constraints on livestock production, and the management practices used to address them. They vary considerably depending on the type of animal, purpose (i.e. milk or beef production), size of the herd, water and feed availability, cultivation and grassland utilization, cultural practices and local regulations.

Worldwide, cattle are raised for diverse reasons – economic production, subsistence, and social (Odubote, 2022; Ramírez-Rivera *et al.*, 2019; Robinson *et al.*, 2018). Most cattle raised for economic purposes are in beef and dairy production, while the provision of draft power, production of manure, provision of a form of investment, and social currency are important in less commercial systems. Cattle production systems can be specialized, such as dairy systems, beef systems and dual production. This will influence the breeding methods, the feed source for cattle, and the amount and

type of grassland utilization. In addition, it will impact cattle movements, and the tick control methods used, while ensuring the safety of the animal-sourced food products (milk and meat). **The production system, therefore, has a significant influence on the scale and nature of the problems arising from ticks** (see [Technical documentation](#) – Planning a tick control strategy [FAO, 2025]).

LIVESTOCK PRODUCTION MANAGEMENT

Nutritional management

Nutrition is a major factor in increasing the animal's resistance and resilience against parasites. A robust immune system requires a good nutritional status. Undernourished animals are prone to have greater parasite loads than well-fed ones. Feeding on good-quality pastures and strategic feed supplementation with energy and protein strengthens the acquired immune resilience to cattle ticks (Sutherst *et al.*, 1983).

Selection of hosts resistant to ticks and tick-borne diseases

Cattle hosts that are naturally resistant to *R. (B.) microplus* and other tick species have evolved through coexistence with ticks or generations of selective breeding for higher resistance. *Bos taurus* breeds are more susceptible to ticks than *Bos indicus*, *Bos javanicus* and their crosses. Hence, in tick-endemic regions of the world, it is recommended that farmers use livestock breeds that are more resistant/resilient to ticks and to be part of integrated programmes for tick control. Additionally, individual animals differ in their resistance to TTBD and hence within- and across-breed selection is another genetic improvement opportunity. Host resistance to ticks is moderately heritable (Burrow, 2015; Burrow and Henshall, 2014), meaning it will respond to genetic selection. However, cattle tick resistance and other adaptive traits (e.g. resistance to gastrointestinal parasites and biting insects, tolerance of high temperatures and humidity) are often genetically negatively correlated with productive traits. Therefore, selection to improve tick resistance should be applied through a multi-trait selection index that also includes economically important productivity traits. The main limitation on selection for host resistance against ticks is the need to measure the tick resistance phenotype, which is labour-intensive and strongly affected by temporal and spatial factors.

The reduction in acaricide treatments arising from the selection and breeding of cattle for increased host resistance is substantial (Rodríguez-Vivas, Jonsson and Bhushan, 2018). Tick larvae that attach to indicine cattle such as zebu have a much lower probability of progressing to adulthood and egg production as female larvae attaching to taurine cattle such as Holstein-Friesians. On indicine cattle, between 0.1 and 1 percent of larvae reach maturity (99–99.9 percent resistance), compared with more than

10 percent of larvae on low-resistance breeds (<90 percent resistance) (Jonsson, Piper and Constantinoiu, 2014). **As a result, the quickest improvements in host resistance can be achieved by substituting taurine cattle with zebu breeds or crossbreeds in the affected regions of the world.** Considerable progress has been made towards the identification of genetic markers for tick resistance, and there is hope that genomic selection, which has transformed dairy cattle production in high income countries (Guinan *et al.*, 2023), can soon be applied to select for host resistance to ticks in cattle (Burrow *et al.*, 2019; Cardoso *et al.*, 2021). It represents a potential for very significant impacts on the productivity, adaptation and profitability of livestock farmers' herds and flocks, while simultaneously addressing the need for improved climate resilience and mitigation.

Biosecurity

In general terms, the aim of biosecurity is to reduce the risk of introduction and distribution of diseases within and between herds or groups of animals. Biosecurity measures applied in the context of TTBD control include active quarantine and appropriate treatment of newly introduced animals, surveillance within the designated herds and area, as well as management of needle use to avoid iatrogenic transmission of blood-borne pathogens. General hygiene measures (cleanliness, boots and hands washing, manure and feed bunk management, disinfection of premises, etc.) will also be important for the general health of the herds.

TICK CONTROL PRACTICES

It is recognized that the most common method for tick control is the application of synthetic acaricides. Alongside good herd management, effective stewardship programmes should include the application of best practice in acaricide use and application (see guidance in [Technical documentation](#) – Tick management [FAO, 2025]). The treatments can be applied to pursue different strategies, including some aimed at managing resistance to acaricides. Non-chemical alternatives can also provide support for sustainable tick control, combining to form an integrated management system. Integrated tick management (ITM) should be designed to achieve long-term sustainable control of ticks and tailored to specific needs of each cattle operation (Perez de León *et al.*, 2014). Ecological and socioeconomic issues should be assessed locally before deciding on specific tick control strategies. Additionally, understanding the nuanced dynamics of human behaviour is pivotal for designing and implementing effective interventions and the adoption of policies to mitigate the increase of resistance (Githaka *et al.*, 2022; Tesfaye and Abate, 2023). It should also be noted that depending on the acaricide product used, it may act on other parasitic species and therefore interact with a strategy to control them.

Suppressive treatment

Absolute tick control is a zero-tolerance strategy implemented in tick-free zones or elimination/eradication programmes as previously mentioned. Treatments are administered at short intervals, typically a maximum of 21 days for *Rhipicephalus (B.)* species. This approach necessitates a long-term commitment and relies on a consistent supply of effective acaricides with minimal or no resistance. Therefore, ongoing monitoring of acaricide resistance is essential.

Opportunistic treatment

When livestock are gathered for general management tasks such as weaning, dehorning or changing pasture, farmers often carry out routine preventive measures, including vaccination and tick/worm control. Typically, farmers determine the timing of these treatments based on their assessments of economic thresholds for tick infestations, available time, climatic conditions, availability of personnel, acaricides and basic infrastructure.

Prerequisites: No special requirements need to be met for this approach, though it is better suited for conditions with light to moderate tick infestations.

The strategy is more effective when the chosen acaricide has a prolonged protective period and when treatments coincide with a period when a higher proportion of ticks are on the host. This approach reduces the need to gather animals frequently, thereby lowering labour requirements. Although fewer treatments and seasonal management can decrease tick burdens, they do not necessarily reduce the number of ticks on cattle enough to prevent the transmission of TBD agents. The effectiveness of this strategy in reducing tick populations is variable, as the intervals between treatments are usually too long to disrupt the tick's life cycle.

Strategic programmes

Strategic control programmes have been developed for *R. (B.) microplus*, particularly in subtropical areas with a well-defined tick season marked by a synchronous hatching of larvae in the spring from eggs laid in the autumn and winter, known as the spring rise. The core concept of these

programmes is to begin intensive treatment of cattle from the start of the spring rise, at intervals no longer than the persistent efficacy of the product used, ensuring that all emerging larvae attaching to the animals are exposed to a lethal concentration of acaricides. For effective control, treatments should continue long enough for all or most larvae in the free-living stage to die from other causes, typically a period of 16 to 20 weeks in subtropical regions. This first generation of ticks is crucial; reducing their numbers significantly impacts the size of subsequent generations. The total number of acaricide treatments depends on the cattle's tick tolerance/resistance and the larval challenge they face.

Prerequisites: Knowledge of local tick ecology and epidemiology.

Strategic programmes decrease the total number of annual treatments, leading to savings in economic and human resources and a reduced likelihood of acaricide resistance (Jonsson *et al.*, 2010b). However, theoretically, if a strategic programme is executed effectively and applied over more than one tick generation, it could result in few refugia, causing high selection pressure and rapid development of acaricide resistance. This could be true for other control strategies (e.g. threshold, selective treatment). Additionally, treatments during this period may interfere with late pregnancy and calving.

Determination of economic thresholds and use of selective treatments

A predetermined threshold of engorged female ticks per animal is established to determine when treatment is necessary (Molento *et al.*, 2013). This threshold varies based on factors such as location, season, production system, tick species, and the risk of TBD (Heesterbeek and Roberts, 1995; Schafaschek *et al.*, 2021; Sutherst and Comins, 1979). The number of ticks that should be considered when deciding to treat cattle is variable worldwide (Table 4), it should be chosen based on the treatment cost and the product's price (meat, milk) in absence of TBD on the farm. However, Smith (1983), considered that optimal infestation

TABLE 4
Economic thresholds used for selective treatments to control *R. (B.) microplus* in some countries

Country	Climate	Threshold (ticks ≥ 4.5 mm/animal)	Reference
Mexico	Tropical	30–50	Rodríguez-Vivas <i>et al.</i> (2014b)
Brazil	Tropical	≥ 30	Nicaretta <i>et al.</i> (2020)
Paraguay	Subtropical	53–54	Brizuela <i>et al.</i> (1996)
Australia*	Tropical	158	Sutherst <i>et al.</i> (1983)

* Reported tick was *R. (B.) australis*.

Source: See references.

rates appear to be between 10–40 engorged ticks/day/per animal to ensure enzootic stability to *Babesia bovis* with minimal economic losses.

Selective treatment is similar to the concept of threshold treatment, in which a portion of the herd that has a tick infestation above a predetermined threshold is treated (Molento *et al.*, 2013). Centenaro *et al.* (2022) assessed two schemes to control a multidrug-resistant *R. (B.) microplus* population on cattle under field conditions: (a) a rotational approach with six treatments per year (from spring to spring) using four different classes of acaricides, and (b) a selective treatment and rotation-based protocol where only the half of the animals with the highest tick counts were treated. The study found that both schemes resulted in lower tick counts compared to the untreated group, with no significant difference between the two treatment schemes.

Prerequisites: Local studies are necessary to determine appropriate infestation threshold levels based on tick species, their impact, the production system, the risk of TBD transmission, the animals' nutritional status, the product's value, and the cost of acaricide treatments (including cattle mustering).

Reducing the number of treatments can lower expenses and selection pressure. However, regular monitoring and occasional additional treatments for the entire herd may be required until safe, appropriate threshold levels are established for each specific situation.

Acaricide resistance management strategies

Acaricide resistance is ubiquitous, although the prevalence of resistance to specific acaricides is regionally heterogeneous. Pragmatic acaricide resistance management strategies should be designed in recognition of the fact that in some locations it might be too late to delay resistance, and the only achievable goal is to use an alternative acaricide group. Resistance management strategies have traditionally been based on the principles of moderation (using the least number of treatments possible), saturation (using a high, effective dose) and multiple attack (using more than one class of active ingredient) (Madgwick and Kanitz, 2024). Multiple attack is most often achieved using rotation of chemical groups, and strongly recommended by IRAC (Madgwick and Kanitz, 2024). Mixtures of acaricides also achieve multiple attacks, but the conditions under which mixtures are effective are more limited than for rotations (Tabashnik, 1990).

Moderation and saturation

Moderation in relation to resistance management is simply using the least number of applications possible, thereby reducing the selection pressure for resistant genotypes, and has long been known to be an important element of sustainable tick control (Madgwick and Kanitz, 2024). Sutherst and Comins (1979) recommended moderation in the

number of treatments, by using resistant breeds of cattle, and by ensuring that the timing of treatments was optimal according to rational economic criteria to make effective use of refugia (Georghiou, 1971). They also recommended saturation with acaricide at concentrations that exceed that required to kill all heterozygotes (if there was a single mutation that conferred resistance).

The recommendations regarding use of resistant breeds to achieve some moderations are straightforward, can be universally applied and are uncontested. The timing recommendations from Sutherst and Comins (1979) were firmly founded on extensive studies of tick ecology in Southeast Queensland (Australia) and cannot be directly translated into other regions without appropriate research. The recommendations in relation to saturation are difficult to implement. First, the genetic model is only relevant where there is a single target-site mutation and no other gene × gene interactions, and in most cases, the lethal concentrations in the field (not *in vitro*) for each of the genotypes are not known. Second, in almost all jurisdictions, **acaricides must be used at the label-specified concentrations, so there is no flexibility in concentration because of safety concerns discussed earlier**. An exception is the USDA-operated Cattle Fever Tick Eradication Program (CFTEP), in which a higher concentration of coumaphos is used (0.3 percent) than recommended elsewhere, specifically to deal with acaricide-resistant ticks (Davey, George and Miller, 2004), and it continues to be effective up to the time of writing.

Rotation of acaricides

The rotation or alternation of acaricides having different MoAs reduces the selection pressure for resistance to any acaricide group (Madgwick and Kanitz, 2024). When resistance appears, the frequency of resistant individuals to each chemical used will decline during the application of the alternate.

For SP products, using a strain of *R. (B.) microplus* ticks with initial low-level field resistance against deltamethrin, a rotation between deltamethrin and coumaphos did not select for strong resistance to deltamethrin over nine generations, whereas the same number of treatments with deltamethrin only selected for strong resistance (Thullner, Willadsen and Kemp, 2007).

A successful approach to acaricide rotation is generational rotation, where each generation of ticks is treated with a different class of acaricide (Centenaro *et al.*, 2022). In Argentina, Nava *et al.* (2020) showed the effectiveness of rotational treatments in controlling cattle ticks by using three different classes of drugs over one year. Generational treatment was originally designed for regions with clearly defined seasons and three tick generations per year (such as southern Brazil, Argentina, and Uruguay), its concept could be used in regions with 4 to 5 generations per year, by performing additional treatments (Centenaro *et al.*, 2022).

Although the generational treatment strategy has successfully been implemented in some countries, this strategy might be carefully considered in regions or times of the year when there are high infestations of cattle with different tick species and overlap between generations.

The theoretical basis of using rotations is very strong (Madgwick and Kanitz, 2024). The practical implementation is more challenging. Depending on infrastructure requirements and local availability, there might be logistic constraints on rotation. The frequency of rotation is also a subject of discussion, and there is little or no empirical data on which to base recommendations. Thullner *et al.* (2007) applied rotational selection to each generation in a combined *in vitro* and *in vivo* system, which was followed in field studies by Jonsson *et al.* (2010b) using a 2-month rotation interval, aiming to approximate a change with each generation. Rodríguez-Vivas *et al.* (2023) recommend rotation every 1.0–1.5 years. Given the availability of molecular markers for some of the main acaricide classes, it should now be possible to test the effect of different rotations.

Acaricide mixtures (combination products) and synergists

The regulatory view on mixtures of active ingredients varies from region to region. The combination of drugs in mixtures is done for many reasons and the terminology around mixtures is important from a regulatory perspective. Hertzberg and MacDonell (2002) provided the US EPA's definition of synergism as "When the effect of the combination is greater than that suggested by the component toxic effects. Synergism must be defined in the context of the definition of 'no interaction,' which is usually dose or response addition". Most mixtures of acaricides have been formulated to address multi-resistance in ticks and to exploit a company's product range rather than to exploit any synergistic effects, so are simple mixtures. Mixtures of acaricides can theoretically reduce the rate of evolution of acaricide resistance based on the "redundant kill" principle (Madgwick and Kanitz, 2024): "an individual that is resistant to one insecticide would be killed by the other", given the likelihood that one individual tick will not have resistant alleles to two chemicals with different MoAs (Githaka *et al.*, 2022). Mixtures can also be synergistic. The following synergistic combinations of acaricide have been demonstrated to control ticks: amitraz and fipronil (Prullage *et al.*, 2011), amitraz and permethrin (Li *et al.*, 2007), amitraz and deltamethrin (Barré *et al.*, 2008). Enzyme activity inhibitors such as piperonyl butoxide (PBO) (a cytochrome P450 monooxygenase inhibitor) (Li *et al.*, 2007) can mitigate metabolic resistances (Showler, Garcia and Caesar, 2020). Studies have shown that PBO at a reduced concentration enhances the effectiveness of amitraz, permethrin, deltamethrin, coumaphos and ivermectin on a resistant

strain of *R. (B.) microplus* (Li, Davey and Miller, 2010; Rodríguez-Vivas *et al.*, 2013; Shakya *et al.*, 2022).

It's important to note that mixing acaricides yourself can pose safety risks to the treated animal. Therefore, it is advised against creating its own mixtures and recommended to strictly follow the instructions displayed on the product label.

NON-CHEMICAL TICK CONTROL

A range of non-chemical control methods is currently available on the market or in the development stage. This section will help us to understand their principles, advantages and disadvantages.

Anti-tick vaccines

Among non-chemical tick control approaches, anti-tick vaccine(s) are viable alternatives, with all commercialized vaccines developed until now for the control of *R. (B.) microplus* based on the Bm86 antigen.

Principle: Bm86 is a glycoprotein antigen located in the gut of ticks. When inoculated into cattle, it stimulates the production of antibodies. These antibodies, when ingested by ticks, cause damage to their gut, resulting in decreased survival, reduced egg production and lower hatchability of eggs. As a result, tick populations gradually decrease over time. However, for the *R. (B.) microplus* species complex, this approach has limited direct impact on tick mortality.

Two vaccines were placed on the market in the 1990s, TickGARD^{®PLUS} (Australia) and Gavac[®] (Cuba) (Pereira *et al.*, 2022), one in 2017, Bovimune Ixovac[®] (Mexico) and Bm86 immunomodulator in the United States of America (Perez de León *et al.*, 2018), all containing a single recombinant glycoprotein Bm86. Currently, only two Bm86 vaccines are still on the market, Bovimune Ixovac[®] in Mexico and Gavac[®] in Angola, Cuba, Ecuador, Mexico, Nicaragua and Panama. Field challenge studies of commercial vaccines show a reduction in the need for synthetic acaricides to control *R. (B.) microplus*, with up to 87 percent reduction in the case of Gavac[®] in Cuba (Valle *et al.*, 2004). Two or three initial doses and a booster every six months with Gavac[®] provided protection in cattle vaccinated in Cuba (Vargas-Hernández *et al.*, 2018). Vaccine efficacy for *R. (B.) microplus* species complex appear to be variable in different geographical regions (Pereira *et al.*, 2022). In Australia, the TickGARD^{®PLUS} vaccine was shown to result in a 56 percent reduction in tick numbers in the field over one generation, with a 72 percent reduction in reproductive efficiency (Jonsson *et al.*, 2000). However, despite strong interest in the product among dairy farmers in tick-infested areas, the declining size of the market limited the commercial interest. On more extensive beef cattle properties, the requirement for frequent booster vaccinations makes the product relatively less appealing than conventional acaricides. The lack of appeal to beef producers and the small number

of users in the dairy industry did not justify continued manufacture and supply of the product in Australia.

Although several tick vaccine research trials have shown higher efficacies and longer protection using alternative non-Bm86 antigens, no new antigens have been commercialized so far as companies tend to focus on registering new broader spectrum drug treatments rather than developing new anti-tick vaccines (de la Fuente and Estrada-Peña, 2019).

Prerequisites: Before recommending the large-scale use of anti-tick vaccines, a cost–benefit analysis should be conducted at the farm level. These vaccines need to be used within an integrated tick control programme with close technical support.

Advantages: Anti-tick vaccines are designed to reduce tick populations, thereby decreasing the frequency of acaricide treatments and the associated risk of acaricide resistance. They are a safe method of tick control, as they do not produce residues that could contaminate the environment, milk or meat, nor do they pose a risk to human and animal health (Willadsen, 2004).

Disadvantages: Bm86 vaccines targeting the *R. (B.) microplus* complex primarily reduce tick populations but lack the immediate knock-down effect of traditional chemical acaricides (Pereira *et al.*, 2022). This lack of immediate tick deaths may lead to initial disappointment among farmers, posing a significant barrier to adoption and marketing (FAO, 2004). For this reason, it is crucial to provide technical support to farmers so that they can understand the benefits of vaccination over a long period of time. In the process of feeding by ticks, cattle are not exposed to the Bm86 antigen, so there is no natural booster. Therefore, the currently available vaccines have a limited (and variable) duration of protection. The currently available technology is of little interest for some production systems, especially in situations of itinerant grazing (i.e. transhumant livestock).

Biological control

Biological control of ticks is using live organisms to reduce tick populations. It includes predators (i.e. birds) and other potential control methods (i.e. entomopathogenic fungi, nematodes).

Research on predators has been conducted on ants, beetles, and many bird species (Alonso-Díaz and Fernández-Salas, 2021; Ojeda-Chi *et al.*, 2011). African oxpeckers (*Buphagus africanus* and *B. erythrorhynchus*) are birds that regularly feed on ticks, with evidence of reducing tick populations (Samish, Ginsberg and Glazer, 2004). In Guadeloupe, for example, the common predators of free or parasitic stages of *Amblyomma variegatum* include birds such as grackles (*Quiscalus lugubris*), free-ranging chickens, cattle egrets (*Bubulcus ibis*), and the tropical fire ant, *Solenopsis geminate* (Kjeldgaard *et al.*, 2019). The impact of most of these predators remains limited as they are either not natural enemies or

are too generalist (Samish, Ginsberg and Glazer, 2004). However, breeding free chicken with cattle may be an interesting tick control method as they can ingest several species of ticks and up to 81 ticks per chicken per hour (Dreyer, Fourie and Kok, 1997; Hassan *et al.*, 1991).

Manual removal of ticks

The manual removal of ticks can better be applied on small-scale farms where the number of cows is low and tick-infested cattle can be managed individually (Rodríguez-Vivas, Jonsson and Bhushan, 2018). Engorged ticks, ranging from 5 to 10 mm in length, and some smaller stages, would be removed from each cattle by scraping. Removed ticks should be destroyed.

Advantages: Manual removal may decrease the frequency of acaricide treatment and therefore the acaricide resistance selection pressure and potential environmental effects are reduced.

Disadvantages: Manual removal of ticks is labour-intensive and associated with a risk of injury and of pathogen transmission to humans such as Crimean–Congo haemorrhagic fever virus (Muhammad *et al.*, 2008). Manual removal of ticks is not effective for preventing transmission of TBD, nor for substantially reducing the direct effects of infestation.

Environmental management

Environmental management is a complementary means of tick control. Pasture management and housing practices are likely to modulate parasite abundance.

Housing practices mainly relates to endophilic ticks as cracks in the walls of the barn and organic materials in surroundings represent potential hiding places. The walls should therefore be as uniform as possible with no crevices and leaf litter and piles of wood removed from around the barn. **It is worth noting that spraying the environment with acaricides to control ticks is not a sustainable and environmentally friendly method and is therefore not recommended.**

Pasture management and pasture-crop integration/alternation

Pasture spelling was implemented to starve larval ticks by rotating cattle into ‘clean’ paddocks at specified intervals. The survival duration of the non-parasitic phase in pastures depends directly on tick species, which may range from 80 days to 2 years, as well as on climate and vegetation (Nava *et al.*, 2013). This method is mainly applied for one-host ticks as the presence of alternative hosts for immature stages of multi-host ticks will limit its application.

Principle: The absence of all competent hosts (including wildlife) prevents the parasitic life cycle from occurring and mortality of the free-living stages results because of starvation and desiccation.

Depending on the weather, under tropical field conditions, *R. (B.) microplus* populations can produce five generations per year (one every 60–75 days) (Evans, 1992) with an average pre-hatching time of 30–35 days. Larvae show better activity to adhere to the potential host at 3–5 days post-hatching, indicating that the adequate time for the presence of viable and vigorous larvae in the pasture could be 33–40 days post detachment of engorged ticks (Rodríguez-Vivas *et al.*, 2014). The effect of spelling was predicted to be most pronounced under challenging environmental conditions such as high temperatures, dry seasons and sparse pasture cover. Effective rotation or resting periods are shorter in hotter climates and during dry summer months (FAO, 2004). Examples of resting period of pasture to reach an adequate control of *R. (B.) microplus* in some countries are presented in Table 5.

Portugal *et al.* (2018) reported that the alternation of pastures for livestock production and crop (i.e. corn, soy, beans) production can have a positive 3-year effect of reducing tick infestation. The authors used a tick count index, reporting that animals in the livestock areas were treated 3.3 times a year, in contrast to 1.7 times when in the crop-livestock integration system.

Prerequisites: Knowledge of tick ecology in the region and availability of suitable quality pasture and fencing.

Advantages: This method can decrease the frequency of treatments and the risk of acaricide resistance. It can be used without significantly increasing tick burdens, thereby reducing the need for intensive tick and TBD control. Additionally, its application is environmentally harmless.

Disadvantages: The location-specific nature of the effect can make the application difficult. Studies on the population

dynamics of *R. (B.) microplus* during its free-living stages are necessary. Additionally, spelling pasture might not align with the most cost-effective use of pasture resources.

Pasture burning

Fire directly affects tick populations because of the exposure of non-parasitic stages to high temperatures. Indirectly, it destroys the vegetation layer that protects the ticks (Rodríguez-Vivas *et al.*, 2014). Most of the studies showed that in the time immediately following a prescribed burn, there is a considerable reduction in the number of ticks at the burn site (Baars, 1999; Fulk, Huang and Agosto, 2022; Gleim *et al.*, 2014) as well as significant reductions of tick burden on cattle in burning-treated pastures (Polito *et al.*, 2013).

Advantages: The non-parasitic stages of ticks can be controlled by high temperatures and the layer that protects the ticks is reduced.

Disadvantages: Fire removes ground cover and increases the risk of erosion. In the long term, a pasture does not gain any additional nutrients because of a fire. Fire generally reduces the quality of pasture. Other non-target beneficial organisms (e.g. dung beetles) can also be affected. In some areas, pasture burning is illegal and may put a risk to houses or farm installations during dry weather.

Therefore, **pasture burning** is not a sustainable and environmentally friendly method and **is not recommended**. Only when pastures have a very high infestation of tick larvae, multiple tick resistance to acaricide is present in a farm, and other non-pharmacological methods are not available, burning of some pasture areas could be recommended. Farmers must talk to local authorities for permission to set a controlled fire.

TABLE 5
Resting period of pasture to reach an adequate control of *R. (B.) microplus* in some countries

Country	Climate	Resting periods	Reference
Mexico	Tropical humid and subhumid	< 32 days in rainy season > 40 days in dry season	Rodríguez-Vivas <i>et al.</i> (2014)
Venezuela	Tropical	30 days	Hernández-A <i>et al.</i> (2000)*
Mexico	Tropical humid	45 days	Cruz-González <i>et al.</i> (2023)
Argentina	Subtropical (northern Argentina)	84–119 days in spring or early summer 140–196 days in late summer, autumn or winter	Nava <i>et al.</i> (2020)

* 4-year *in-silico* simulation of rotational grazing.

Source: See references.

FUTURE ALTERNATIVE METHODS FOR TICK MANAGEMENT

Plant species that are unfavourable to ticks

Some grass or leguminous plants with acaricidal or repellent effects have been identified (Furlong, 1998; Jonsson, 2004) and might be strategically incorporated in pastures. However, using this grass as a control method still needs additional assessments for possible inclusion in schemes for ITM.

Entomopathogenic fungi

A plethora of laboratory (*in vitro*) and field studies have demonstrated the anti-tick activities of entomopathogenic fungi (EPF) applied in the environment and on experimentally infected cattle (Barbieri *et al.*, 2023; Camargo *et al.*, 2014, 2016; Nogueira *et al.*, 2020).

Principles: EPF penetrates actively into the tick cuticle and can induce high mortality, reduce fecundity and egg viability in ticks.

So far, most studies on the anti-tick activities of EPF have mainly used isolates of three fungal genera: *Beauveria* (Hypocreales: Cordycipitaceae), *Metarhizium* (Hypocreales: Clavicipitaceae) and *Akanthomyces* (formerly, *Lecanicillium*, Cordycipitaceae, Hypocreales) (Alonso-Díaz and Fernández-Salas, 2021; Ojeda-Chi *et al.*, 2011). Usually the *in vitro* acaricide efficacy of EPF is not extrapolated to field studies, but there are exceptions, for example Camargo (2016) observed an average *in vivo* efficacy of 75 percent.

However, **no entomopathogenic fungus-based product is currently registered for use in cattle.** New methods consider applying the fungus on the pasture using innovative fungal formulations and targeting the tick's non-parasitic phases (Marciano *et al.*, 2021; Mesquita *et al.*, 2020; Sullivan, Parker and Skinner, 2022). **Commercial products are currently registered for agricultural use with insecticide and acaricide indications in some regions of the world.**

Advantages: They are easily isolated from the hosts and soils and can be mass-produced at a reasonable cost, particularly for fungal submerged cultures (Jaronski and Mascarin, 2017). Myco-acaricides are suitable for organic livestock producers and are easy to apply with little toxicity to the personnel (Zimmermann, 2007a, 2007b). These fungi can be used on the pasture targeting non-parasitic phases of ticks (Marciano *et al.*, 2021; Mesquita *et al.*, 2020).

Disadvantages: Optimal formulations and delivery methods have yet to be fully developed, thereby restricting the action of EPF under field conditions. Low relative humidity, high UV radiation, and high temperature can negatively affect EPF virulence (Alonso-Díaz and Fernández-Salas, 2021; Corval *et al.*, 2021; Paixão *et al.*, 2021), reducing or not delivering the expected efficacy. Unpredictable weather (too dry or too wet periods) may cause the loss

of treatments, increasing costs with no tick reduction. The effect may take months to seasons to be measured. The introduction of external isolates can cause some kind of biodiversity disequilibrium. Cattle producers claim a lack of familiarity with using EPF to kill ticks (Sullivan, Parker and Skinner, 2022).

Entomopathogenic nematodes

Over the last 35 years, dozens of studies have been published demonstrating that entomopathogenic nematodes (EPNs) of the genera *Heterorhabditis* associated with bacteria *Photobacterium*, and genus *Steinernema* associated to *Xenorhabdus* can infect ticks, especially engorged females, on cattle or field (Filgueiras *et al.*, 2023; Kocan *et al.*, 1998; Monteiro *et al.*, 2020, 2014; Samish, Ginsberg and Glazer, 2008; San-Blas *et al.*, 2019; Singh *et al.*, 2018). EPNs applied to the soil, simulating a pasture environment containing tick-engorged females, exhibited 70–98 percent efficacy (Alekseev, Glazer and Samish, 2006; Monteiro *et al.*, 2020; Samish and Rehacek, 1999).

Principles: Nematodes search for the host (i.e. pest), penetrate through natural openings, and, in the hemocoel, release entomopathogenic bacteria that multiply and produce toxins and enzymes that kill the host (Samish, Ginsberg and Glazer, 2008; San-Blas *et al.*, 2019).

However, studies that apply EPNs on tick-infested cattle did not report good results (de Carvalho, 2008; Goolsby *et al.*, 2018). The animal's body temperature, the presence of the tick stages less susceptible to EPN infection, and the exposure to stressful abiotic factors are suggested to explain these results (de Carvalho, 2008).

Therefore, no entomopathogenic nematode-based product is currently registered for cattle use nor with specific tick indication (EPNs are currently only registered in different countries for pest control across crops).

Advantages: The current EPNs indication for agriculture use is safe for vertebrates and shows a low risk to non-target organisms. They can be used alone or in partnership with other biological or conventional pest management programmes (Golo *et al.*, 2016; Monteiro *et al.*, 2014). They do not require special application equipment and can be applied using any spray system (simple or more sophisticated). This could be a viable alternative to conventional or organic acaricides, especially in environmentally sensitive and rich areas (Shapiro-Ilan, Hazir and Glazer, 2017).

Disadvantages: The action is more restricted to infection in engorged females and application to pastures; seeking to target ticks in the non-parasitic phase could be limited. Literature highly recommends adjuvants that can protect EPNs against desiccation and incidence of ultraviolet radiation, particularly for foliar application of EPNs in agriculture. This may be a way to apply EPNs in cattle and reduce the negative impact of the biotic and abiotic effects.

Plant products and secondary metabolites

In the past, plants were the source of significant discoveries about the synthetic acaricides used today, such as pyrethroids. Numerous plant species have been evaluated for acaricidal activity, primarily from the families Lamiaceae, Fabaceae, Asteraceae, Piperaceae, Verbenaceae and Poaceae. Several studies have also identified secondary metabolites such as terpenes, stilbenes, coumarins, acids, alcohols, sulphur compounds and aldehydes in essential oils and hydroalcoholic extracts, which are associated with acaricidal effects (Gonzaga *et al.*, 2023; Molento *et al.*, 2020; Rosado-Aguilar *et al.*, 2017).

A commercial registration by the United States Environmental Protection Agency was granted for nootkatone, a sesquiterpenoid isolated from Alaska yellow cedar (*Cupressus notkatensis*). This compound demonstrated repellent and acaricidal potential for many tick species (Behle *et al.*, 2011; Bharadwaj, Stafford and Behle, 2014; Carr and Salgado, 2019; Dolan *et al.*, 2009; Flor-Weiler, Behle and Stafford III, 2011) including *R. (B.) microplus* (De Oliveira Souza Higa *et al.*, 2023). Studies have also advanced in understanding the mechanism of action involved related to GABA receptors (Norris *et al.*, 2022).

In some countries, plant-based formulations for humans as personal repellents are commercially available. For example, MyggA Natural® from Sweden (Corymbia citriodora oil with a minimum of 50 percent p-menthane-3,8-diol [PMD]), Citriodiol® from the United Kingdom of Great Britain and Northern Ireland (64 percent PMD), and Ixodes® from Mexico (Neem extract) are being used for tick control.

Principles: Plant secondary metabolites can protect against biotic and abiotic stress and attract pollinators. However, they can also inhibit tick feeding or chitin synthesis and decrease tick growth, development and reproduction.

Advantages: Bioactive metabolites could represent an alternative for the control of ticks mainly to control ticks resistant to conventional acaricides and be composed by locally available plants.

Disadvantages: Compounds in extracts, particularly essential oils, exhibit substantial variability because of diverse biotic and abiotic stresses, significantly influencing their efficacy (Gonzaga *et al.*, 2023). Plants of the same species can vary in genotype, and some may possess distinct chemotypes, resulting in differences in acaricidal efficacy (Monteiro *et al.*, 2017; de Oliveira Cruz *et al.*, 2013; Peixoto *et al.*, 2015; dos Santos Soares *et al.*, 2016). Further, circadian and seasonal interferences contribute to variations in both chemistry and acaricidal activity (Camara *et al.*, 2023; Silva Lima *et al.*, 2018). Identifying the active compound in essential oils or extracts proves challenging because of the antagonism or synergism among compounds, hindering their use as quality control markers in some countries. Although it is widely touted that plant products are safe, it is inaccurate

to assume that all natural compounds are inherently safe (Gonzaga *et al.*, 2023). These factors demonstrate that the recommendation for farmers to prepare their own extracts and apply them to animals lacks reliability regarding efficacy, quality and safety.

The development of new biopesticides and the extension of their use will require further research as well as the evaluation of the cost benefits.

REGULATORY REQUIREMENTS FOR NON-CHEMICAL TICK CONTROL PRODUCTS

Main guidelines are available for immunologicals and biological products (EMA, CFR, VICH). However, in some countries, the VMP regulations apply to biologicals, in others no regulations exist for this type of product. Regulations for biological products will have to evolve with the various discoveries in the future, so that safe, high-quality, effective products can be marketed worldwide. Recommendations for standardized protocols for the calculation of efficacy of alternative products for tick control are needed to establish guidelines that will lead recommendations for data to submit to regulatory authorities.

Regional landscaping of vaccine and other biological products for tick control in cattle is provided in [Technical documentation](#) – Regulatory requirements (FAO, 2025).

INTEGRATED TICK MANAGEMENT

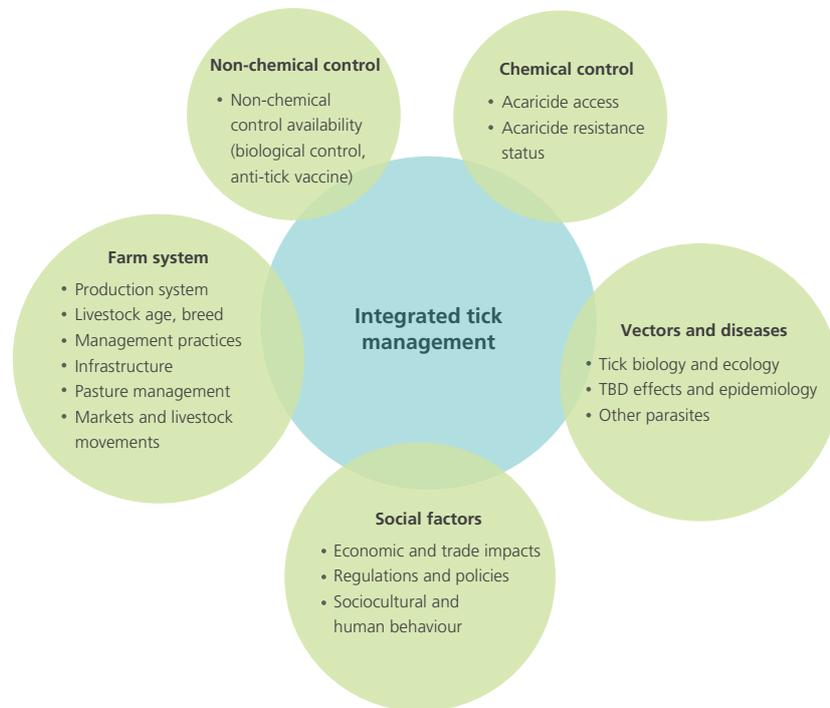
ITM, a concept that parallels the more widely used integrated pest management (IPM), refers to the combination of all available information, tools and methods to control ticks. The aim of ITM is to reduce the requirement for acaricides, thereby delaying resistance, reducing environmental contamination and potential risk for users. Integrating acaricidal control methods with biological and physical control strategies is anticipated to yield better results for tick control and delay drug resistance compared to using acaricides alone (FAO, 2004; Rodríguez-Vivas, Jonsson and Bhushan, 2018).

Successful examples of ITM implementation, and a tool to support field workers in generating appropriate recommendations for a given cattle production unit relevant to tick control are available in the [Technical documentation](#) – Tick management (FAO, 2025).

Factors to consider for implementation

Knowledge of the biogeography of the farm, including local management practices, infrastructure, tick biology and TBDs epidemiology as well as knowledge of the pharmacological and non-pharmacological control tools, and government policies, are necessary to establish the best strategies to be applied (Figure 8). In designing ITM programmes, it is also important to consider the potential for either synergistic or antagonistic elements of control programmes for other vectors/parasites, particularly where product effects might overlap.

FIGURE 8
Basic knowledge for the design of an integrated tick control programme



Source: Authors' own elaboration.

Barriers and critical elements of success or failure to implementation of ITM

Despite the potential benefits, there has been poor adoption of IPM for crop and cattle protection, particularly in LMIC. Parsa *et al.* (2014) found that the greatest obstacle to IPM adoption in LMIC was insufficient training and technical support to farmers. The lack of research investment and the prominence of pesticide-based solutions have also long been put forward as reasons for poor IPM adoption.

When setting up an ITM programme, it is important to know what the farmer's expectations are. Implementing alternative measures to chemical acaricide control requires a greater commitment of time and technique on the part of the farmer than the simple application of an acaricide, for results that are not as fast as with an effective acaricide treatment. ITM is economically justifiable, as the investment cost will be offset by increased revenue (Orr, 2003). However, its effectiveness largely depends on tick pressure and the extent of losses experienced by farmers. The return on investment from an ITM programme is often not immediately visible. Therefore, the success of an ITM programme will depend either on a "regulatory obligation", with the implementation of a regional or national programme, or

on the full involvement of the farmer, who is faced with such parasite pressure that it jeopardizes the sustainability of his business, and who has understood the need for such a programme. Further, implementing an ITM must involve farmers' groups in decision-making and programme monitoring. Involving farmers in the programme's early stages will help to ensure that the measures are implemented in the field. Finally, where possible, political support, in the form of financial and/or technical assistance, is an important asset when setting up these programmes.

The success of an integrated tick control programme depends on many factors, such as basic knowledge of the tick species affecting cattle in a region, their biology, their ecology, as well as their economic impact that they produce in livestock. For example, not all control methods for one-host ticks will be available for three-host ticks. It's also important to remember that implementing a programme against one tick species can have consequences – sometimes negative – for the other tick species and parasites present.

Models or computer simulations can also help to assess the effect of potential control programmes (Beugnet, Chalvet-Monfray and Sabatier, 1998; Wang *et al.*, 2017).

The dynamics of tick fluctuations (Rodríguez-Vivas, 2023), and their interaction with climate change, should be included in any control programme. A successful tick control strategy will depend on the interaction of biotic and abiotic factors that influence seasonal population abundance, which in turn determines tick behaviour in each region (Cruz-González *et al.*, 2023).

The chemical and non-chemical control tools available in each region or country should be analysed, as well as the cost of implementing each tool. The tick control programme should be proposed by professionals who understand the population dynamics of ticks on cattle (parasitic phase) and its non-parasitic phase, the animal production systems of the region, the existing cattle breeds, ranch infrastructure, acaricides efficacy, acaricide application forms and tick resistance problems to acaricides. All these elements will contribute to the decision to implement comprehensive measures that aim to reduce acaricide use, efficient tick control, reduce the transmission of pathogens, and reduce the selection for drug resistance (Rodríguez-Vivas, Jonsson and Bhushan, 2018).

INTEGRATING SOCIAL AND BEHAVIOURAL SCIENCES IN ACARICIDE RESISTANCE STRATEGIES

As the spread and emergence of acaricide resistance persists, addressing this issue requires an approach that extends beyond conventional biomedical perspectives. Acaricide resistance is influenced by diverse social, cultural, individual, economical, and environmental factors (Perez de León *et al.*, 2021; Perveen, Muzaffar and Al-Deeb, 2021). Addressing this complexity requires collaboration across disciplines, including social and behavioural scientists.

In recent years, the role of social and behavioural science in addressing complex problems has gained increasing recognition (Johansson, Mysterud and Flykt, 2020; Laing *et al.*, 2018). Understanding the nuanced dynamics of human behaviour and its effects on acaricide usage and tick control strategies is pivotal for designing and implementing effective interventions and the adoption of policies to mitigate the increase of resistance (Githaka *et al.*, 2022; Tesfaye and Abate, 2023).

Efforts to address acaricide resistance often depend on fostering behaviour change at various levels, such as farmers' choices regarding the selection, application, frequency of acaricide use and tick control practices (De Meneghi, Stachurski and Adakal, 2016), the retailers selling acaricides for animal health management (Mugabi, Mugisha and Ocaido, 2010), consumer demand for pesticide-free or organic products (Quadros *et al.*, 2020), and to policymakers to articulate regulatory policies governing the registration, sale, and use of acaricides and relevant control strategies (FAO/WHO, 2021).

Despite the increasing recognition of achieving behaviour change across these levels, our strategies to manage acaricide resistance frequently remain limited to educational and awareness-raising approaches (Grisi *et al.*, 2014; Rodríguez-Vivas *et al.*, 2017). These approaches aim to inform individuals about the significance and benefits of certain behaviours and how to enact them correctly. However, these strategies implicitly assume a direct, positive correlation between increased knowledge/awareness and behaviour change. While the assumption that knowledge directly translates into behaviour change is not inherently incorrect, it oversimplifies a complex relationship influenced by a multitude of factors.

Behavioural science is an interdisciplinary field that applies theories, methods, and empirical evidence from psychology, anthropology, sociology, economics and other related disciplines to understand human behaviour, how they make decisions and respond to programmes, policies, and incentives (United Nations Innovation Network, 2021).

In the context of acaricide use, farmers' decisions may be shaped by factors such as past experiences, access to information and animal health services, and risk perceptions (Hlatshwayo and Mbat, 2005). Similarly, commercial distributors or marketers may influence the use of acaricides by farmers when offering acaricides (FAO, 1998; Lopez-Arias *et al.*, 2014; Moyo and Masika, 2009).

Behavioural mapping is a systematic approach to identifying behaviours targeted for change within specific contexts. By mapping behaviours, it is possible to define areas where interventions may be most effective.

Example: In the context of acaricide resistance in livestock farming, behavioural mapping could be done by observing and documenting farmers' practices related to TTBD biology and acaricide use (Garforth, 2015; Namgyal *et al.*, 2021).

Behavioural mapping helps identify common practices contributing to acaricide resistance, such as over-reliance on a single type of acaricide, improper application techniques, limited implementation of tick control strategies, using acaricides as the sole control method and inadequate training and education.

Identifying root causes: Social and behavioural science offers a wide range of tools and methodologies for identifying the root causes of behaviours, including social dynamics, individual characteristics, cultural norms, economic constraints, environmental influences and structural barriers.

Example: Farmers may already know about alternative tick control practices but prefer those they are familiar with (Mingolla *et al.*, 2019). This is referred to as status quo bias, which is considered as an emotional preference of some individuals who hold to maintain the current or previous situation or a preference not to undertake any action to change this current or previous state (Samuelson and Zeckhauser, 1988).

Intervention design: A key emphasis of social and behavioural science is designing interventions that are human-centred and contextually relevant. This approach recognizes that successful behaviour change initiatives must account for the diverse needs and preferences of the target group. This is best accomplished using participatory processes to involve stakeholders in intervention design. Interventions are more likely to be accepted, adopted, and sustained over time (Bishop *et al.*, 2023).

Monitoring and evaluation (M&E) methods: social and behavioural science draws upon methodologies from psychology, economics, and other quantitative social sciences to develop robust M&E methods. These approaches enable stakeholders to systematically assess the impact of interventions on behaviour change and outcomes (Biesheuvel *et al.*, 2021).

Example: Utilizing psychological assessment tools, such as surveys measuring farmers' risk perception and attitudes towards acaricide use, as part of their M&E methods. A study on farmers' practices and knowledge of tick management reported that, despite significant field experience, farmers in a region of France have limited spatial awareness and understanding of ticks and TBD, resulting in inadequate control practices (Dernat *et al.*, 2021).

For a detailed review of the incorporation of social and behavioural sciences in intervention design, please consult the guidelines found in the [Technical documentation](#) – Tick management (FAO, 2025). These guidelines provide guidance on the use of a mixed methods approach to contextualize and understand acaricide use and how to use results from this approach to develop and evaluate behaviour change interventions.

Part 4

Collective pathway for sustainable tick control and acaricide resistance management in livestock

VISION, GLOBAL GOALS AND KEY OBJECTIVES

A “collective pathway” seeks for advancements in developing and implementing multi-sectoral (national/regional) initiatives to address ticks and manage acaricide resistance in livestock by emphasizing strategic priorities. This collective pathway was based on an initial gap analysis, which led to a vision, three global goals and six key objectives representing the strategic pillars of this collective pathway. Specific recommendations on future priority actions were

then developed for the six key objectives for the short (0–5 years), medium (5–10 years) and long-term (10 year - +). Furthermore, a “research agenda” was developed to provide cross-cutting support for these key objectives. This exercise was made by the FAO expert group for sustainable tick control and acaricide resistance management in livestock and subsequently submitted to the FAO community of practice on acaricide resistance management of livestock ticks for consultation.

The shared vision is a world in which ticks and acaricide resistance no longer jeopardize food safety and security, animal welfare and global health.

Cooperation between all stakeholders is encouraged to collectively develop economically, socially and environmentally sustainable solutions that strengthen the efficiency and resilience of agrifood systems.

The ultimate goal is to improve living standards for everyone, with emphasis on supporting the most vulnerable populations.



Key objectives	Specific recommendations	Key driving forces
Reinforce diagnostic and surveillance of ticks, tick-borne diseases and acaricide resistance (AR)	Short-term <ul style="list-style-type: none"> Set up FAO reference centres at the regional level supporting a network of diagnostic laboratories working under FAO recommendations to: <ul style="list-style-type: none"> Ensure AR testing protocol alignment. Ensure access and regular updates of diagnostic instructions and protocols. Reinforce inter-laboratories collaboration. Enhance the coverage of diagnostics and implementation of management strategies. Facilitate laboratory capacity building and enhance laboratory quality standards. Stimulate reflection on sustainable business models for diagnostics. 	<ul style="list-style-type: none"> FAO (HQ, regional, national)/FAO reference centres/laboratories/WOAH (Performance of Veterinary Services Pathway)/multilateral agencies/subregional agencies
	Mid-term <ul style="list-style-type: none"> Establish monitoring capabilities at the regional/country level. 	<ul style="list-style-type: none"> National public authorities/ intergovernmental organizations and multilateral agencies/FAO reference centres/pharmaceutical – private sectors
	Long-term <ul style="list-style-type: none"> Develop integrated surveillance systems for ticks, TBD and AR that combine advanced technologies and predictive models to allow monitoring, risk assessment and adapted intervention strategies. Monitoring systems for acaricide use allowing to track progress associated with stewardship efforts across regions. 	<ul style="list-style-type: none"> National public authorities/research Institutions and laboratories/ intergovernmental organizations and multilateral agencies/pharmaceutical sector
Enabling best practices, responsible use of acaricides and integrated tick management	Short-term <ul style="list-style-type: none"> Ensure adaptation of the global guidelines at regional, national, and local levels while ensuring their alignment. Invest in training of stakeholders involved in tick control (retailers, animal health professionals, end users). Ensure regular updates of global guidelines supported by a sustainable advisory expert panel. 	<ul style="list-style-type: none"> National public authorities/FAO (HQ, regional, national) and other Intergovernmental organizations and multilateral agencies National public authorities/ intergovernmental organizations and multilateral agencies/pharmaceutical sector FAO
	Mid-term <ul style="list-style-type: none"> Incentivize proper use of acaricides through training and certification. Integrate behavioural and social sciences in tick control strategy design for better acceptance and implementation. Illustrate feasibility and long-term added value of ITM at farm level. Promotion of the diversification of tick control methods and integrated tick management supported by tools development to facilitate implementation at the farm level. 	<ul style="list-style-type: none"> National public authorities National public authorities/research funding agencies/ research institutions Veterinary services/research institutions/pharmaceutical sector/ national public authorities Veterinary services/research institutions/pharmaceutical sector/ national public authorities/ intergovernmental organizations and multilateral agencies
	Long-term <ul style="list-style-type: none"> Ensure M&E of tick control strategies while allowing accessibility of data on sales and consumption of acaricides. Improve geographical coverage and quality of veterinary services. 	<ul style="list-style-type: none"> National public authorities/ pharmaceutical sector/research institutions and laboratories

(Continues)

Key objectives	Specific recommendations	Key driving forces
Increase stakeholders' awareness and empowerment	Short-term <ul style="list-style-type: none"> • Ensure guidelines dissemination, access and knowledge-sharing to all stakeholders. • Promote and incentivize translation and simplification of the scientific content on tick control. • Support awareness of AR testing options, their added value and accessibility. 	<ul style="list-style-type: none"> • FAO/FAO community of practices/ WOAH/national public authorities • Research funding agencies/research institutions/national public authorities • Veterinary services/veterinary faculty – paravet schools/pharma and private sector/laboratories
	Mid-term <ul style="list-style-type: none"> • Develop up-to-date and customized educational materials based on specific audiences and aligned with the global guidelines to provide best practices recommendations for tick control and AR management. • Enhanced capacity of local extension services, veterinary organizations and schools to provide effective and up-to-date training on tick control and resistance mitigation to professionals. • Create evidence-based information for global communication of cattle tick AR risks. • Improve access to knowledge by developing simple and attractive communication tools (mobile app, social media content, web page, comics, podcasts...) while ensuring basic communication infrastructure. 	<ul style="list-style-type: none"> • Research Institutions/private sector/ sponsor/national public authorities • National public authorities/veterinary faculty – paravet schools/pharma and private sector • Research institutions/national public authorities • National public authorities/ intergovernmental organizations and multilateral agencies/research institutions
	Long-term <ul style="list-style-type: none"> • Develop and use fact-checking tools specific to tick management. 	<ul style="list-style-type: none"> • Research institutions/private sector
Develop new and innovative solutions for tick control and AR management	Short-term <ul style="list-style-type: none"> • Develop and ensure regular updates of research agenda for prioritization. • Set up research networks and promote AR discussions in scientific events. 	<ul style="list-style-type: none"> • National public authorities/funding agencies/pharmaceutical sector and private sector research Institutions and associations/research funding agencies/ intergovernmental organizations and multilateral agencies • Research funding agencies/research institutions and associations/scientific societies (WAAVP, AAVP, EVPC, CBPV)
	Mid-term <ul style="list-style-type: none"> • Establish regional and international research consortium with a strategy for tick control. • Support training for early career researchers. 	<ul style="list-style-type: none"> • Research funding agencies/research Institutions and associations • Research funding agencies/ national public authorities/research institutions

(Continues)

Key objectives	Specific recommendations	Key driving forces
Strengthen drugs regulatory framework	Short-term <ul style="list-style-type: none"> Establish a platform including drug manufacturer associations, regulators and multilateral bodies at global level and local stakeholders' platform at national/regional level. Encourage countries to establish pharmacovigilance systems (WOAH, 2022). 	<ul style="list-style-type: none"> FAO and other intergovernmental organizations and multilateral agencies/regulatory authorities/pharmaceutical sector Regulatory authorities and other national public authorities/ intergovernmental organizations and multilateral agencies
	Mid-term <ul style="list-style-type: none"> Develop VICH guidelines for efficacy evaluation of acaricides and tick vaccines. Adapt product literature to include a section on resistance mitigation and safe disposal (where not already present) and classification of MoA to ease product selection. Reinforce the surveillance of substandard and falsified veterinary products through post-marketing surveys and reporting in the Veterinary Monitoring and Surveillance System of Substandard and Falsified Veterinary products (VSAFE). 	<ul style="list-style-type: none"> VICH/WAAVP Regulatory authorities/ pharmaceutical sector National public authorities/WOAH
	Long-term <ul style="list-style-type: none"> Fostering regulatory reliance between countries (regions) and globally. Strengthen regulatory bodies (training, resource), legislations and policies to ensure the efficacy, quality and safety of acaricides and biological products along the supply chain. 	<ul style="list-style-type: none"> Regulatory authorities/ intergovernmental organizations and multilateral agencies/national vet public authorities
Reinforce engagement and sustainably allocate resources	Short-term <ul style="list-style-type: none"> Perform cost-benefit analysis to demonstrate to the decision-makers impacts of tick, TBD and AR on economies and illustrate long-term added value of ITM and capacity building investment. Define M&E indicators of impact with baseline and targets. Provide policymakers with relevant information on the challenges and possible solutions (via policy brief and other communication channel). Integration of tick, TBD and AR in One Health/Quadripartite priority framework. Facilitate multi-stakeholder forum and early career professional networks at global/regional and national levels. 	<ul style="list-style-type: none"> Research institutions/intergovernmental organizations and multilateral agencies/national public authorities Research institutions/ intergovernmental organizations and multilateral agencies Research institutions/veterinary services Quadripartite/national public authorities Research institutions/national public authorities/intergovernmental organizations and multilateral agencies/sponsor
	Mid-term <ul style="list-style-type: none"> Establish international collaborative consortia and institute public-private partnerships to generate collaborative environment, synergies and opportunities. Sustainably allocate resources to support the implementation of the collective pathway including investment in research and development for sustainable tick management (see research agenda). 	<ul style="list-style-type: none"> National public authorities/ /private sector/intergovernmental organizations and multilateral agencies/sponsor National public authorities/ intergovernmental organizations and multilateral agencies/pharmaceutical – private sectors/sponsors – funding agencies/research funding agencies

RESEARCH AGENDA

Achieving TTBD control likely requires new interventions and strategies to counter acaricide resistance and reach the global goal of a world where ticks and acaricide resistance no longer jeopardize food safety and security, animal welfare and global health. Investing in innovative solutions will be critical, while the effectiveness of existing tools must be preserved.

Eight priority areas of research were identified to serve the first three pillars' objectives of the collective pathway for sustainable tick control and acaricide resistance management.

They are listed in the following agenda, which also includes ambitious target achievement in a five-year timeline.

Research area	Five-year target (2030)
<p>1 SPECIFIC BASIC KNOWLEDGE RESEARCH WITH TRANSVERSAL APPLICATION</p> <p>1-1 Generation of genomic data on ticks and endosymbionts: genomics is critical to pursue and extend understanding of tick genomic structure, reference genomes, and variability in antigen targets across different tick species and geographies and for exploring resistance mechanisms among others.</p> <p><i>Area of application:</i> resistance diagnosis, new drug target, new vaccine target</p> <p>1-2 Tick biology: Better understanding of tick biology in specific contexts is essential for the development of new control interventions especially in areas where multiple tick species coexist.</p> <p><i>Area of application:</i> tailored ITM strategy development, genetic control</p> <p>1-3 Computer sciences: foster application of computational and computer sciences in acarology by developing and validating software and tools based on Artificial Intelligence (AI), machine learning and automated technologies for accurate identification of globally important tick species.</p> <p><i>Area of application:</i> tailored ITM strategy development, host genetics, resistance diagnosis.</p>	<p>By 2030:</p> <ul style="list-style-type: none"> Centralized access to existing genetic resource is in place and benefits from research collaborations in public health and agronomic research. Availability of complete annotated genomes for the main species of tick infesting cattle <i>R. (B.) microplus</i>, <i>R. (B.) decoloratus</i>, <i>R. appendiculatus</i> <i>A. variegatum</i> and their endosymbionts. Distribution and biology of the main tick species affecting cattle is well known worldwide including in Africa and Asia. Acarology research is supported by AI tools for tick counts and identification.
<p>2 RESISTANCE DIAGNOSTIC</p> <p>Develop new fast, specific, sensitive, standardized, validated and affordable diagnostic tools</p> <p>2-1 Improved bio-assay tests</p> <p><i>Bioassays for centralized laboratory:</i></p> <ul style="list-style-type: none"> extended optimization of test for multiple tick species based on standardized protocols (LPT, AIT, RIT). modelling of the relationships between <i>in vitro</i> results and resistance in the field for optimal translation of bio-assay results into farm- applicable recommendations. development of AI tools and automation for high throughput screening. <p><i>Point-of-care bioassays:</i> The current gold standard bioassays, the LPT and AIT are not adapted for field diagnosis because they require specialized parasitological facilities and take several weeks to be completed. New simplified approaches to provide recommendations on farms are needed – for example, the use of a field kit allowing adult tick exposure for quick sensitivity testing (Jongejan <i>et al.</i>, 2024).</p> <p>2-2 Molecular test for resistance diagnosis: Identify mutations strongly associated with resistant phenotypes and develop molecular tests to monitor their presence in the field. The identification and complete coding sequences of sites of mutation from tick with resistance phenotypes would allow identifying suitable molecular markers of resistance.</p>	<p>By 2030:</p> <ul style="list-style-type: none"> Automated and standardized optimized bioassays are conducted in diagnostic labs with results available in less than 2 weeks for all main tick species of cattle. A validated point-of-care test is available for in farm resistance detection for all main tick species of cattle. Genetic profiling of resistant tick population is allowed by rapid molecular test for <i>R. (B.) microplus</i> tick for 5/7 of the current acaricide class.

(Continues)

Research area	Five-year target (2030)
<p>3 SURVEILLANCE SYSTEM AND RISK MODEL</p> <p>Identify and integrate innovative active surveillance and forecasting tools to better track, interpret and manage ticks, TBD and AR and model the impact of control measures</p> <p>3-1 Development of a formal analytical framework for information system and mapping of tick and AR distribution: Development of network for consistent data collection and information-gathering; evaluation of the data and methodology requirements for ticks and AR monitoring; standard protocol for data collection (tick distribution, resistance distribution).</p> <p>3-2 Development of models for risk analysis and risk assessment methodologies to inform policies and control strategies: Temporal model, economical model, predictive model etc.</p> <p>3-3 Development of AR information system and associated management at farm level: User-friendly, affordable, and accessible (digital) tools are needed for data collection, risk assessment and information sharing as well as to support management of tick control at farm level.</p>	<p>By 2030:</p> <ul style="list-style-type: none"> • Descriptive distribution maps and effective predictive simulation models and digital interface available at the regional level for policymakers in priority areas (areas where resistance is the most widespread). • Mobile apps will be available for management at farm level based on tick and AR risk assessment and related factors. • An accessible global interface (including digital dashboard) allows data collection and near real-time communication. • Informed models allow control strategy monitoring at the country level.
<p>4 TAILORED ITM STRATEGIES</p> <p>Develop efficient, safe, affordable and field validated innovative approaches to achieve global food safety and security through environmentally, socially and economically sustainable tick management and AR management</p> <p>4-1 Improve and validate integrated intervention strategies to optimize the use of existing tools for sustainable tick and AR management.</p> <p>4-2 Establish ITM baseline and define endpoint criteria in different environments and production systems (field trials).</p> <p>4-3 Define on-farm ITM tools: model for pasture management, acaricide choice and application (rotation, combination), farmers' behaviour and decision-making in different environments and farming systems.</p>	<p>By 2030:</p> <ul style="list-style-type: none"> • Tailored ITM strategies are defined in priority areas and supported by tools for on-farm management (e.g. pasture rotation calendar). • ITM endpoint criteria are recognized and used for control strategy evaluation (including product registration).

(Continues)

Research area	Five-year target (2030)
<p>5 DEVELOPMENT OF NEW BIOPHARMACEUTICAL ANTI-TICK SOLUTIONS</p> <p>5-1 New synthetic acaricides: The use of synthetic chemicals will continue to play an important role in controlling tick infestation and TBD. The objective is to establish a pipeline of modern ectoparasiticide molecules with new MoAs and a high animal, user and environmental safety profile.</p> <p>In addition, new formulations of existing acaricides must be explored to improve or adapt the efficacy of current ectoparasite molecules and allow a better and safer exposure of ticks to acaricide compounds.</p> <p>5-2 Anti-tick vaccines:</p> <ul style="list-style-type: none"> Establish the foundational science to enable rational vaccinology approaches for anti-tick vaccines in cattle (primary target: <i>Rhipicephalus (B.)</i> spp. with further extension to a broader spectrum of species). The identification of correlates of protection based on standardized protocol and approaches minimizing variability includes: (i) The development of a high throughput <i>in vitro</i> tick feeding platform for antigen screening in which defined baseline parameters and endpoints allow the screening of vaccinated animal sera on targeted tick stages (ii) the quantification and characterization of the immune response in the cattle host elicited by the target Ag(s) (iii) the evaluation of the vaccinal efficacy in standardized <i>in vivo</i> challenge of identified candidate Ag. Explore different components of cattle immunity to tick to identify other immunological pathways for vaccinal research. Apply new vaccinology algorithms to design vaccines with combined protective epitopes and foster vaccine formulation (e.g., nanoparticle (NP)-based formulations, lipid NP-mRNA, viral vectors, virus-like particles) research to allow development of a vaccine with a relevant schedule of vaccination, the possibility to target both tick infestations and pathogen infection-transmission, to improve delivery for better efficacy and longer residual activity (engage with behavioural science to improve vaccine adoption). <p>5-3 Alternative biocontrol: Non-synthetic compounds such as phyto-acaricides, semiochemicals and other biocontrols (e.g. entomopathogenic fungi) should be investigated. For all those models the establishment of the foundational science to enable the evaluation of quality, sustainable efficacy and safety are needed. Product development programmes will require the generation of extensive data packages including safety, efficacy and manufacturing information.</p>	<p>By 2030:</p> <ul style="list-style-type: none"> A pipeline of new biopharmaceutical anti-tick products (including synthetic chemicals, vaccines and alternative solutions) safe for use in dairy and beef cattle and for the environment and affordable for small-scale farmers in LMIC is in place. New formulations of existing resistance-breaker compounds are registered in priority countries. A new anti-tick vaccine with a consistent efficacy against tick infestation is registered in priority countries.
<p>6 VECTOR GENETIC CONTROL</p> <p>The translation of technologies developed for malaria vector and myiasis control to tick control such as self-limiting genetic transformation or gene drive, would allow reducing the use of acaricides. Further fundamental research is required to develop viable ancillary transformation methods for ticks, identify suitable genetic components and evaluate the approach using population dynamics simulations. The first viable transgenic tick strain remains to be established.</p>	<p>By 2030:</p> <p>Proof of concept of vector genetic control application for tick control is established and timelines to implementation are defined.</p>

(Continues)

Research area	Five-year target (2030)
<p>7 CATTLE GENETICS AND SELECTIVE BREEDING</p> <p>Host genetics can be used to limit the burden of parasites</p> <ul style="list-style-type: none"> • Selective breeding: Informed phenotypic profiling on a significant population size is required to improve the current knowledge of tick resistance genetics and requires practical and cost-effective definition of phenotypic indicators that are highly correlated with the level of tick infestation (currently measured by half-body tick counts). • Further high-density genome-wide sequence data from phenotyped animals will be needed for genomic selection. 	<p>By 2030:</p> <p>Breeding programmes are in place in priority countries to allow selection, including tick resistance for both beef and dairy cattle.</p>
<p>8 SOCIOECONOMIC AND BEHAVIOURAL SCIENCES</p> <p>8-1 Socioeconomic impact evaluation</p> <p>Study economic impacts of tick, TBD and AR and cost–benefit analysis (AR testing, ITM, investment) are conducted to inform decision-making at regional level.</p> <p>8-2 Social and behavioural sciences application</p> <p>Apply social and behavioural sciences to understand the most effective communication/education and implementation strategies for tick management stewardship involving perception of tick and AR and their impacts, rational acaricide use, vaccine use, breed selection strategy.</p>	<p>By 2030:</p> <ul style="list-style-type: none"> • Socioeconomic models are available for priority countries (countries where resistance is the most widespread). • Behavioural science support the deployment of integrated approach for tick control.

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These guidelines offer a comprehensive resource for managing tick control and tackling acaricide resistance in livestock. They emphasize the growing problem of acaricide resistance, which has been observed in various regions. The document provides in-depth information on tick biology, available synthetic chemical controls, and the underlying mechanisms of acaricide resistance. It stresses the importance of continuously monitoring tick populations and resistance levels to inform more effective control strategies. To address this resistance, the guidelines recommend Integrated Tick Management (ITM), a holistic approach that integrates chemical treatments with non-chemical methods. This strategy aims to reduce acaricide use, helping to slow resistance development and minimize potential environmental and public health risks. Additionally, the guidelines highlight the necessity of strong regulatory frameworks to ensure the quality, safety and effectiveness of tick control products.

In conclusion, these guidelines deliver a thorough overview of the challenges and strategies related to tick control and acaricide resistance, advocating for sustainable practices and ongoing research to improve livestock health and productivity while reducing the risks posed by tick infestations and the diseases they transmit.

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