ACCEPTABILITY OF BIOSECURITY MEASURES AGAINST BOVINE TUBERCULOSIS

Official Master in Zoonosis and One Health

2020 – 2021

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ABSTRACT

Preventive measures are one of the key elements in the control of bovine tuberculosis (bTB). The aim of this study was to evaluate veterinarians' opinions related with biosecurity measures against bTB in extensive beef cattle farms and identify most viable and appreciated measures. A bibliographic review was carried out to investigate recommended biosecurity measures against bTB. Focus group discussions with private veterinarians from two Autonomous communities of Spain, Catalonia and Extremadura, were conducted to evaluate a list of two groups of measures: biosecurity measures to avoid cattle herds interactions and biosecurity measures to avoid cattle/wildlife interactions. The Analytic Hierarchy Process was used to prioritize biosecurity measures during focus group discussions. Transcripts of the focus group discussions were analysed qualitatively by the scissors-and-sort technique. The most preferred measure related to cattle herds interactions was to cull old animals in farms. In relation to avoiding cattle/wildlife interactions, measures were ranked similarly making it difficult to prioritize any. The qualitative analysis of focus group discussions showed some concerns about the difficulty, feasibility and real effectiveness of some biosecurity measures in day-to-day practice, especially against wildlife interactions. Other topics such as the role of wildlife in the control of bTB and the eradication programme were discussed during meetings. This study is the first step in investigating stakeholders' opinions of some biosecurity measures that will help to know their acceptability and support.

1. INTRODUCTION

Bovine tuberculosis (bTB) is a chronic infectious disease of cattle caused by any species of *Mycobacterium tuberculosis* complex, being *M. bovis* and *M. caprae* the most frequent (OIE, World Organization of Animal Health, 2021). The main reservoirs are bovine species, although other domestic species such as goats (Napp et al. 2013), sheep (Muñoz-Mendoza et al. 2016; Vidal et al. 2018) and extensively raised pigs (Di Marco et al. 2012; Cano-Terriza et al. 2018a) may also act as reservoirs. In addition to domestic animals, many wild species can have a role in the maintenance of the disease. In Spain, the Eurasian wild boar (*Sus scrofa*), the red deer (*Cervus elaphus*), the fallow deer (*Dama dama*) and to a lesser extent the badger (*Meles meles*) are considered main wildlife reservoirs (Gortázar et al. 2011).

Humans can also get infected through direct contact or consumption of contaminated animal products (WHO, OIE, FAO 2017). In developed countries, zoonotic tuberculosis is not a major public health concern due to milk pasteurization and control campaigns (OIE, World Organization of Animal Health, 2021). However, in 2019, 147 confirmed cases of zoonotic tuberculosis (136 due to *M. bovis* and 11 to *M. caprae*) were reported by 26 European Member States, of which 32 were reported by Spain, but the number of cases might be underestimated (EFSA and ECDC 2021).

Bovine tuberculosis is included in the OIE list of notifiable animal diseases. The national bTB eradication program (Royal Decree 2611/1996 and amendments) is based on the routine testing and the slaughter of positive animals, with the application of movement restrictions to positive farms. Additionally, passive surveillance is carried out at slaughterhouses and animals are subject to a pre- movement test before leaving the farm, with a few exceptions (e.g., when animals are transported to slaughterhouses). Official ante-mortem tests are the intradermal tuberculin test and the gamma-interferon (IFN-γ) assay. Goat herds in contact with cattle are also tested for TB (Anonymous, 2021). Moreover, different actions to reduce TB transmission between domestic and wildlife species have been implemented, which resulted in the publication of the "Spanish Wildlife TB Control Plan" (PATUBES) in 2017 (Anonymous, 2017) and the Royal Decree 138/2020 that provides the basic regulations.

This disease has a huge economic impact for farmers and countries. In countries where bTB eradication programs are in place, economic losses are due to the slaughtering and replacement of positive animals, devaluation of meat and movement and trade restrictions (Pérez-Morote et al. 2020). Costs are attributable to testing and compensation schemes for slaughtered animals (European Commission, 2020).

Despite the eradication program has been systematically applied since the 90s, bTB is still present in Spain, with a low decrease in prevalence in last years. The incidence is different depending on the region, being the South and Central part of Spain the most affected areas (Anonymous, 2021), and according to the production type: bullfighting farms are the most affected, followed by beef cattle and dairy cattle farms (Anonymous, 2019a). Several factors may hinder the eradication of bTB, such as presence of infected wildlife species which act as reservoirs (García-Bocanegra et al. 2012; Guta et al. 2014), high persistence of *Mycobacterium* species in the environment (Santos et al. 2015) and failure of diagnostic tests to detect all the infected animals or not testing all the animals, that can lead to residual infection in farms (Álvarez et al. 2014; Guta et al. 2014; Ciaravino et al. 2021). Furthermore, sociological, economical and psychological factors may also challenge the success of control strategies (EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare) (2014)); Ciaravino et al. 2017; Ciaravino et al. 2020; Renault et al. 2020).

On-farm biosecurity is an important tool to reduce the risk of introduction and spreading of infectious diseases. Nevertheless, the implementation of biosecurity measures (BSMs) remains limited in the cattle industry (Renault et al. 2018; Villaamil et al. 2020; Moya et al. 2021). In accordance with Regulation (EU) 2016/429, biosecurity is considered a requirement in the management of livestock farms and farmers are responsible for its implementation. Nevertheless, up to date, only recommendations are available (Good Management Practices and Guidelines) at national level and there is no specific legislation on biosecurity in cattle farms. Recommended BSMs against bTB are mainly based in avoiding the entrance of infected cattle, contact with neighbouring farms and direct or indirect contact with domestic animals from other farms and wildlife (EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare) (2017)).

Biosecurity implementation requires that people adopt procedures and behaviours to reduce risks in all their working routine activities, which is influenced by their believes, technical knowledge, personal experience and perceptions of responsibility towards public, animal and environmental health, among other factors (Brennan and Christley 2013; Ritter et al. 2017; Moya et al. 2020). In addition, the perceived effectiveness and feasibility of recommended practices, financial constraints, workload and lack of infrastructures are also important factors for the adoption of BSMs (Brennan et al., 2016; Moya et al. 2020; Renault et al. 2020). It has been suggested that a collaborative approach, including farmers and other stakeholders in policy meetings, where they could express their understandings and opinions, would help gaining commitment and support (Hamilton 2019), and would strengthen their involvement in prevention, surveillance and control of animal diseases (Catley et al. 2012). Regarding bTB, some BSMs are highly costly, require maintenance and can be difficult to implement, especially in extensive beef cattle farms. Moreover, in Spain, most people consider that there are no effective BSMs to prevent interaction between cattle and wildlife (Ciaravino et al. 2017; Ciaravino et al. 2020). Therefore, it is particularly necessary to evaluate the acceptability of BSMs by stakeholders.

Factors influencing the application of BSMs have been assessed through both qualitative and quantitative methodologies such as, surveys (Renault et al. 2018; Renault et al. 2020), in-depth interviews (Brennan et al. 2016; Moya et al. 2020) and best-worst scaling exercises (Cowie et al. 2015). Qualitative methods, such as interviews and focus group discussions, can provide a complete description and understanding of behaviours and attitudes, giving a deep view of data; but normally provide a limited number of observations (Kelle 2006). In contrast, quantitative methods like surveys and questionnaires, can study a bigger sample population that allow to classify features, accurate measures, replicability and objectivity, but its capacity to explain meaning and thorough understating of the studied issue is more limited (Bryman 1984; Mason 2006). The advantages of combining both qualitative and quantitative methods are widely recognised; their combination allows to explore different aspects of the same problem, by addressing different but associated questions, and ensure that findings are grounded in people' experiences (Brannen, 2005; Kelle 2006; Broughan 2016; Catley et al 2012).

In this study, veterinarians' opinions about the acceptability and feasibility of some BSMs against bTB were assessed through focus group discussions and the Analytic Hierarchy Process (AHP) which allowed a quantitative ranking of different BSMs based on stakeholders considerations.

2. OBJECTIVES

The objectives of this project were:

1. Review recommended biosecurity measures against bTB, especially for extensive beef cattle farms.
2. Identify the most appreciated and viable biosecurity measures among the proposed.
3. Investigate the opinions of private veterinarians related with biosecurity measures against bTB.

3. MATERIALS AND METHODS

3.1. Study areas

The study was carried out in two Autonomous communities of Spain: Extremadura (South-West) and Catalonia (North-East), with 6.64 % and 0.04 % of herd prevalence and 3.27 % and 0.04 % herd incidence of bTB, respectively (Anonymous, 2021). The beef cattle production system in these areas is different. Extremadura is characterized by the "*dehesa*" landscape, a multifunctional agro-forestry system, which includes wooded pastures and scrub where livestock is extensively reared during all year (González, 2016). Mixed systems of domestic livestock species are frequent (cattle, sheep, goats and pigs) and, in some cases, game hunting activities are also carried out. In the case of pastoral leases owned by the town hall or by the municipality authority, such as the "*dehesas boyales*" of Extremadura, different farmers rear their cattle together in communal pastures, being considered as a single epidemiological unit (regarding the health controls of official veterinary services) (González, 2016; Anonymous, n.d.; MAPA, n.d.). Catalonia is characterized by mountain Mediterranean landscape (i.e., Spanish Pyrenees) and the extensive management system traditionally involves a short-term transhumance (or valley-mountain system). During summer (from May-June to October-November), cattle are moved from the lowland to the upland Pyrenean grazing areas. Often, the high mountain pastures are communal grazing grounds where different herds can be reared together (González, 2016; MAPA, n.d.).

3.2. Study design

A narrative review (Green et al. 2006) was carried out to get an overview of the biosecurity measures recommended for the control of tuberculosis in cattle farms. Results of the narrative overview were used as a basis for the selection of the BSMs to evaluate.

To investigate veterinarians' opinions on some proposed BSMs, a mixed approach was used in this study. Focus group discussions were conducted with private veterinarians from Catalonia and Extremadura to discuss BSMs related with cattle herds interactions and wildlife interactions. During the meetings, the Analytic Hierarchy Process (AHP) was used to rank the most appreciated BSMs.

3.2.1. Bibliographic review of biosecurity measures recommended against bTB

The methodology used for this narrative bibliographic review consisted in consulting different scientific articles, Good Management Practices Guidelines and official documents elaborated by the Ministry of Agriculture, Fisheries and Food of Spain regarding biosecurity measures and management practices related to tuberculosis. Documents were sourced from PubMed, Google Scholar, Science Direct databases and from the website of Ministry of Agriculture, Fisheries and Food of Spain official webpage.

Key words used for the search were: "bovine tuberculosis", "tuberculosis", "*Mycobacterium bovis*", "biosecurity measures", "control measures", "preventive measures", "wildlife", "cattle", "farm", "transmission", "interaction", "risk factors", "control" and "mitigation".

3.2.2. Focus group discussions

Participants were selected by non-probabilistic and intentional sampling, among private veterinarians with experience and knowledge in extensive beef cattle farming (i.e., working as clinicians and/or performing bTB tests). They were contacted by telephone or email and informed about the objectives of the study. Three online meetings were held: one with Catalan veterinarians in December 2020 and two with veterinarians from Extremadura between March and April 2021 (it was decided to split the meeting into two group sessions). Prior to the focus groups discussions, researchers from the Autonomous University of Barcelona (Catalonia) and the University of Extremadura met in order to decide which BSMs were the most appropriate to consider for the group discussion, taking into account the results of the narrative bibliographic review and the management practices from the area. The Catalan group was used as a pilot focus group.

Meetings were conducted through Microsoft Teams platform. At the beginning of the online meetings, participants gave their consent and agreed to be audio and video recorded. Then, moderators explained the objectives of the study, the different BSMs to be evaluated and the method used to rank them.

Recordings of the meetings were transcribed to perform a qualitative analysis. Transcripts were analysed by the scissor-and-sort technique. The first step of this method consisted in performing several readings of the transcripts and identifying those parts significant to the study question. Then, selected parts were classified into topics and summarized (Stewart et al. 2007). The most illustrative citations were translated into English and included in the results. In Annex 1 they can be found in their original language (i.e., Spanish or Catalan). Each citation was labelled as [Cn], where "C" means citation and "n" the number of the citation.

The focus group discussion conducted in Catalonia served as a pilot for the quantitative assessment (i.e., AHP). It allowed to test the discussion guide and the selected BSMs, to gain practice in moderating the activities scheduled in a session, and to detect possible difficulties in conducting the ranking.

3.2.3. Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making method (Baffoe 2019) that allows the ranking of different items (i.e., alternative choices). It is based in pairwise comparisons of two given alternatives considering different criteria (Saaty 1987).

The first step in the AHP is to define the objective, criteria and alternatives and to construct a hierarchy that represents them (Saaty 1987). In this study, the objective was to know which BSMs against bTB were preferred by the veterinarians (Figure 1). The criteria considered for the evaluation of the BSMs were: i) cost, defined as the economic resources needed to implement a biosecurity measure and maintain it; ii) practicality, defined as how easy is to implement and maintain in time the biosecurity measure; and iii) effectiveness, defined as how successful a biosecurity measure is in preventing bTB. The alternatives were different BSMs which were selected among those identified through the narrative bibliographic review. Measures related to wildlife and cattle herds were evaluated separately.

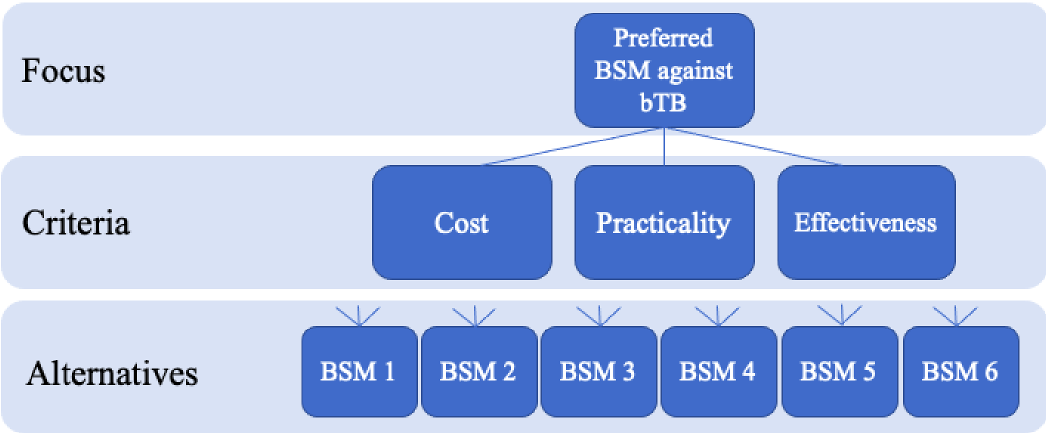

Figure 1. Hierarchy tree.

The second step was to develop a pairwise comparison matrix for the 3 criteria to establish the priority (weight) of them (Figure 2).

	Criteria 1	**Criteria 2**	**Criteria 3**
Criteria 1	1		
Criteria 2		1	
Criteria 3			1

Figure 2. Pairwise comparison matrix for the selected criteria. The entries above the main diagonal are completed with the score assigned to criteria. The lower triangular part is completed by the reciprocal of the value.

In this study, participants compared the importance of each criteria by answering questions such as: "*What is more important, the practicality or the cost of a biosecurity measure?*". In order to grade the importance of every criteria, a judgment scale from 1 to 5 was used, where one stands for the least important, and five for the most important (Table 1).

Table 1. Scoring scale for pairwise comparison (Adapted from Saaty, 1987).

Intensity of importance	Definition
1	Equal importance
2	Moderate importance
3	Strong importance
4	Very strong importance
5	Extreme importance
Reciprocals	If an alternative *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*

When performing pairwise comparisons on the *n* x *n* matrix, a score (i.e., numerical rating) was assigned to the most important item and the reciprocal of this value was assigned to the other element. Once compared all criteria, the criteria priority vector was computed: the matrix of weights was normalized (dividing each element by the sum of its column) and averaged (computing the average of each row, obtaining an average weight for each criteria) (Saaty 1987). The priority vector showed the relative importance of compared criteria.

The third step was to obtain vectors of priorities for the alternative choices, under each of the selected criteria. These vectors reflected the weight, or relative importance, of each alternative for each criteria. Three *n* x *n* matrices of alternatives were built to perform paired comparisons of the selected BSMs related to wildlife/cattle interactions and three to compare BSMs related to cattle herds interactions. BSMs were compared following the same scale used for comparisons of the criteria. In this case, participants answered questions such as: "*Between these two BSMs, which is more economic/effective/practical?".* Then, the score matrices were normalized and averaged, obtaining the average normalized scores (BSMs priority vector) that represented the weight of each BSM in relation to a criteria (Saaty 1987). Finally, to obtain the relative score for each BSM (i.e., the ranking of the preferred BSMs), BSMs scores (obtained when comparing the BSMs versus each criteria) were multiplied by the criteria weights and summed (Saaty 1987).

When using the AHP method, the consistency of the pairwise comparison matrices have to be determined. The consistency, measured by the consistency ratio (CR) determines if the decision made when prioritizing alternatives by pairs is coherent (Saaty 1987). A matrix will be consistent when its CR score is inferior to 0.1 or 0.15 for individual experts or to 0.20 or 0.25 for groups (De Marinis and Sali 2020). The CR was computed as follows:

$$CR = \frac{CI}{RI}$$

Where CI was the consistency index and RI the random consistency index. The RI refers to the consistency index of a random matrix of order *n*, where *n* is the rank of the matrix. The RI were obtained from Table 2, that shows the values calculated by Saaty (1987) averaging the random consistency index of a sample size of 500 matrices. The CI was computed as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Where n is the rank of the matrix and λ_{max} was calculated summing the columns of the pairwise comparison matrix and multiplying the result with the priority vector of the matrix (averaged normalized scores) (Saaty 1987).

Table 2. Random consistency index (RI) (Adapted from Saaty, 1987).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

As a result of conducting the pilot focus group (Catalan focus group), the list of selected BSMs was modified. BSMs evaluated in Catalonia and Extremadura were different (BSMs evaluated in the Catalan group are presented in Annex 2). Therefore, data collected in Catalonia were excluded from the quantitative analyses (i.e., AHP) and the results are not presented in this study. Although, for the purpose of this study, the Catalan focus group was considered for the qualitative analysis (i.e., the scissor-and-sort technique).

4. RESULTS

4.1. Recommended biosecurity measures and practices to prevent bTB

The proposed BSMs were selected from a total of 34 publications. 26 scientific articles recommended measures related with avoiding cattle and wildlife interactions and 4 proposed BSMs to prevent bTB transmission between cattle herds. Moreover, a biosecurity guide of beef cattle farms elaborated by the Spanish association of beef cattle producers, a chapter of a book, a document elaborated by EFSA and a document elaborated by the Ministry of Agriculture, Fisheries and Food were also consulted.

4.1.1. Practices related with the age and immunological status of animals

Older animals have a higher likelihood for reactivation of mycobacteria in infected animals (Humblet et al. 2009), are more prone to develop immunosuppression or to have chronic infections and as a consequence to develop anergy, leading to non-reactors animals and consequently residual infection in herds (Hermoso de Mendoza, 2020). Therefore, culling of older animals has been recommended to reduce the likelihood of intra-herd transmission. Some authors recommend culling ages, in bTB infected herds, between 8 and 12 years old in dairy and beef cattle, respectively (Álvarez et al. 2018).

Immunosuppression is also a known risk factor for bTB and other diseases (Humblet et al. 2009). It hinders the control of infection, facilitates the transmission and can interfere with the diagnosis, leading also to non-reactors animals. There are several causes of immunosuppression, such as coinfections with some viral diseases (e.g., Bovine Viral Diarrhoea or Paratuberculosis) (Humblet et al. 2009) or malnutrition (Hermoso de Mendoza, 2020). In order to avoid them, vaccination and deworming programmes should be implemented. Providing supplementary feed, minerals and vitamins, especially Calcium and vitamin $D_{3,}$ has been recommended to strengthen the immunological response of cattle against bTB (Hermoso de Mendoza, 2020).

4.1.2. Measures related with animal movements

Animal movements and introducing new cattle in herds have been associated with bTB breakdowns in several studies (Kaneene et al. 2002; Humblet et al. 2010; García-Saenz et al. 2014; O'Hagan et al. 2016; Pozo et al. 2020). Therefore, maintaining a closed herd (i.e., without the purchase of animals) is one of the most effective control measures. As this is challenging to achieve, other alternatives are: minimizing the purchasing of animals, performing pre or post movement testing (Humblet et al. 2010; Mee et al. 2012; O'Hagan et al. 2016) and carrying out a quarantine period in a separated area from the other animals (Mee et al. 2012). A quarantine and a post-movement test is recommended when cattle return from common pastures, where they may have been in contact with other herds, domestic species, wildlife or contaminated material (e.g., transport vehicles) (Mee et al. 2012).

In relation to the transport of animals, not sharing vehicles with animals from different sources is important (Mee et al. 2012). Vehicles must be cleaned and disinfected after loading animals and their entry into the farm should be restricted (Anonymous, 2016). In addition, vehicle drivers should avoid being in contact with animals of the farm.

4.1.3. Measures to avoid interactions with other herds

Being in contact with infected neighbour farms and sharing pastures with cattle from other herds are known risks for bTB in Spain (Guta et al. 2014) together with being in contact with other domestic animals such as goats, sheep and extensively-raised pigs (Napp et al. 2013; Cano-Terriza et al. 2018a; Vidal et al. 2018). Goat herds in contact with cattle herds have to be tested for bTB, but that is not the case for sheep and pigs (Anonymous, 2021). Proposed actions related to this aspect are: implementing exclusion measures such as the use of double fencing (with a gap that avoids nose-to-nose contact) (Mee et al. 2012; Campbell et al. 2020), separating goats and pigs from cattle (Martínez-Guijosa et al. 2021) or managing grazing pastures through changing time and use of them to avoid contact with other herds (Campbell et al. 2020).

4.1.4. Measures related with shared material and farm visitors

Mycobacterium species can survive from a few days to a few months, depending on the climatological conditions and sunlight exposition (Santos et al. 2015; Allen et al. 2021). For that reason, contaminated farm equipment, tractors or infrastructures (e.g., cattle crush) can be a risk for disease transmission (Mee et al. 2012). Therefore, cleaning and disinfecting before and after use or not sharing material between farms is recommended (Mee et al. 2012; Anonymous, 2016). Effective disinfectants against *Mycobacterium* species contain phenol-based compounds, sodium hypochlorite, glutaraldehyde, formaldehyde or peracetic acid (Anonymous, 2016; Anonymous 2019b).

Visitors can act as pathogen carriers through their clothes, boots, equipment and vehicles, thus restricting and controlling visits and providing personal protective equipment such as overalls and boots are important measures (Mee et al. 2012; Anonymous, 2016).

4.1.5. Measures to avoid/reduce domestic-wildlife interactions in aggregation points

Contact with infected wildlife is a frequent cause of bTB breakdowns (Guta et al. 2014), especially in Southern territories, where TB prevalence in wildlife is high (García-Bocanegra et al. 2012). Interaction between livestock and wildlife have been evaluated in several studies, reporting that direct inter-specific contacts are rare, being indirect contacts more frequent (Kukielka et al. 2013; Carrasco-García et al. 2016; Cowie et al. 2016; Triguero-Ocaña et al. 2019; Triguero-Ocaña et al. 2020). Studies conducted in South Central Spain found *Mycobacterium* persistence in water and mud around waterholes (Barasona et al. 2017) and water sites as the places where most direct and indirect contacts took place; being therefore a potential source of infection, especially during the dry season (Kukielka et al. 2013; Cowie et al. 2016; Triguero-Ocaña et al. 2019; Triguero-Ocaña et al. 2020). To reduce the likelihood of domestic-wildlife interaction in water points, it has been recommended to increase the number of water points and to avoid leakages and muddy areas to reduce the persistence of *Mycobacterium* species in the mud around them (Anonymous, 2016; Martínez-Guijosa et al. 2021). It has also been suggested to raise waterers, so wild boars cannot access to them, and to use top roofs in waterers for other livestock domestic species such as goats or pigs, so they cannot be used by cattle (Anonymous, 2016; Martínez-Guijosa et al. 2021).

Regarding water ponds, it has been recommended to enlarge small ponds or remove them, as it has been found a positive relation between presence of *Mycobacterium* species and small water ponds (Barasona et al. 2017). Exclusion methods such as the use of fences around water ponds have also been proposed (Walter et al. 2012; Barasona et al. 2017). Barasona et al. (2013) evaluated the effectiveness of a cattle operated bump gate and exclusion fences. Livestock-proof fences and wildlife-proof fences with a bump gate (that could be opened by cattle activation) were placed around different waterholes. Livestock-proof fences achieved 100 % effectiveness in impeding cattle access (Barasona et al. 2013).

In relation to feeding points, it is recommended not providing feed on the ground (Anonymous, 2016), as it is an associated risk to bTB (Kaneene et al. 2002; Humblet et al. 2009) and reducing its amount to minimize the amount of leftover that could attract wildlife (Knust et al. 2011). Wild boar and red deer are crepuscular/nocturnal species, although the red deer presents a diurnal activity in autumn (Kukielka et al. 2013; Carrasco-García et al. 2016), therefore, providing feed during daytime may prevent wildlife from visiting feeding points (Carrasco-García et al. 2016).

The use of selective feeders is advised, too (Anonymous, 2016). Balseiro et al. (2019) designed a calf selective feeder to avoid indirect transmission with wild boars. It had movable bars that could be adapted to calf size (in width and height), hindering access to wild boars. Authors tested its effectiveness and achieved a reduction of wild boars accessing the feeder of 97.8 % and a reduction of 56.3 % in the number of wild boards being around it. In addition, the quantity of feed that fell into the ground was reduced by the fact that calves had to put the head and neck across the bars, reducing therefore the quantity of feed on the ground and the likelihood of indirect contacts. Apart from this selective feeders, it has been recommended to use elevated feeders to impede the use by badgers or wild boars (Ward et al. 2006; Martínez-Guijosa et al. 2021).

Shared pastures and acorn fields can also be contaminated with faeces, urine and saliva from wildlife (Carrasco-García et al. 2016). When wildlife access is not controlled, grazing management measures such as avoiding grazing risk points, especially during the critical season (Martínez-Guijosa et al. 2021), and woodland edges (Carrasco-García et al. 2016) may decrease potential contacts with wildlife. Fencing risky areas could be considered, too (Carrasco-García et al. 2016).

Mineral lick blocks can be a potential point of aggregation of animals and a source of contamination due to the fact that *Mycobacterium* species can survive in salt block surfaces (Kaneene et al. 2017). Elevating mineral blocks to avoid their usage by wild boars (Martínez-Guijosa et al. 2021) or providing minerals in other type of formulas (e.g., granulate) could be preferred in extensive beef cattle farms.

4.1.6. Measures to restrict wildlife access to feed storages and farm buildings

Wildlife species are attracted to feed storages and farm buildings and can contaminate them with sputum, faeces or urine (Walter et al. 2012; Anonymous, 2017). Biosecurity measures to prevent access of badgers and deer have been extensively studied in UK and Michigan, respectively, due to the importance of these species as host maintenance in these regions (Garnett et al. 2002; Ward et al. 2010; Judge et al. 2011; Knust et al. 2011; Lavelle et al. 2015). Although in Spain the role of badgers as reservoirs is not clear, in Atlantic Spain, they may act as potential maintenance reservoirs, thus preventive measures are recommended (Acevedo et al. 2019). Badgers visits to farm buildings and feed storages can be reduced using exclusion measures such as electric fences (Ward et al. 2010; Judge et al. 2011) or metal gates (Judge et al. 2011), being very effective when they are used properly (Judge et al. 2011). Moreover, these measures can also achieve a reduction of visits to the rest of the farm (Judge et al. 2011). In relation to deer, fences and gates to protect feed can also be effective. A reduction of 82.5 % of deer visits was observed in a study carried out by Lavelle et al. (2015). However, contrary to badgers, deer continued to attempt accessing feed storages after fences were placed, which remarks the importance of maintaining fences in good condition and keeping gates closed (Lavelle et al. 2015).

In some studies carried out in South Central Spain, where they evaluated wildlife and livestock use of farm resources, farm buildings were not identified as risk points and deer or wild boars were not detected inside farm buildings or feed storages (Carrasco-García et al. 2016; Martínez-Guijosa et al. 2021), nonetheless, avoiding the entry of wildlife in farm buildings and feed storages is recommended (Anonymous, 2016).

4.1.7. Measures to avoid wildlife access to farmlands

As mentioned before, the use of farm resources by wild ungulates is frequent in South Central Spain, because of their dual use (hunting/livestock) in several of them (Carrasco-García et al. 2016). It is recommended stopping this practice (Anonymous, 2017), although conflict of interests has been reported within farms (Martínez-Guijosa et al. 2021).

Physical exclusion through fences, to impede access to farms or agricultural resources, is the most extensively studied, especially in badgers and deer. Game fencing consists in excluding large game species from the whole farm to separate farming from hunting activities (Cowie et al. 2014). To exclude cervid species and wild boars, fences need to be 2,5 m high and stapled to the ground in order to impede them jumping or passing under, respectively (Barasona et al. 2013; Martínez-Guijosa et al. 2021). These measures are highly costly and require maintenance, being one of the most expensive biosecurity measures that farms may assume (Judge et al. 2011; Lavelle et al. 2015; Martínez-Guijosa et al. 2021). Regarding Spanish legislation, Royal Decree 138/2020 allows fencing a field up to 500 hectares with a wild boar proof fence (unless it interferes with environmental laws).

Another measure is the use of livestock guarding dogs. It has been reported that they reduced the use of pastures by deer and thus direct and indirect interactions with livestock (Gehring et al. 2010).

4.1.8. Reduction of wildlife population

Reducing population of infected wildlife or other domestic species that share the same environment is also another recommended control measure (EFSA AHAW Panel (EFSA Panel on Animal Health and Welfare) (2017)). Restricting supplemental feeding and increasing hunting pressure is a measure with contradictory results. Despite in areas like Michigan, the reduction of deer population decreased deer TB prevalence (O'Brien et al. 2011) or in some areas of Spain, hunting wild boars decreased TB prevalence in sympatric wildlife like red deer (Boadella et al. 2012) and fallow deer (García-Jiménez et al. 2013), and also in cattle (Boadella et al. 2012). It has also been described that TB prevalence in wild boars can continue to be high due to the migration of species to depopulated areas (García-Jiménez et al. 2013) or compensatory reproduction of wild boars (Boadella et al. 2012).

Culling badgers is a method that has been applied in UK and Ireland, but this strategy did not worked as expected due to social perturbation in badgers and the consequent movement from the edge of culled areas, which in fact increased disease transmission and thus failure to reduce bTB incidence in cattle (Delahay et al. 2005; Carter et al. 2007).

4.1.9. Management of hunting waste

Hunting waste, generated during hunting activities, poses a risk because it can facilitate the transmission of pathogens. Management of hunting waste has been studied in the South of Spain: measures focused in proper disposal of hunting waste such as transport and disposal by incineration in processing plants or the use of avian scavengers feeding points reduced 25 % TB seroprevalence of wild boar in that area (Cano-Terriza et al. 2018b). In addition, Royal Decree 138/2020 and 50/2018 make compulsory the correct hunting waste management.

4.1.10. Vaccination

Vaccine effectiveness has been studied in some species that can act as reservoirs in different countries. Oral administration via baits with heat inactivated *M. bovis* and BCG vaccines in wild boars reduced the severity of the lesions, the infection burden and its transmission, but did not prevent infection (Garrido et al. 2011; Díez-Delgado et al. 2018). In a study conducted in Central Spain in natural and managed hunting areas, they vaccinated piglets using *M. bovis* and BCG vaccines via baits in selective feeders. The *M. bovis* vaccine achieved a 34 % reduction in TB compatible lesions prevalence in managed hunting areas (Díez-Delgado et al. 2018).

In relation to badgers, an injectable BCG vaccine has been licensed in UK since 2010 (Anonymous, 2011). Oral BCG vaccines achieved a reduction in the severity of lesions, bacterial load and dissemination of infection in vaccinated badgers after *M. bovis* challenge (Murphy et al. 2014; Chambers et al. 2017; Balseiro et al. 2020). Heat-inactivated *M. bovis* vaccine also demonstrated a protective effect when administered orally (Balseiro et al. 2020). The implementation of badger vaccination (as well as conducting a monitoring and control program) has also been recommended in Atlantic Spain where badgers may be potential maintenance hosts (Acevedo et al. 2019). With reference to deer, oral and parenteral vaccination with *M. bovis* and BCG vaccines, reduced lesions and disease severity, which may reduce TB rate of transmission between susceptible hosts (Palmer et al. 2009; Palmer et al. 2014).

4.2. AHP for biosecurity measures

Table 3 shows BSMs selected among those identified through the narrative bibliographic review, pre-tested in Catalonia and adapted to be used in the focus group discussion of Extremadura.

Table 3. Biosecurity measures evaluated in the focus group discussion with veterinarians from Extremadura.

BSMs related to cattle herds interactions
Know the origin of animals, quarantine them and perform an additional bTB test at least in case the origin is unknown, or it comes from a market or trader
Avoid sharing transport with animals from another farm
Avoid having old cows in herds (cull old animals)
Have fences that avoid interaction with neighbouring herds (double fencing)
Avoid sharing bulls
Avoid using shared cattle crush, or if shared, use it when it has been cleaned and disinfected and following health criteria (i.e., first the non-infected herd)

BSMs related to cattle and wildlife interactions
Implement exclusion fences with cattle operated devices that avoid wildlife/cattle interaction in aggregation points
Separate farming and hunting activities in farms (implement game fencing)
Adequate number of water points to reduce animal (wildlife/cattle) aggregation
Use feeders and waterers that avoid access of wildlife (with correct maintenance, avoiding leakages)
Avoid using mineral lick blocks: use granulated formulas to provide vitamins and minerals
Keep feed in a warehouse avoiding the access of wild boars and deer (proper feed storage)

Figures 3 and 5 show the ranking and the weighted final score of the evaluated BSMs obtained in the meeting with veterinarians from Extremadura. Figures 4 and 6 show the representation of the score attributed to each BSM in relation to the cost, practicality and effectiveness. The consistency (CR) of the pairwise comparison matrices was always inferior to 0.20, thus the assessment of the participants can be considered reliable. Further details on the calculations performed for AHP analysis are given in Annex 3.

The effectiveness was seen as the most important criteria (48 % of weight) followed by the practicality (35 %) and the cost (15 %).

Among BSMs recommended to avoiding transmission between cattle herds, the most preferred by the participants was "Cull old animals" (Figure 3), that is seen as the most effective, the most practical and the least expensive (Figure 4). The second most valued BSM was "Know the origin of the animals, isolating them and performing an additional bTB test", followed by "Avoid sharing transport of animals", although there was a little difference between the two BSMs (Table 5, Annex 3). The least preferred option was "Implement double fences", which was considered the least practical, the second most expensive and second least effective BSM (Figure 4).

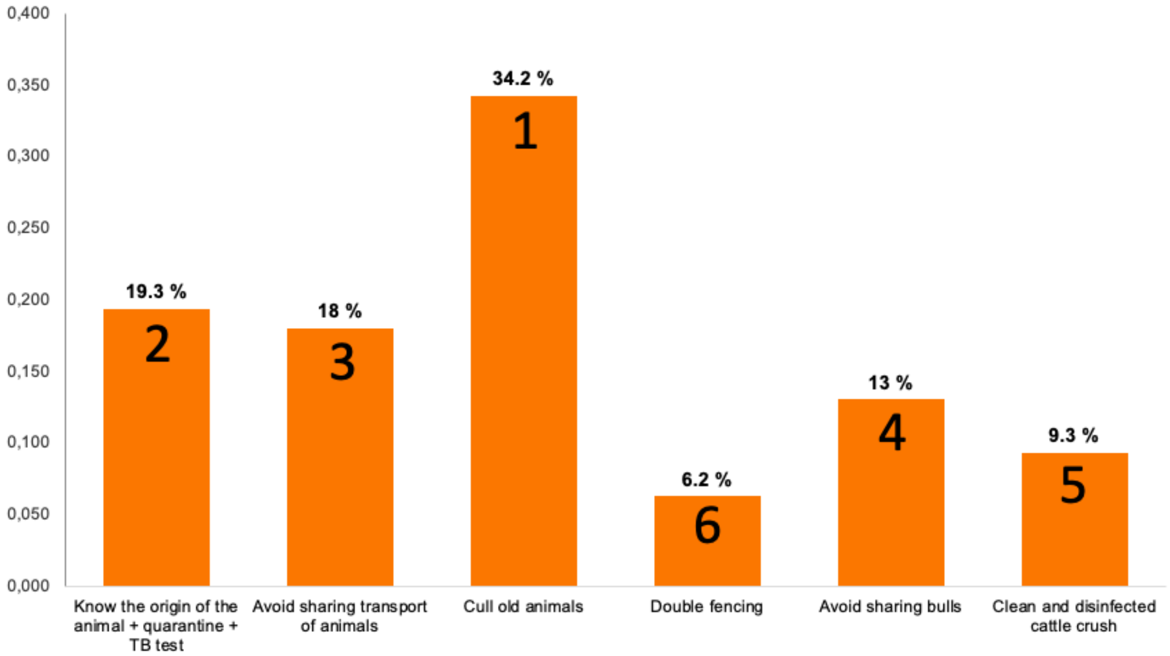

Figure 3. Ranking and weighted final score of BSMs related to avoiding interaction between cattle herds obtained in the focus group discussion of Extremadura.

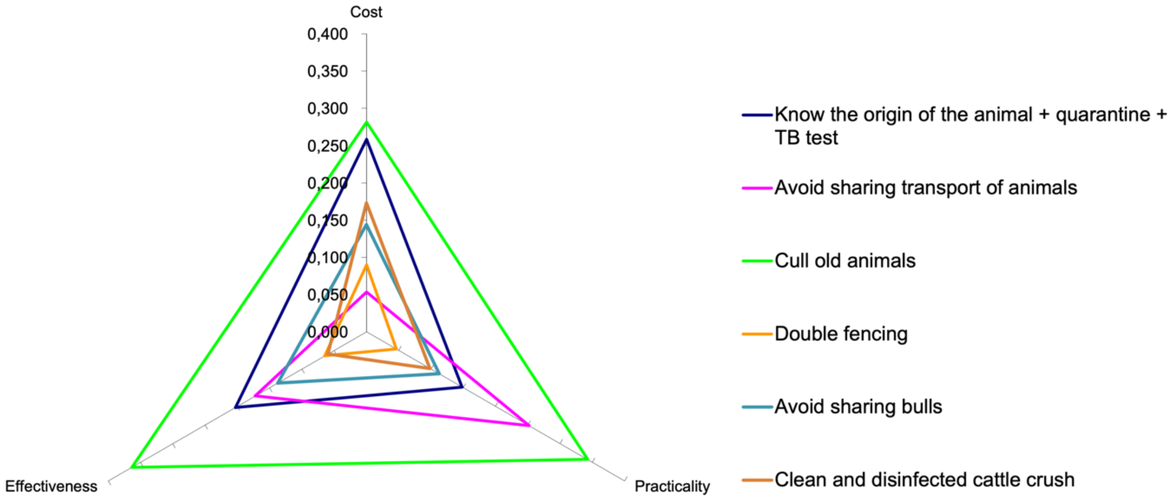

Figure 4. Score obtained by each criteria of BSMs related to avoiding interaction between cattle herds obtained in the focus group discussion of Extremadura.

The difference in the ranking scores of BSMs related to avoiding cattle interaction with wildlife was not very marked (Figure 5). Implementing a game fence to separate farming and hunting activities was viewed as the most effective but the least practical and the most expensive BSM, nevertheless it was the first BSM in the ranking (Figure 5 and 6), since the effectiveness was considered the most important criteria when implementing BSMs (Table 1, Annex 3). The second BSM in the ranking was "Implementing exclusion fences with cattle operated opening device", which was seen as very effective, but also very expensive and less practical (Figure 5 and 6). The least valued BSM was providing feeders and waterers that limit wildlife interaction, that was considered the least effective, the third most expensive and the second less practical (Figure 5 and 6).

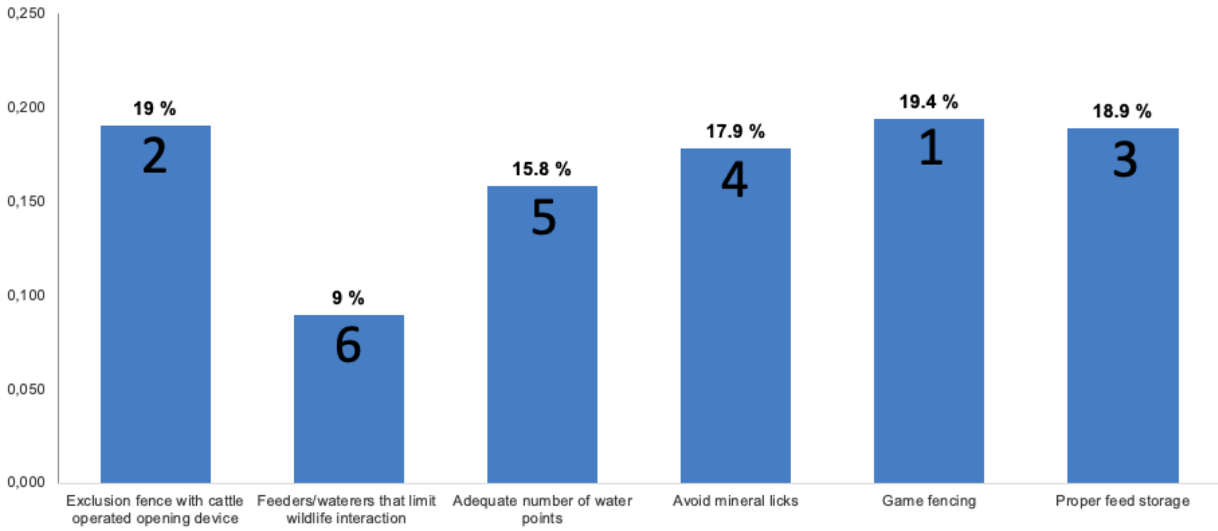

Figure 5. Ranking and weighted final score of BSMs related to avoiding interaction with wildlife obtained in the focus group discussion of Extremadura.

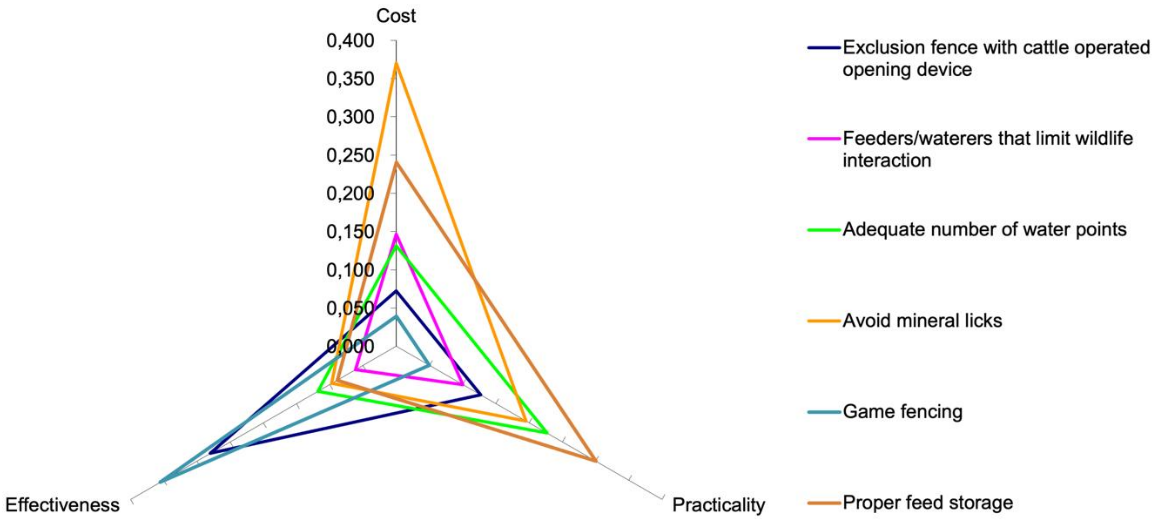

Figure 6. Score obtained by each criteria of BSMs related to avoiding interaction with wildlife obtained in the focus group discussion of Extremadura.

4.3. Focus group discussion: the scissor-and-sort analysis

All sessions lasted approximately 2 hours. Overall, 16 private veterinarians participated in the study: 1 woman and 6 men in the group from Catalonia; and 2 women and 7 men in the group from Extremadura.

4.3.1. The importance of the different criteria

Veterinarians from Catalonia considered that practicality was the most important one, followed by the effectiveness and the cost. They expressed that considering extensive beef cattle farms in Catalonia, where in spring and summer cattle are moved to mountain pastures, all BSMs should be practical. They also emphasized on the importance of the cost: [C1] "*We have always the same problem, it can be very effective* (a measure), *but if it is not affordable*…". On the other hand, veterinarians from Extremadura evaluated the effectiveness as the most important criteria, followed by the practicality and the cost. They also expressed the necessity of an equilibrium between the effectiveness and the cost, reiterating that from farmer's point of view the cost cannot be ignored. Moreover, some scepticism in relation to the existence of effective BSMs against bTB was raised: [C2] "*The effectiveness is the most important, the thing is to see if there are effective measures or not against tuberculosis*".

4.3.2. Measures related to different types of fences

In this section we included all comments related with the implementation of different type of fences (i.e., exclusion fences with an opening device operated by cattle, game fences and double fences). During the focus group discussions, veterinarians expressed negative opinions towards the implementation of fences. The group from Catalonia considered that fences were not effective in preventing the entry of wildlife and that were difficult to implement in mountain areas. Some expressions that were used to describe fences were: [C3] "*Fences are so surrealist…*", [C4] "*Fences are a little bit of science fiction*", [C5] "*I don't see any fence capable of preventing the entry of wildlife*".

Veterinarians from Extremadura considered that implementing double fencing was not acceptable from an economic point of view, nor practical, because of its maintenance: [C6] "*I think the double fence is not going to be implemented in any place, that is not feasible*.", [C7] "*The fence is not that effective, there is less contacts between farms than we think*", [C8] *"I don't see the point in the double fencing, it is very expensive and it is not very effective nor practical, because animals are gregarious…"*. Moreover, two veterinarians pointed out that existing fences are not kept in good conditions, therefore, they perceived as very challenging to implement new improved ones: [C9] "*If we don't repair fences from 30 years ago that are falling, how do we intend to put a double fence. We should require them to keep fences in good condition*".

Implementing game fencing was seen as the most effective, but also most expensive measure in the group from Extremadura. Moreover, some comments about its effectiveness in day-to-day practice were raised, especially regarding wild boars: [C10] "*I still think that game fences are not that effective with wild boars, because I have seen them doing "tricks" to pass under them. I know that there is nothing 100 % effective, but what wild boars do is incredible*", [C11] "*I think that these are measures very expensive with a relative effectiveness, because if we try to avoid that the wild boars enter and at the end they enter, considering the money I have spent, I don't know if it is viable*".

4.3.3. Measures related to direct or indirect cattle contacts

Here we grouped those comments related to sharing bulls, sharing cattle crush, avoiding sharing transport and culling old animals (i.e., over 12 years old). Sharing bulls was considered an obsolete practice in the Extremadura meeting, except for herds reared in the "*dehesas boyales*", which are considered as a single epidemiological unit. Veterinarians also emphasized that, out of such situation, the sharing of bull without a pre-movement testing for bTB would be an illegal practice. On the other hand, in the Catalonia meeting, veterinarians expressed that in some cases sharing bulls is unavoidable, due to the fact that cattle herds are in the mountains, and there are no fences separating herds. The alternative of not moving the bulls to communal pastures was also considered, but veterinarians expressed that it could imply economic losses to farmers (for example, if not all cows were pregnant before moving to pastures).

Regarding the sharing of cattle crush, veterinarians from Catalonia described that it was a common practice in some areas, especially in communal pastures (i.e., mountain areas). On the other hand, veterinarians from Extremadura commented that a cattle crush is shared only among herds in the "*dehesas boyales*", hence it is used by herds that are considered a single epidemiological unit.

Avoiding sharing the transport with animals from other farms was seen as a very effective measure in both groups. Veterinarians agreed that when animals are transported (except if they go to the slaughterhouse), they should not be mixed with animals from other farms. However, they also commented that in some cases, small farms have to share transport when they incorporate new animals to their herds.

The recommendation of knowing the origin of animals, quarantining them, and performing an additional tuberculin test was seen as an important BSM. Quarantine animals was considered as a necessary measure to prevent transmission not only of bTB, but also other infectious diseases. Some veterinarians commented this measure was more practiced among young farmers: [C12] "*Lately, I'm seeing it more, mostly among young farmers, they have these types of quarantines more present, more than older farmers. Young people are more aware of quarantine, know where they buy, be careful where they buy, wait a while…*".

Culling old animals was evaluated only by veterinarians from Extremadura, participants agreed that it is an economic measure that is necessary not only for the bTB control, but also for the adequate management of a farm due to productive reasons.

4.3.4. Measures related to cattle-wildlife interactions

Comments related to avoiding wildlife/cattle interactions at aggregation points (i.e., water points, feeders and mineral lick blocks) were included in this topic. Veterinarians from both groups highlighted difficulties in the implementation of such BSMs and they expressed their concerns about the difficulty of implementing effective BSM against wildlife: [C13] "*I don't know to which extent you can control the contact with wildlife, maybe a little bit, but they live there, they sleep there* (…) *It would be like putting doors to the fields",* [C14] "*A conclusion that I see is that the measures related to domestic animals are feasible, the problem is that controlling wildlife is going to be very complicated, and consequently having an eradication programme".*

Some practices, such as increasing the height of feeders and waterers or hanging mineral lick blocks from trees could be feasible to implement and effective against wild boars, but concerns on their effectiveness against deer were highlighted. Regarding selective feeders, veterinarians from both groups stated that they had never seen such type of feeders in any farm. In relation to water points, a veterinarian from Extremadura considered that they are one of the most important contagion sources, stating that farmers do not give enough importance to waterers: [C15] "*The waterer is the most important source of contagion; we don't give enough importance to water. Many farmers worry about the feed, silage, mineral supplements... but only few farmers worry about water points, and for me, waterers are the most important"*. Veterinarians from Extremadura also expressed the difficulty of maintaining waterers in good condition during the dry season.

4.3.5. The eradication programme

At the end of the focus group discussions, veterinarians talked about the bTB eradication programme and they expressed some opinions about farmers. Veterinarians related some negationist attitudes of farmers towards the disease: [C16] "*There are farmers that do not believe in tuberculosis, they think that it is a "cleaning" and it doesn't exist"*; and reported the existence of some conflict of interests in farmers that have a mixed farm (i.e., dual use farming/hunting), stating that farmers prefer to have some bTB positive cows rather than implementing BSMs against wildlife:

- [C17] *"Those farms that have two activities, I think that the tuberculosis, is not that they do not care, but it is an inherent problem.*

– *They do not care, I agree with you"*

They also expressed some negative and concerning opinions about the bTB eradication: [C18] *"(…) We are not going to be able to eradicate it. I find the eradication of tuberculosis very complicated; I think it would be better a control programme in Europe, I think we are wrong, the eradication is complicated"*, [C19] *"I don't know if this* (bTB eradication) *could advance a lot with biosecurity measures, it also depends on the people's willingness, because sometimes you don't know if the willingness is failing or what"*.

It is worth mentioning that there were also some positive comments of veterinarians from the Extremadura group that mentioned the progress made with hunting waste management and game farms, where now it is compulsory to implement some BSMs. In the Catalan group, they also expressed positive comments about the implementation of BSMs against wildlife: [C20] "*It is good that we implement measures against wildlife, because it is always criticized, all is wildlife fault… although it is not true*".

5. DISCUSSION

Stakeholders' acceptability and support of control measures are important factors in the success of animal diseases control strategies (Pfeiffer 2006). This study represents the first step to investigate stakeholders' opinions of biosecurity measures against bovine tuberculosis. Mixing qualitative and quantitative methods has allowed to establish a list of preferred biosecurity measures and to investigate veterinarians' points of views on them. Nevertheless, it has to be taken into account that this study has several limitations.

Focus group discussions were held online, which interferes in some aspects related to their performance, such as poor or loss of connection, that can hinder the fluency of the conversation (Nyumba et al. 2018); and their analysis. Moreover, some participants did not connect her/his camera hindering the interpretation of the non-verbal communication (Onwuegbuzie et al. 2009). On the other hand, transcripts of the meetings were analyzed qualitatively by the scissors-and-sort technique, which is a quick and simple technique, but it is very subjective, hence it relies on the analyst judgement that choses which sections of the transcripts are important and interprets them (Stewart et al. 2007). In addition, data saturation was not reached as only 2 focus groups were evaluated (taking into consideration that the Catalan focus group was used as a pilot study). In this type of studies, it is recommended to carry out 3 to 6 focus groups to reach data saturation (Onwuegbuzie et al. 2009). In this regard, the study will be continued to have 5 focus groups in total: 2 in Catalonia (one with farmers and one with veterinarians) and 3 in Extremadura (2 with farmers and one with veterinarians). In relation to participants, in this study only private veterinarians were included in the focus groups. These veterinarians have been identified as the most suitable figure to inform farmers about BSMs, being one of the most relevant information sources to farmers about preventive measures (Ciaravino et al. 2017; Renault et al. 2018; Moya et al. 2020), and being therefore important to investigate their opinions. Other stakeholders such as farmers and official veterinarians should also be interviewed to complement results on the acceptability of BSMs.

Nevertheless, and despite the limitations of this study, our results showed that among the evaluated BSMs related to interaction with cattle herds, the most preferred measure of the Extremadura group was “Culling old animals”. This result is in accordance with previous studies that have identified residual infection (i.e., persistence of the disease within the herd) as an important cause of bTB breakdowns (Guta et al., 2014; Ciaravino et al al., 2021). Having older animals could contribute to residual infection as it increases the risk of having non-reactors animals that will remain in herds infecting other animals. Extremadura is one of the Autonomous communities which has herds with animals above the recommended age: 9.8 % and 3.7 % of animals older than 12 and 15 years old, respectively, in beef cattle herds (Álvarez et al. 2018). Therefore, culling old animals is recommended to reduce the number of potential non-reactor animals in herds. In this regard, a protocol of culling old animals combined with applying serologic tests to animals older than 12 years old (beef cattle) in infected herds with recurrent positive animals or herds with bTB in previous years, was proposed in 2018 (Álvarez et al. 2018). It will be therefore interesting to evaluate if farmers do also perceive that this is a good measure to reduce the likelihood of bTB breakdowns in cattle herds and if it is economically feasible.

The second most preferred measure was “Know the origin of the animals, perform a quarantine and an additional bTB test”. Performing an additional bTB test is a measure that is already contemplated in the eradication programme, but it has to be accorded with the official veterinary services. In this case, animals have to be isolated and tested within 45 days after the movement, if health authorities allowed (Anonymous, 2021). These two measures (culling old animals and performing a quarantine) were seen by the veterinarians as essential measures necessary to have a good production and to avoid infectious diseases in general, not only for bTB.

Regarding BSMs related to cattle and wildlife interactions, the difference in preference of the measures was not evident. Except for “Use feeders and waterers that avoid access of wildlife”, the other measures had similar scores in the ranking. The two measures that were considered most effective, "Implement exclusion fences with cattle operated devices that avoid wildlife/cattle interaction in aggregation points" and "Implement game fencing" were also perceived as the ones most expensive and were among the three least practical. On the other hand, those measures perceived as economic and practical were not seen as very effective. These results hindered the prioritization of any measure, making evident the lack of clear BSMs against wildlife. Further studies to develop such BSMs might be desirable.

The qualitative analysis of discussions performed during the meetings allowed to identify some points of view in relation to the proposed BSMs and the bTB eradication programme. There were some comments questioning the existence of effective BSMs to avoid bTB transmission between wildlife and cattle and scepticism about eradicating the disease because of the important role of wildlife. These, were also identified in other studies (Ciaravino et al. 2017; Ciaravino et al. 2020). The conflict of interests of farmers with dual use of their farms (cattle farming and hunting activities) was also described by Martínez-Guijosa et al. (2021). This reflects that these thoughts are widespread among stakeholders in Spain, which can hinder the implementation of BSMs and therefore the progress in the eradication of bTB.

Although from these results we cannot derive if these measures will be the most accepted and supported in the future, due to the fact that only two groups of veterinarians have been considered, they can help to illustrate which are the opinions of veterinarians. Veterinarians are key sources of information for farmers in relation to implementing BSMs (Ciaravino et al. 2017; Renault et al. 2018; Moya et al. 2020), so if they believe some measures are not effective, that could influence negatively in the application of measures by farmers. The perceived effectiveness, the affordability and feasibility of measures are important factors that influence in farmer's decision to implement BSMs (Ritter et al. 2017), that are in the end the main responsible figure of the implementation of biosecurity measures in farms.

6. CONCLUSIONS

According to these preliminary results, avoiding having old animals in herds is the most preferred BSM by veterinarians to prevent bTB breakdowns related to cattle herds interactions. However, in relation to BSMs to avoid transmission between cattle and wildlife no measure stood out among those proposed. Concerns about the feasibility and effectiveness of some biosecurity measures in day-to-day practice were raised, which remarks the importance of conducting studies to evaluate the effectiveness of BSMs.

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ANNEX 1: **Citations from the qualitative analysis of the focus group discussions in their original languages (i.e., Spanish or Catalan)**

[C1] "*Estamos en lo de siempre, puede ser muy efectivo, pero si no es asumible…".*

[C2] "*La efectividad es lo más importante, el tema es ver si hay medidas efectivas o no frente a tuberculosis".*

[C3] "*Lo del vallado es tan surrealista* …".

[C4] "*Un poco ciencia ficción*…".

[C5] "*Yo no veo ningún vallado capaz de evitar la entrada de la fauna salvaje".*

[C6] "*La doble valla, yo creo que no se va a poner en ningún sitio, eso no es asumible".*

[C7] "*La valla es poco efectiva, no hay tanta intercomunicación entre explotaciones como nos pensamos".*

[C8] "*No le veo mucho sentido al doble vallado, me parece de un coste muy alto y es poco efectivo y práctico, porque los animales de por si son gregarios…".*

[C9] "*Si no arreglamos las de hace 30 años que están que se caen, como pretendemos poner una doble valla. Exijamos que mantengan lo que tienen".*

[C10] "*Yo sigo pensando que la efectividad del vallado impermeable no sé si es del todo efectivo con los jabalíes, porque yo les he visto hacer verdaderas virguerías para pasar por debajo por muy impermeable que sea. Efectividad al 100 % ya se que no hay nada, pero lo de los jabalíes es por demás"*.

[C11] "*Yo creo que son medidas muy costosas con una eficacia relativa, porque si intentamos impedir que el jabalí entre y al final entra con lo que me ha costado hacerlo, pues no sé hasta que punto es viable".*

[C12] "*Últimamente lo estoy viendo cada vez más, sobretodo en ganaderos jóvenes, tienen más presente este tipo de cuarentenas, más que los que tienen más años. La gente más joven está más concienciada de la cuarentena, ver donde compran, tener cuidado donde compran, esperar un tiempo…".*

[C13] *"No sé fins a quin punt pots arribar a controlar el contacte amb la fauna, potser una mica, però és que hi viuen allà, dormen allà (...) sería poner puertas al campo"*.

[C14] "*Una conclusión que saco yo es que las medidas a adoptar en los animales domésticos son relativamente factibles, el problema es que controlar la fauna salvaje va a ser muy complicado y por lo tanto tener un programa de erradicación".*

[C15] "*El bebedero es el mayor punto de contagio, no le damos la importancia suficiente al agua. Muchos ganaderos se preocupan por la alimentación, el ensilado, pastillas… pero en cuanto al agua muy pocos se preocupan por los puntos de agua y para mi, los bebederos son importantes…".*

[C16] "*Es que hay ganaderos que no creen en la tuberculosis, muchos creen que es una limpieza y no existe tuberculosis".*

[C17]

- *"Esas explotaciones que tienen dos actividades, yo creo que el tema de la tuberculosis, no es que se la trae al fresco, pero es un problema inherente.*
- *Les trae al fresco completamente, estoy de acuerdo".*

[C18] "*No vamos a ser capaces de erradicar. La erradicación yo la veo muy complicada, yo creo que tenemos que tener un programa de control de tuberculosis en Europa, creo que estamos equivocados, la erradicación como tal, complicada".*

[C19] Y*o no sé si esto podría avanzar mucho ni con medidas de bioseguridad ni con nada, también depende de la voluntad de la gente claro, porque a veces ya no sabes si es que falla la voluntad o que".*

[C20] *"(…) Ja està bé que hi hagi alguna mesura encarada a la fauna, ni que sigui perquè es critica sempre, perquè tot és culpa de la fauna… encara que no és veritat".*

ANNEX 2: Biosecurity measures evaluated in the group of veterinarians from Catalonia

BSMs related to cattle herds interactions
Avoid contact between vehicle driver and farm animals
The vehicle that comes to get animals is empty
Use clean and disinfected cattle crush when they are shared with other farms
Avoid sharing bulls
Implement exclusion fences

BSMs related to cattle and wildlife interactions
Avoid the use of mineral licks
Keep feed in a proper feed storage
Have adequate waterers and in sufficient number
Use selective feeders
Use selective waterers
Implement game fencing

ANNEX 3: Calculations of Extremadura's group

Table 1 of presents the pairwise comparison matrix of criteria, the weight obtained and the CR of the priority matrix. Tables 2, 3, 4, 6, 7, 8 show the pairwise comparison matrices of the BSMs under each criteria, the BSM weight (average normalized score) in relation to each criteria and the CR of matrices. Tables 5 and 9 present the final weighted score of the evaluated BSMs.

Table 1. Priority matrix (pairwise comparison matrix of criteria) (a), normalized priority matrix, criteria weight (average normalized score) and consistency ratio (CR) (b).

(a)

Priority matrix	Cost	Practicality	Effectiveness
Cost	1	0.333	0.5
Practicality	3	1	0.5
Effectiveness	2	2	1
Total	6	3.333	2

(b)

Normalized	Cost	Practicality	Effectiveness	Criteria weight
Cost	0.166	0.1	0.25	0.172
Practicality	0.5	0.3	0.25	0.350
Effectiveness	0.333	0.6	0.5	0.478
CR = 0.13				

Table 2. Pairwise comparison matrix of BSMs related with transmission between cattle herds versus the cost (a), normalized matrix, average score attributed to each BSM and consistency ratio (CR) (b).

(a)

Cost	Know the origin of the animal + quarantine + TB test	Avoid sharing transport	Cull old animals	Double fencing	Avoid sharing bulls	Clean and disinfected cattle crush
Know the origin of the animal + quarantine + TB test	1	3	3	3	1	1
Avoid sharing transport	0.333	1	0.2	0.5	0.333	0.333
Cull old animals	0.333	5	1	3	3	3
Double fencing	0.333	2	0.333	1	1	0.333
Avoid sharing bulls	1	3	0.333	1	1	1
Clean and disinfected cattle crush	1	3	0.333	3	1	1
Total	4	17	5.2	11.5	7.333	6.666

(b)

Normalized	Know the origin of the animal + quarantine + TB test	Avoid sharing transport	Cull old animals	Double fencing	Avoid sharing bulls	Clean and disinfected cattle crush	Average normalized score
Know the origin of the animals + quarantine + TB test	0.250	0.176	0.577	0.261	0.136	0.150	0.258
Avoid sharing transport	0.083	0.059	0.038	0.043	0.045	0.050	0.053
Cull old animals	0.083	0.294	0.192	0.261	0.409	0.450	0.282
Double fencing	0.083	0.118	0.064	0.087	0.136	0.050	0.090
Avoid sharing bulls	0.250	0.176	0.064	0.087	0.136	0.150	0.144
Clean and disinfected cattle crush	0.250	0.176	0.064	0.261	0.136	0.150	0.173
CR = 0.10							

Table 3. Pairwise comparison matrix of BSMs related with transmission between cattle herds versus the practicality (a), normalized matrix, average score attributed to each BSM and consistency ratio (CR) (b).

(a)

Practicality	Know the origin of the animal + quarantine + TB test	Avoid sharing transport	Cull old animals	Double fencing	Avoid sharing bulls	Clean and disinfected cattle crush
Know the origin of the animal + quarantine + TB test	1	0.5	0.333	3	1	3
Avoid sharing transport	2	1	0.5	5	3	3
Cull old animals	3	2	1	5	3	3
Double fencing	0.333	0.2	0.2	1	0.333	0.333
Avoid sharing bulls	1	0.333	0.333	3	1	1
Clean and disinfected cattle crush	0.333	0.333	0.333	3	1	1
Total	7.666	4.366	2.7	20	9.333	11.333

(b)

Normalized	Know the origin of the animal + quarantine + TB test	Avoid sharing transport	Cull old animals	Double fencing	Avoid sharing bulls	Clean and disinfected cattle crush	Average normalized score
Know the origin of the animals + quarantine + TB test	0.130	0.115	0.123	0.150	0.107	0.265	0.148
Avoid sharing transport	0.261	0.229	0.185	0.250	0.321	0.265	0.252
Cull old animals	0.391	0.458	0.370	0.250	0.321	0.265	0.343
Double fencing	0.043	0.046	0.074	0.050	0.036	0.029	0.046
Avoid sharing bulls	0.130	0.076	0.123	0.150	0.107	0.088	0.113
Clean and disinfected cattle crush	0.043	0.076	0.123	0.150	0.107	0.088	0.098
CR = 0.04							

Table 4. Pairwise comparison matrix of BSMs related with transmission between cattle herds versus the effectiveness (a), normalized matrix, average score attributed to each BSM and consistency ratio (CR) (b).

(a)

Effectiveness	Know the origin of the animal + quarantine + TB test	Avoid sharing transport	Cull old animals	Double fencing	Avoid sharing bulls	Clean and disinfected cattle crush
Know the origin of the animal + quarantine + TB test	1	5	0.33	3	1	3
Avoid sharing transport	0.2	1	0.2	5	3	3
Cull old animals	3	5	1	5	3	3
Double fencing	0.333	0.2	0.2	1	0.333	2
Avoid sharing bulls	1	0.333	0.333	3	1	3
Clean and disinfected cattle crush	0.333	0.333	0.333	0.5	0.333	1
Total	5.866	11.866	2.4	17.5	8.666	15

(b)

Normalized	Know the origin of the animal + quarantine + TB test	Avoid sharing transport	Cull old animals	Double fencing	Avoid sharing bulls	Clean and disinfected cattle crush	Average normalized score
Know the origin of the animal + quarantine + TB test	0.170	0.421	0.139	0.171	0.115	0.200	0.203
Avoid sharing transport	0.034	0.084	0.083	0.286	0.346	0.200	0.172
Cull old animals	0.511	0.421	0.417	0.286	0.346	0.200	0.364
Double fencing	0.057	0.017	0.083	0.057	0.038	0.133	0.064
Avoid sharing bulls	0.170	0.028	0.139	0.171	0.115	0.200	0.137
Clean and disinfected cattle crush	0.057	0.028	0.139	0.029	0.038	0.067	0.060
CR = 0.21							

Table 5. Calculation of the final scores of the BSMs related with transmission between cattle herds. The final score is the weighted summation of the product of the criteria weigh and the BSMs scores (average normalized scores obtained in each pairwise comparison matrices of BSMs versus the criteria).

Biosecurity measures to avoid transmission between cattle herds	Cost	Practicality	Effectiveness	Final weighted score (weighted summation)
	Criteria weight x BSM score	**Criteria weight x BSM score**	**Criteria weight x BSM score**	
Know the origin of the animal + quarantine + TB test	0.172 x 0.258	0.350 x 0.148	0.478 x 0.203	0.193
Avoid sharing transport	0.172 x 0.053	0.350 x 0.252	0.478 x 0.172	0.180
Cull old animals	0.172 x 0.282	0.350 x 0.343	0.478 x 0.364	0.342
Double fencing	0.172 x 0.090	0.350 x 0.046	0.478 x 0.064	0.062
Not sharing bulls	0.172 x 0.144	0.350 x 0.113	0.478 x 0.137	0.130
Clean and disinfected cattle crush	0.172 x 0.173	0.350 x 0.098	0.478 x 0,060	0.093

Table 6. Pairwise comparison matrix of BSMs related with cattle interaction with wildlife versus the cost (a), normalized matrix, average score attributed to each BSM and consistency ratio (CR) (b).

(a)

Cost	Exclusion fence with cattle operated opening device	Feeders/ waterers that limit wildlife interaction	Adequate number of water points	Avoid mineral lick blocks	Separate farming/ hunting activities	Proper feed storage
Exclusion fence with cattle operated opening device	1	0.20	0.25	0.25	4	0.25
Feeders/waterers that limit wildlife interaction	5	1	1	0.333	4	0.333
Adequate number of water points	4	1	1	0.25	4	0.333
Avoid mineral lick blocks	4	3	4	1	5	3
Separate farming/ hunting activities	0.25	0.25	0.25	0.2	1	0.20
Proper feed storage	4	3	3	0.333	5	1
Total	18.25	8.45	9.5	2.366	23	5.116

(b)

Normalized	Exclusion fence with cattle operated opening device	Feeders/ waterers that limit wildlife interaction	Adequate number of water points	Avoid mineral lick blocks	Separate farming/ hunting activities	Proper feed storage	Average normalized score
Exclusion fence with cattle operated opening device	0.055	0.024	0.026	0.106	0.174	0.049	0.072
Feeders/ waterers that limit wildlife interaction	0.274	0.118	0.105	0.141	0.174	0.065	0.146
Adequate number of water points	0.219	0.118	0.105	0.106	0.174	0.065	0.131
Avoid mineral lick blocks	0.219	0.355	0.421	0.423	0.217	0.586	0.370
Separate farming/ hunting activities	0.014	0.030	0.026	0.085	0.043	0.039	0.039
Proper feed storage	0.219	0.355	0.316	0.141	0.217	0.195	0.241
CR = 0.13							

Table 7. Pairwise comparison matrix of BSMs related with cattle interaction with wildlife versus the practicality (a), normalized matrix, average score attributed to each BSM and consistency ratio (CR) (b).

(a)

Practicality	Exclusion fence with cattle operated opening device	Feeders/ waterers that limit wildlife interaction	Adequate number of water points	Avoid mineral lick blocks	Separate farming/ hunting activities	Proper feed storage
Exclusion fence with cattle operated opening device	1	4	0.333	0.25	3	0.25
Feeders/waterers that limit wildlife interaction	0.25	1	0.333	1	3	0.333
Adequate number of water points	3	3	1	1	3	1
Avoid mineral lick blocks	4	1	1	1	5	0.333
Separate farming/ hunting activities	0.333	0.333	0.333	0.2	1	0.25
Proper feed storage	4	3	1	3	4	1
Total	12.583	12.333	4	6.45	19	3.163

(b)

Normalized	Exclusion fence with cattle operated opening device	Feeders/ waterers that limit wildlife interaction	Adequate number of water points	Avoid mineral lick blocks	Separate farming/ hunting activities	Proper feed storage	Average normalized score
Exclusion fence with cattle operated opening device	0.079	0.324	0.083	0.038	0.158	0.079	0.127
Feeders/ waterers that limit wildlife interaction	0.019	0.081	0.083	0.155	0.158	0.105	0.100
Adequate number of water points	0.238	0.243	0.25	0.155	0.158	0.316	0.227
Avoid mineral lick blocks	0.317	0.081	0.25	0.155	0.263	0.105	0.195
Separate farming /hunting activities	0.026	0.027	0.083	0.031	0.053	0.079	0.050
Proper feed storage	0.317	0.243	0.25	0.465	0.210	0.317	0,300
CR = 0.14							

Table 8. Pairwise comparison matrix of BSMs related with cattle interaction with wildlife versus the effectiveness (a), normalized matrix and average score attributed to each BSM and consistency ratio (CR) (b).

(a)

Effectiveness	Exclusion fence with cattle operated opening device	Feeders/ waterers that limit wildlife interaction	Adequate number of water points	Avoid mineral lick blocks	Separate farming/ hunting activities	Proper feed storage
Exclusion fence with cattle operated opening device	1	5	4	4	1	1
Feeders/waterers that limit wildlife interaction	0.2	1	0.333	1	0.2	1
Adequate number of water points	0.25	3	1	1	0.2	3
Avoid mineral lick blocks	0.25	1	1	1	0.2	3
Separate farming/hunting activities	1	5	5	5	1	5
Proper feed storage	1	1	0.333	0.333	0.2	1
Total	3.7	16	11.666	12.333	2.8	14

(b)

Normalized	Exclusion fence with cattle operated opening device	Feeders/ waterers that limit wildlife interaction	Adequate number of water points	Avoid mineral lick blocks	Separate farming /hunting activities	Proper feed storage	Average normalized score
Exclusion fence with cattle operated opening device	0.270	0.312	0.343	0.324	0.357	0.071	0.280
Feeders/ waterers that limit wildlife interaction	0.054	0.062	0.028	0.081	0.071	0.071	0.062
Adequate number of water points	0.067	0.187	0.086	0.081	0.071	0.214	0.118
Avoid mineral lick blocks	0.067	0.062	0.086	0.081	0.071	0.214	0.097
Separate farming/ hunting activities	0.270	0.312	0.428	0.405	0.357	0.357	0.355
Proper feed storage	0.270	0.062	0.028	0.027	0.071	0.071	0.089
CR = 0.13							

Table 9. Calculation of the final scores of the BSMs related with cattle interaction with wildlife. The final score is the weighted summation of the product of the criteria weigh and the BSMs scores (average normalized scores obtained in each pairwise comparison matrices of BSMs versus the criteria).

Biosecurity measures to avoid cattle-wildlife interactions	**Cost**	**Practicality**	**Effectiveness**	**Final weighted score** (weighted summation)
	Criteria weight x BSM score	**Criteria weight x BSM score**	**Criteria weight x BSM score**	
Exclusion fence with cattle operated opening device	0.172 x 0.072	0.350 x 0.127	0.478 x 0.280	0.191
Feeders/waterers that limit wildlife interaction	0.172 x 0.146	0.350 x 0.100	0.478 x 0.062	0.090
Adequate number of water points	0.172 x 0.131	0.350 x 0.227	0.478 x 0.118	0.158
Avoid mineral lick blocks	0.172 x 0.370	0.350 x 0.195	0.478 x 0.097	0.179
Separate farming/ hunting activities	0.172 x 0.039	0.350 x 0.050	0.478 x 0.355	0.194
Proper feed storage	0.172 x 0.241	0.350 x 0.300	0.478 x 0.089	0.189