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Evidence-based guidelines for the post-fire assessment of domestic ruminants: a scoping review

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Abstract

Wildfires globally impact farmers, with risk expected to rise in the next thirty years. Beyond fatalities, wildfires impair the reproductive capabilities of surviving livestock due to smoke exposure. Effective interventions require considering animal welfare, prognosis, and costs. Enhanced clinical assessment is crucial. There is a paucity of data concerning decision-making processes regarding burn injuries in livestock. This study establishes evidence-based guidelines for wildfire-affected ruminants in field settings. The goal is categorizing scientific evidence to create prognostic guidelines. English and Spanish publications from Web of Science, Medline, and Google Scholar were searched using keywords related to burn injuries, disaster management, and animal welfare. A research matrix was populated based on inclusion criteria and evidence strength, leading to the development of visual triage guidelines for sheep and cattle. Most evidence comprises case reports (expert opinion) and observational trials. Ovine controlled trials in the 80 s and 90 s significantly advanced burn injury understanding in humans and animals. Key clinical factors determining burn severity include burn extent and depth, anatomic location, and smoke inhalation. Core non-clinical factors implicated in decision-making include feed, water, and shelter, amongst others. Animal categorization by burn severity creates a model for prioritising resources towards animals with the best recovery chances, protecting animal welfare.

Keywords Ruminants, Burns, Triage, Prognosis, Welfare

Introduction

The devastating occurrence of wildfires affects farmers emotionally and financially [1]. Moreover, according to recent studies in South Africa [2] and at a global level [3], the risk of wildfires is expected to increase in the next thirty years, exposing animals and farmers to fire risk for more than half of the year. However, there is a paucity of data regarding decision-making processes with burn injuries in livestock, and this review aims to derive evidence-based guidelines for decision-making regarding domestic ruminants affected by wildfires in the context of field animal production practice.

The United Nations Sustainable Development Goal (SDG) 15, "Life on Land", directly addresses the connection between wildfires and livestock losses [4]. Forest degradation due to unsustainable agricultural practices destroys animal habitats, displaces wildlife, disrupts food chains, and increases fire vulnerability, impacting food security and livelihoods. Wildfire-related livestock and farmland losses intensify pressure on remaining land, further stressing the ecosystem [5]. Wildfires inflict significant social and economic damage, impacting both human and animal health. These disasters devastate the natural environment, demanding restoration. Recovery

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efforts are hampered by the financial strain in affected communities, compounding their sense of loss [6]. Moreover, uncoordinated aid efforts undermine the core goal of emergency management, which is collaborative community recovery [7]. Wildfire-related livestock injuries represent a significant veterinary crisis. Preparedness is crucial for bolstering social and economic recovery in affected communities [8].

A multidisciplinary team of various stakeholders is essential at both national and local levels. Their roles include: 1) developing wildfire mitigation and prevention strategies; 2) establishing clear communication channels; and 3) providing on-the-ground response during a fire. Veterinary services are critical during the active fire event for triaging injured animals and aligning needs with available resources. Collaboration with farmers and farm managers is vital for effective decision-making, as they possess first-hand knowledge of what their available and accessible resources are for sustainable recovery efforts. Finally, a lessons-learned review and analysis process is invaluable for continuous improvement in future responses [8].

The Five Domains model is commonly used to assess livestock welfare [9], covering environment, behaviour, nutrition, health and mental state. While often neglected, subjective animal experience is crucial, not just production indicators like feed intake and mortality [10, 11]. Objective welfare assessment measures physiological stress responses to threats [12], but the allostatic approach suggests these responses (hormone and cytokine release) can be adaptive [13]. In disasters like wildfires, livestock needs are paramount, and triage becomes the first step in animal welfare care [6, 14, 15]. The goal is to categorize animals for resource allocation based on clinical condition, guiding decisions within a comprehensive framework.

Post-fire, some animals will require immediate euthanasia due to severe injuries, while others with minor and mild injuries have better recovery chances [15]. Mobile, alert animals with minor and/or mild injuries can be kept if promptly treated and regularly assessed by a veterinarian [16]. Minor and mild injuries should be prioritized for resource allocation to maximize successful outcomes. Severely injured animals have a poor prognosis and often require euthanasia [17].

Traditionally, burn severity in both humans and animals relies on estimating the burn's depth and extent (Total Body Surface Area or TBSA). These factors are used to predict clinical severity and mortality, guiding treatment decisions [18–20]. Historically, this assessment has been subjective, based on visual evaluation of the lesions, leading to variability in outcomes depending on the evaluator [21].

Skin burns in livestock result from direct flame or heat radiation and often occur concomitantly with smoke inhalation. The "Wallace rule of 9 Principle" typically used for human burns [22], helps estimate burn extent also in animals for partial-thickness burns and deeper. Pierson proposed specific body surface percentages for cattle: head and back 7% each; each side of the costal and abdominal wall 24%; udder 4%; ventral thorax and abdomen 7%, forelegs 4% each; hindleg 6% each, perineal area 6% and tail 1% (Fig. 1) [23]. To the authors' knowledge, no comparable method exists for sheep.

Burn survivability decreases with increasing burn size (%TBSA), depth of burn lesions, smoke inhalation and burns in critical anatomic locations. Human burn cutoffs are not applicable to wildfire-affected animals due to limited care and transport options [8, 12]. Experts report almost 100% survival for 10–20% TBSA partial-thickness burns, approximately 87% for 20–30% partial thickness with care and only 27% for TBSA greater than 30% combined partial- and full thickness burns under specialist care. Smoke inhalation and function-impairing burns drastically reduce survival [23].

The newest approach for the classification of burn injuries [24, 25] considers the need for surgical treatment for complete healing and is as follows:

- Superficial burns affect the superficial layers of the epidermis: animal shows pain, erythema, oedema, and peeling of the skin. Not contemplated on TBSA appraisal because it does not require fluid replacement.
- Superficial partial-thickness burns can reach the basal layer of the epidermis, pain is evident, and the capacity for recovery is preserved, showing improvement in a period of two weeks with proper care.

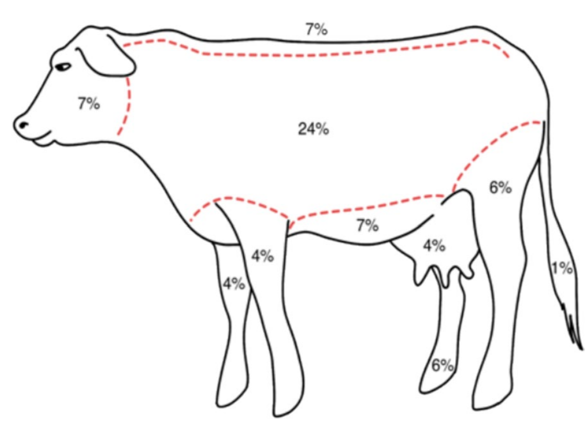

Fig. 1 Schematic depiction of total body surface area (TBSA). Adapted from Pierson et al., [23]

– Deep partial-thickness burns affect all the layers, including the basal layers of the skin, and are seen as erythema, oedema, necrosis of the epidermis, and eschar formation. These lesions exhibit reduced pain due to the destruction of pain receptors.
– Full-thickness burns destroy the epidermis, dermis, and supportive structures. There is extensive fluid loss and tissue reaction with eschar formation. These lesions are highly susceptible to infection; repair often involves surgical procedures and specialized care.
– Deep full-thickness burns involve all layers of skin, underlying muscles, bones, ligaments, fat, and fascia.

Burn location affects prognosis. Assessing the extent, depth, and specific anatomical location of tissue damage is crucial for predicting healing and functionality [15]. Ruminant burns often occur on the face, eyes, ears, mouth, and lower body (limbs, feet, genitals, and udder). The presence of erythema, slight oedema, and pain suggest partial-thickness burns, which can worsen, progressing to eschar, ampullas, and infection (full-thickness) without proper care. Animals with movement-restricting limb lesions require soft bedding and easy access to feed and water. Healing may lead to further movement restriction owing to scarring constriction [26].

It is generally agreed that animals affected by burn wounds covering more than thirty per cent of their Total Body Surface Area or TBSA (> 30% TBSA) require immediate euthanasia. In these cases, the severity of the burns is compounded by systemic involvement, and the likelihood of delayed veterinary assistance due to difficulties accessing disaster areas renders a hopeless prognosis for the animal [27].

In dealing with severe burn injuries, the body immediately starts an inflammatory response comprising a massive release of mediators and cellular peroxidation, leading to extensive tissue damage and systemic compromise [28]. Further consideration must be given to injuries of the respiratory tract due to smoke inhalation, especially in sheep. Smoke inhalation exacerbates the inflammatory response and the hypermetabolic response, increasing clinical severity and decreasing survivability [29]. Recent studies have considered the longer-term consequences for livestock exposed to smoke concerning reproductive performance, presented as lower conception rates, uterine growth retardation, low-weight offspring and abortions, especially in surviving sheep [30].

Burn shock, often presenting in animals with > 20%TBSA, requires intensive care and has two stages: resuscitation (24—72 h) and hyperdynamic/hypermetabolic state (3—5 days post-burn) [31]. Stage one prioritizes fluid therapy to stabilize the patient by managing vascular permeability, oedema and inflammation. Stage two emphasizes enteral nutrition to combat immune suppression and sepsis risk due to increased metabolic rate and body mass loss [31]. Ringer's lactate is the recommended fluid at 2 – 4 ml/Kg per %TBSA (Parkland Formula), half given in the first 8 h, the rest in the next 16 h [32]. Vitamin E supplementation in sheep with skin burns and smoke inhalation (SB/SI) reduces tocopherol depletion and improves recovery [33, 34]. Vitamin C as a free radical scavenger in resuscitation fluid reduces fluid needs and improves cardiovascular function in burns [35].

Severely smoke-inhalation-affected animals should be euthanised. Treatment is costly and often unsuccessful in the field. Mild cases of bronchopneumonia can use long-acting penicillin or tulathromycin. Systemic antibiotics are recommended for respiratory involvement or mastitis [36]. However, topical antibiotics are preferred for skin burns due to compromised circulation. Silver sulphadiazine and aloe vera, or propolis/medical-graded honey, can be used topically for their antibacterial properties.

Wildfires are considered veterinary disasters, requiring careful decision-making. These decisions must integrate clinical factors, such as systemic involvement, burn severity (based on depth and area of injury), and the long-term consequences of exposure to smoke [30, 36, 37]. Equally important are non-clinical factors, including accessibility to the affected area, the value of the livestock involved, and the availability of sufficient human and financial resources. Treatment of affected animals often begins with limited resources. Availability of medicine, trained personnel to monitor animals, shaded enclosures, sufficient feed, and good water quality are critical factors in determining a course of action [38, 39]. Decisions should not be based on a single assessment unless the severity of the case is such that euthanasia is the only humane option. Animals not initially affected may later develop smoke inhalation, requiring observation [6].

Safeguarding animal welfare is a primary concern in veterinary disaster management, as highlighted in existing literature [1, 21]. It is crucial to consider both animal and human well-being, because emotionally distressed farmers may be unable to care for injured animals [40]. Providing hope for animals with minor and/or mild burns while ensuring their welfare could mitigate the farmers' sense of loss [41, 42]. Conflicts can arise among the multidisciplinary teams involved in post-fire recovery, breeding distrust [7]. Animal welfare is often eclipsed by emotional biases and anthropomorphic interpretation of suffering, resulting in decisions not based on evidence [13, 42]. This study aims to develop clear guidelines for these teams, improving outcomes for animals and humans alike and fostering community recovery.

Materials & Methods

This study conducted a scoping review using the six steps of the Arksey and O'Malley framework [43–45]. A scoping review was necessary to broaden the foundational knowledge and understanding of the topic, enabling the principal investigator to thoroughly consider all relevant factors involved in post-fire decision-making. This review addressed the objective of standardizing guidelines based on scientific evidence. Ethical approval was granted by the Research Ethics Committee of the Faculty of Veterinary Science of the University of Pretoria (reference number REC055-22) and the Research Ethics Committee of the Faculty of Humanities of the University of Pretoria (reference number REC055-22 line 1). The review aims to identify the key factors to consider when assessing and prioritizing burned domestic ruminants. English and Spanish publications were retrieved from sources including Web of Science, Medline, Google Scholar, government agencies, and non-governmental organisations (NGOs) websites for expert-opinion-based publications. Two independent researchers evaluated the methodological rigour of the included publications to assign scientific strength according to the quality of Evidence Pyramide [46]. The review seeks to develop evidence-based guidelines for classifying burn severity in domestic ruminants and to propose directions for further research.

Inclusion criteria

Keywords used in this research included "animal welfare", and "burn severity assessment" (for general prognosis and specifically in livestock), and "disaster aid", and "triage", and/or "veterinary triage". A research matrix and database were compiled, documenting publication year, authors, country of origin, article title and evidence category based on methodologic rigour for each selected publication.

Allocation of a category of evidence and Level of clinical recommendation

Evidence strength was categorized using the standard framework for clinical guidelines [47], ranging from C1 to C4. C1 represents recommendations based on systematic reviews of randomised clinical trials, while C2 reflects cohort studies, case–control, and non-randomized trials. C3 derives from descriptive studies, case series and case reports, and C4 from experts' opinions. Levels of recommendation for clinical decision-making were categorized as highly recommended (HR) for C1, recommended (R) for C2, expert's opinion (EO) for C3 and good practices (GP) for C4.

Results

These results are divided into two parts. The first part categorizes the current literature on veterinary disaster management and burn injuries in general and in domestic ruminants; and the second part integrates these findings into clear triage guidelines for the transdisciplinary team involved in veterinary disaster management.

Analysis of literature for evidence and level of recommendation categorization

A preliminary search yielded over 180 publications. However, after evaluating their strength of evidence, only 38 met the criteria (Fig. 2).

Table 1 shows the database created to summarize the literature compliant with selection criteria, its evidence category and corresponding level of clinical recommendation.

Figure 3 presents the distribution of the literature categorised according to scientific evidence per searched topic. The distribution shows that animal welfare topics and general burn severity assessment are mainly based on C2 evidence, burn assessment in livestock is represented by C3 and C4 evidence, and disaster management presents an even distribution between C2-C4 evidence strength.

Recommendations used for the conceptualization of the triage guidelines were mainly allocated within the C2, C3 and C4 categories corresponding to R, EO, and GP. The main findings relate to conducting an initial visual inspection of casualties, which has been recommended as a measure to reduce stock losses [48]. The same authors recommend appraisal of skin burn, systemic involvement, and possible smoke inhalation [48]. Burn lesion assessment regarding % TBSA, depth and its potential increase in severity in the following hours and days after the insult are recommended at EO level, as well as complications derived from the anatomic localisation of skin burns (legs, feet, head, eyes, mouth, genitals, mammary gland and perineum) which can compromise healing and/or future organ function/mobility [49, 50]. The degree of head and front limb oedema in ovine within the first 24 h after the insult and its association with the occurrence of smoke inhalation and the prognosis related to survivability have been noted in EO/GP and have been backed with HR evidence in this review [51].

Current evidence at the EO/GP level recommends euthanasia for the following cases:

- animals with equal or > 30% TBSA
- unconscious and/ or conscious but unable to stand animals
- animals that are not able to walk

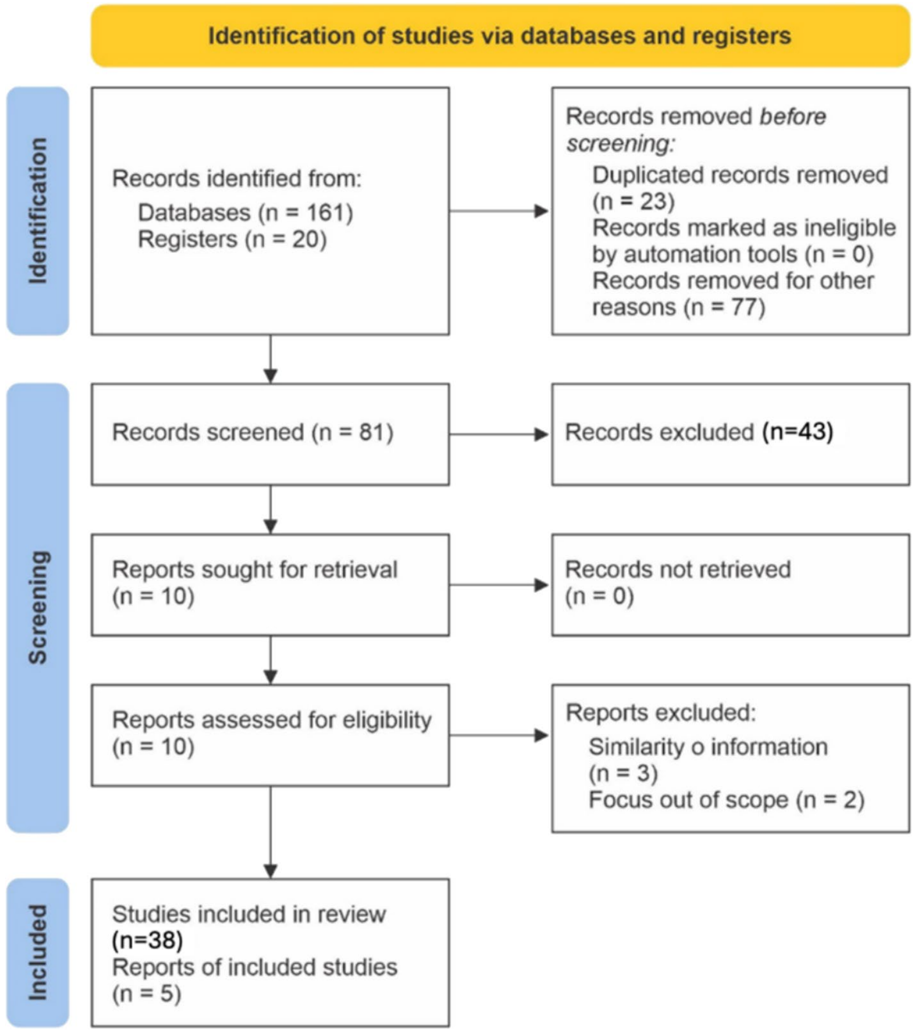

Fig. 2 Prisma chart for reporting systematic reviews

- completely blind animals
- animals in heavy respiratory distress with evidence of burn/smoke injury compromising the respiratory tract
- sheep with major swelling of the front limbs and head within the first 24 h after injury
- animals with severe burns (deep-partial and full-thickness) in the oral cavity and genital areas, compromising function
- cattle with severe foot burns due to the difficulty and extended healing time for these injuries

Decisions regarding the treatment of burned animals, especially in production field practice, involve various non-clinical factors, as noted at the EO/ GP recommendations level. These factors include the availability of animal care, the farmer's capacity to provide treatment, financial limitations, the complexity of the treatment plan, and the necessary feed, shelter, and pain management. Extended treatment periods are often impractical in production animals due to cost and the unpredictable length of convalescence, which varies depending on burn severity and potential complications. Recovery can range from three weeks for minor/mild cases up to two years in severe cases, significantly impacting finances [16]. Consequently, when examining current recommendations for wildfire-affected production animals, the available evidence primarily consists of case reports supporting experts' opinions, categorized as C3 and C4 evidence.

Proposed triage for burned ruminants

This literature review informed the development of a visual triage guide for the multidisciplinary team involved in post-fire assistance. The goal of veterinary triage in disasters is to pair patient needs with available resources [14]. In production animals, triage considers factors such

Table 1 Review database showing topics [1) Assessing burns in livestock, 2) Disaster management and Triage, 3) Assessing burn severity and 4) Animal welfare] by country, year of publication, evidence classification and corresponding recommendation

Year	Country	Authors	Title	Evidence classification/ Recommendation
		Topic: Assessing burns in livestock		
2018	USA	Rethorst, Spare and Kellenberger	Wildfire Response in Range Cattle	C4/EO
2015	AUS	Rogers, Scholz and Gillen	Dealing with Livestock affected by the 2014 bushfires in South Australia: decision-making and recovery	C4/EO
2021	USA	O'Hara, Ranches, Roche et al	Impacts from Wildfires on Livestock Health and Production: Producers perspectives	C2/R
2016	USA	Wohlsein, Peters, Schulze et al	Thermal injuries in veterinary forensic pathology	C4/EO
1966	AUS	Willson RL	Assessment of bushfire damage to stock	C4/EO
2022	AUS	Cowled, Bannister, Doyle et al	The Australian 2019/2020 Black Summer Bushfires: Analysis of the Pathology, Treatment Strategies and Decision-making	C4/EO
2003	USA	Cox, Burke, Soejima et al	Airway Obstruction in Sheep with Burn and Smoke Inhalation Injuries	C2/R
2008	USA	Madigan, Wilson and Stull	Wildfires, Smoke and Livestock	C4/EO
2007	AUS	Vaughan J	Assessing and caring for Alpacas after bushfires	C4/EO
2018	AUS	NSW-DPI	Assessing bush fire burns in livestock	C4/EO
2017	Chile	Lara, Cartes, Jerez et al	Guia Clinica: Pacientes Equinos Quemados	C4/EO
2001	USA	Soejima, Schmalstieg, Sakurai et al	Pathophysiological analysis of combined burn and smoke inhalation injuries in sheep	C2/R
2007	USA	Traber, Shimoda, Murakami et al	Burn and smoke inhalation injury in sheep depletes vitamin E: Kinetic studies using deuterated tocopherols	C2/R
1981	AUS	Carroll SN	After the fire—what then?	C4/EO
1969	USA	Pierson, Larson, Horton et al	Treatment of second-degree thermal burns in cattle	C4/EO
1980	AUS	McAuliffe, Hucker and Marshal	Establishing a prognosis for fire damaged sheep	C4/EO
1987	AUS	Morton, Fitzpatrick, Morris et al	Teat burns in dairy cattle—the prognosis and effect of treatment	C4/EO
2018	Chile	Salaberry-Pincheira and Vera-Olivera	Manual basico operacional para rescate y rehabilitacion de fauna silvestre en situaciones de desastres	C4/RO
1992	USA	Lalonde, Knox, Youn et al	Burn edema is accentuated by a moderate smoke inhalation injury in sheep	C2/R
2015	RSA	NSPCA	Veldfires response guide	C4/GP
2020	USA	Chigerwe, Depenbrock, Heller et al	Clinical management and outcomes for goats, sheep and pigs hospitalized for treatment of burn injuries sustained in wildfires: 28 cases (2006, 2015, and 2018)	C3/EO
		Topic: Disaster management and Triage		
2002	USA	Knight JE	After Wildfire	C4/EO
2009	USA	Wingfield	Veterinary Disaster Triage: Making the Tough Decisions	C4/EO
2016	France	OIE/Ed	Guidelines on Disaster Management	C4/EO
2018	Poland	Surowiecka-Pastewka, Witowski and Kawecki	A new triage method for burn disasters: fast triage burns (FTB)	C2/R
2019	RSA	Forsyth, LeMaitre, LeRoux et al	Green Book. The impact of climate change on wildfires in South Africa	C2/R
2021	AUS	Squance, MacDonald, Stewart et al	Strategies for Implementing a One Welfare Framework into Emergency Management	C4/EO
2022	AUS	UNEP/Ed. Sullivan, Baker and Kurvits	Spreading like Wildfire—The Rising Threat of Extraordinary Landscape Fires	C4/EO
		Topic: Assessing Burn Severity		
2014	UK	Lee, Joory and Moiemen	History of Burns: The past, present and the future	C2/R
2016	USA	Nielson, Deuthman, Howard et al	Burns: Pathophysiology of Systemic Complications and Current Management	C2/R
2020	CAN	Jeschke et al	Burn Injury	C2/R
2020	Japan	Kaita et al	Reevaluation for prognostic value of prognostic burn index in severe burn patients	C2/R

Table 1 (continued)

Year	Country	Authors	Title	Evidence classification/ Recommendation
2021	USA	Rice and Orgill	Assessment and classification of burn injury	C2/R
2021	USA	Moore, Waheed and Burns	Rule of Nines	C2/R
		Topic: Animal Welfare		
2015	NZ	Mellor and Beausoleil	Extending the five domains model for animal welfare assessment to incorporate positive welfare states	C2/R
2016	Brazil	Cardoso, von Keyserlingk and Hotzel	Trading off animal welfare for production goals: Brazilian dairy farmers' perspectives on calf dehorning	C2/R
2015	NZ	Hemsworth, Mellor, Cronin et al	Scientific assessment of animal welfare	C2/R
2021	AUS	Narayan, Barreto, Hantzopulou et al	A restrospective literature evaluation of the integration of stress physiology indices, animal welfare and climate change assessment of livestock	C2/R

Key: C1 = evidence derived from systematic reviews of randomised clinical trials; C2 = evidence derived from cohort studies, controlled case studies and non-randomised trials; C3 = evidence derived from descriptive studies, case series and case reports; C4 = expert opinions. Recommendations: R = Recommended; EO = Expert Opinion; GP = Good Practice

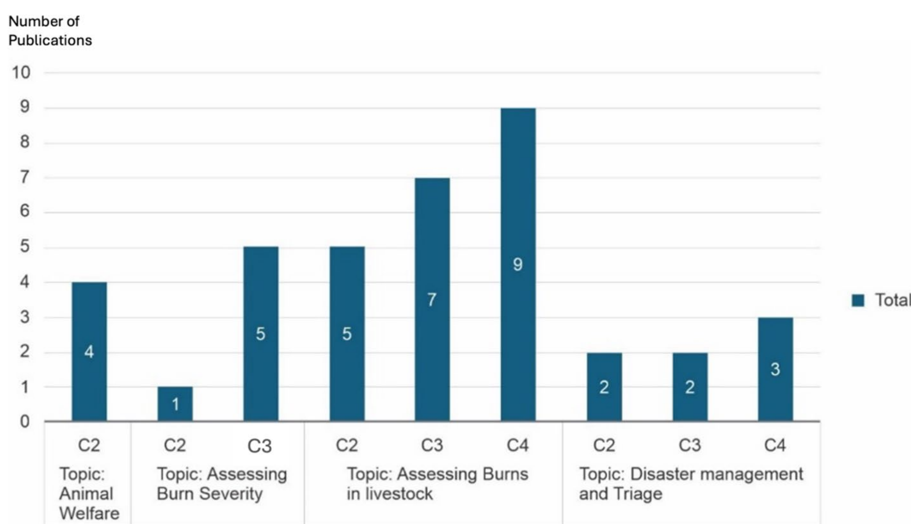

Fig. 3 Distribution of literature included in the review according to classification of scientific evidence. Key: C1 = evidence derived from systematic reviews of randomised clinical trials; C2 = evidence derived from cohort studies, controlled case studies and non-randomised trials; C3 = evidence derived from descriptive studies, case series and case reports; C4 = expert opinions

as limited tolerance for long treatments, the difficulty of animal loading and transportation, resources availability (skilled personnel, facilities, supplies, and equipment) and the option of euthanasia [17]. Moreover, affordability and providing adequate space, food and water are also key considerations for safeguarding animal welfare [30].

A first-line assessment

Wildfire response is first hampered by access to the area and the need to relocate animals to safer ground [6]. Hence, the First-Line Assessment (FLA), by triage principles [14, 17] needs to rapidly identify animals to be relocated for care versus those requiring immediate euthanasia. Assessment must focus on neurological status (comatose vs. alert) and mobility (can walk vs. can't rise, can't walk). Comatose sheep, especially with severe burns on lower legs/hooves, swelling and dry skin, often have a hopeless prognosis. Euthanasia is recommended for burned animals unable to stand or move due to poor survival chances [16, 50]. Table 2 shows the prioritization outcome from FLA.

A second-line assessment

The Second-Line Assessment (SLA) involves a physical exam evaluating the %TBSA affected by burns, burn depth and anatomic location, basic physiological parameters, and the likelihood of smoke inhalation (SI) [14, 17]. The SLA is crucial for prioritizing animals for treatment based on their chances of survival and available resources for treatment and safekeeping.

Evaluation of burn lesions

Extent and depth

Burn assessment should, when feasible, determine the extent and depth of the injury to gauge severity and inform prognosis. As a rule of thumb, larger and deeper burns indicate a poorer outcome. Figure 4 represents Mild, Major and Severe burns in bovine, from left to right, defined by cutoffs of %TBSA and depth of burn. Current literature indicates euthanasia for animals affected by burns on > 30%TBSA of any burn [15]. This triage proposes reducing this cutoff for bovine and ovine to 20%TBSA of deep partial-thickness burns and < 5%TBSA of full-thickness burns. This is based on the limited availability of resources to treat, according to adequate indications, burned animals in the field (Fig. 5).

Table 3 provides a useful guide for the classification of burn injuries based on Noorbakhsh et al. [24] according

Table 2 Colour-coded grouping after first-line assessment (FLA – visual assessment) of ruminants injured in wildfires

Colour code	Observation		Plan
	Mentation	Locomotion	
GREEN	Alert	Able to walk	Appears not to need assistance Observation
ORANGE	Alert	Able to walk	Likely to survive with adequate treatment. If resources are not available, welfare will deteriorate rapidly.
RED	Comatose	Unable to rise/walk	Euthanise
BLACK	Dead/dying	Unable to rise/walk	Disposal/Euthanise

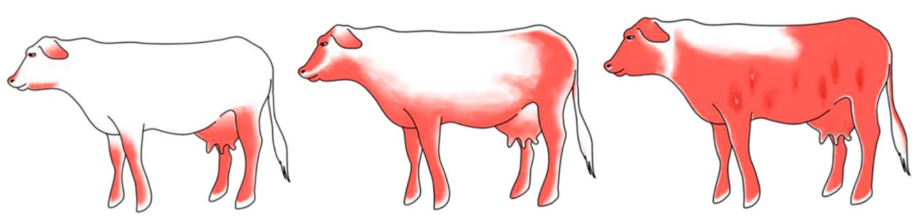

Fig. 4 Bovine left to right: Mild burn > 10% < 20% TBSA, partial-thickness burns. Major burn > 20% TBSA partial-thickness burn, face, udder and feet affected, rule out smoke inhalation (SI). Severe burn > 20% TBSA partial-thickness and > 5% full-thickness burn. Adapted from Pierson, 1969

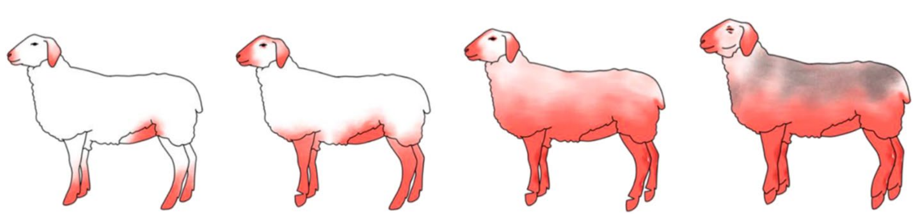

Fig. 5 Ovine left to right: Mild burn > 10% < 20% TBSA partial-thickness burns. Major burn > 20% TBSA partial-thickness burn: face, udder/prepuce, feet. Rule out smoke inhalation (SI). Severe burn > 20% partial-thickness, < 5% full-thickness burn. Severe burn > 5% TBSA full-thickness burn, signs highly suggestive of SI (swollen head and front limbs within first 24 h of injury). C Cardoso, 2022

Table 3 Classification of burn wounds according to depth and need for surgical intervention [24, 26]

Depth of Burn	Presenting signs	Pain	Healing time
Superficial (Epidermal)	Dry, red, becomes white under pressure	Need pain management	Within one week
Superficial partial thickness	Blisters, moist and red, becomes white under pressure	Need pain management (temperature and air elicit pain not only touch)	Within 3 weeks
Deep partial thickness	Blisters, wet/waxy variable color, no changes in color under pressure	Pain perception on pressure	Over 3 weeks
Full thickness	Leathery gray, charred, black. Skin dry/inelastic	Pain only under strong pressure	Does not heal especially if > 2% TBSA. Needs surgical intervention
Deep full thickness	All layers of skin are involved as well as muscles, bones, ligaments, fat and fascia	Massive tissue destruction	No healing compatible with function

to depth, with detailed presenting signs, pain category, healing time and need for surgical intervention, which impairs the possibility of field treatment.

Burn anatomic location

Species-specific factors apply, but generally, sheep with severe head and front limb swelling within 24 h of injury have been correlated with lung involvement and should be euthanized [51]. Furthermore, frequent reassessment is crucial for animals with claw detachment or severely affected coronary bands because of pain and the risk of fly strike or secondary infection. In sheep, leg burns are a significant prognostic factor; severe cases are associated with poor outcomes [14, 19, 50, 51]. However, localized leg burns not associated with severe swelling have been reported to heal in approximately thirty days with appropriate care [50]. All treated animals require pain management, antibacterial treatment, fly strike prevention and consistent nursing care [14]. Limited resources prompt harsher decisions.

Endoparasite and myiasis control are crucial in treating burned sheep to prevent complications and should always be considered in the treatment plan [49]. Daily weight monitoring can indicate survivability by reflecting the burn-induced hypercatabolic state. Experts consider the impact of bovine foot burns to be more severe than in ovine due to cattle's reluctance to move and eat when injured, making nursing care costly and physically demanding [40]. Euthanasia is recommended [49]. Burns on the perineum, genitals (including udders—especially in cows), and rectum require special attention due to potential functional impairment [36].

Cattle are commonly burned on their feet, limbs, and ventral abdomen, including the udder. Mature dairy cows with teat burns heal faster and more satisfactorily than heifers, with less anatomic distortion and a higher return to normal lactation [36]. Severe burns (75% of teat area affected with superficial burn) in adult cows require at least four months to heal and, while usually having a good prognosis, necessitate careful consideration regarding treatment length and care needs. Partial-thickness teat burns have a poorer prognosis, especially in heifers needing to be in lactation within three months. Young animals with teat or canal obstruction have a worse prognosis. Topical treatment with emollients and antibiotics is recommended, with systemic antibiotics reserved for complications such as mastitis [36].

The final categorization and ranking of priority after SLA are summarized in Table 4. Mild, Major and Severe burns correspond to cases needing increasing amounts of resources for treatment, respectively. Severe and Major burns are recommended to be euthanized, while Mild burns may be considered for treatment, provided that the resources are available. Minor burns often do not necessitate intervention other than pain management, and the Normal category only requires observation in case smoke inhalation manifests. All animals will need non-clinical resources (feed, water, shelter) for safekeeping and buffering the effects of stress.

Animals with > 20% TBSA require fluid resuscitation. Moreover, animals with full thickness burns > 5% have a hopeless prognosis in the field due to complications such as infection and sepsis, plus the high cost of specialized care, which is otherwise absent. Hence, these categories cannot be treated in the field [16]. A full visual flow diagram is presented in Fig. 6, integrating FLA and SLA stages.

Discussion

Conflicting guidance exists on the assessment of farm animals and wildlife. Butkus et al. (2021) [53] found that veterinarian involvement did not significantly impact burned wildlife survival at rehabilitation centres. Conversely, Cowled et al. (2022) emphasized the importance of regular clinical reassessment in livestock to monitor burn progression and to improve prognostic accuracy [16]. Chigerwe et al. (2020) outlined burn treatment for small ruminants and pigs in a United States hospital

Table 4 Categorization of burned animals after Second-line Assessment (SLA). C Cardoso, 2022

Priority	Cut-offs	Category	Action	Presenting signs	Prognosis
I Major burns	> 20 % TBSA Partial thickness < 5 % TBSA Full thickness	Critical	Needs lifesaving measures in seconds or minutes	Apnoea, bradycardia, shock, intoxicated/Smoke Inhalation	Poor
II Severe burns	> 20 % TBSA Deep partial thickness > 5 % TBSA Full thickness	Euthanasia	Cannot be saved, utilize resources for other patient	> 5% TBSA full-thickness burn, need grafting. Critical locations affected	Hopeless
III Mild burns	> 10 % TBSA Partial thickness	Urgent	Can evolve to critical in the next minutes/hours, provide treatment in less than an hour	Critical locations mildly affected	Fair
IV Minor burns	Superficial burns	Stable	Treatment can wait more than one hour	Similar to sunburn. No signs of smoke inhalation	Good
V Normal	No burn injuries seen	Apparently unaffected	Evaluate and discharge or keep on observation (possible smoke inhalation)	Alert, normal respiration, No signs of skin burn	Good

setting, noting common burn locations [54]. They, along with others [50] suggest that sheep and pigs may have a less favourable prognosis compared to goats. However, some authors argue that pigs and goats exposed to fire have a very poor prognosis because of their higher susceptibility to stress [40, 55]. Bolcato et al. (2023) emphasize that treating burned cattle is challenging due to limited clinical evidence and recognize the importance of identifying the systemic effects of severe burn injuries for proper resource allocation [37]. In contrast, other authors focus only on the burn's anatomic presentation and topical treatments, neglecting the broader impacts of wildfires on the animals [52].

Madigan et al. (2011) [48] and Cowled et al. (2022) [16], drawing from US and Australian mass casualty veterinary experience, emphasized preparedness and coordination for improved outcomes in fire-affected animals and humans. The proposed triage guidelines presented in this paper concur with these and other authors [1, 15, 38] who cite containment and mitigation as primary goals in mass casualty events. Madigan et al. (2011) described using simple measures such as luring animals with food and water to assess their level of awareness and mobility, enabling prioritization for assessment and treatment, and significantly reducing casualties. This method led to a shift from initially considering euthanasia for 90% of affected stock to treating 65% with observed progress over the study period of 42 days [48].

Livestock wildfire guidelines rely heavily on observations from case reports presented by professional experts [15, 48–50, 55] considered low-strength evidence but still valid for the context of production animal field practice. Ovine research [29, 33, 51] provides stronger evidence for burn systemic effects and treatment, contributing to improving clinical decision-making. Publications highlight the need for a better understanding of livestock burn injuries for accurate decision and recovery prediction. However, burn injury is only one factor in field decisions; animal welfare, including pain management, is also key, as well as the availability of non-clinical resources to manage surviving animals. The proposed FLA and SLA prioritize welfare and cost-effectiveness based on field practices that include evidence-based actions to create a practical triage model.

Conclusion

In the chaotic aftermath of a fire disaster, with limited resources, accurate burn prognosis is crucial for effective resource allocation. Veterinary triage prioritizes animals with the greatest chance of survival, ensuring critical care reaches them. Understanding recovery trajectories allows efficient distribution of supplies, personnel, and shelter. Prognosis guides ethical decisions, distributing resources fairly based on the needs of the animals with the best chances of recovery. However, disaster environments are unpredictable, limiting prognosis accuracy. Thus, ethical principles and compassion must be combined with severity categorization and monitoring treatment progress. Continuous updates are essential. Balancing accurate prognosis with its limitations enables efficient, equitable

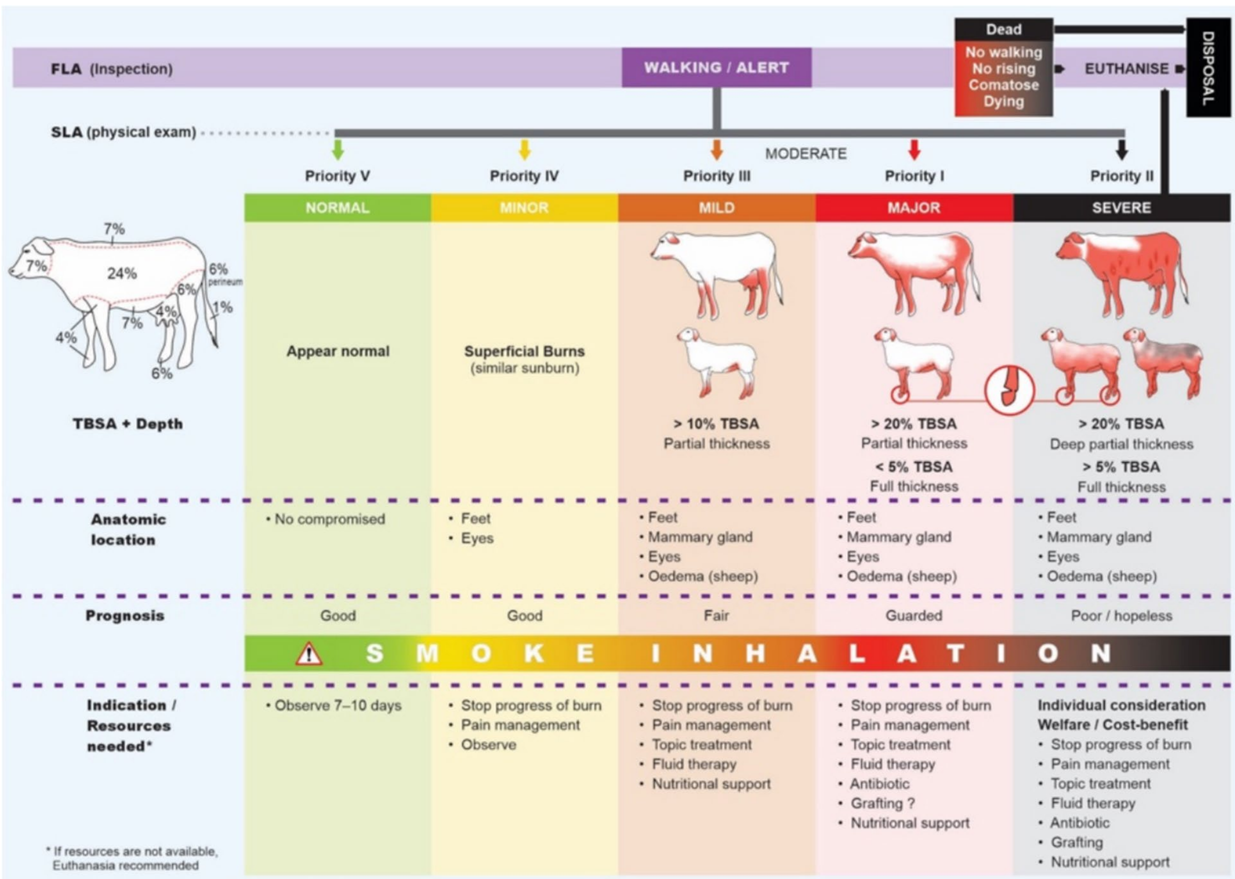

Fig. 6 Triage Guidelines for Domestic Ruminants Burned in Wildfires. Note: Considering the most commonly used predictors for survivability in ruminants: % total body surface area (TBSA), depth of burns, oedema location on the first 24hs (sheep), limbs/feet involvement (sheep and cattle), respiratory involvement/smoke inhalation (sheep most affected), mammary gland/age (cow). *FLA: First-line assessment, SLA: Second-line assessment. C Cardoso, 2022

and cost-effective resource use. These triage guidelines aid the transdisciplinary group in making evidence-based decisions for wildfire-affected livestock.

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C.L.C. methodology, data search and selection, image design, and main manuscript writing. C.E.M. Manuscript review and design input. R.L. Manuscript review and supervision.

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Data availability
The review matrix file is available upon request to the corresponding author.

Declarations

Ethics and consent to participate
The project was approved by the Research Ethics Committee of the Faculty of Veterinary Science of the University of Pretoria (reference number REC055-22) and the Research Ethics Committee of the Faculty of Humanities of the University of Pretoria approved a written informed consent to participate (reference number REC055-22 line 1).

Consent to publication
Not applicable.

Competing interest
The authors declare no competing interests.

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