# Evidence-based guidelines for triage and prognostication for domestic ruminants burned in wildfires

By

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# DECLARATION

I, the undersigned Claudia L. Cardoso, whose name appears on the title page of this dissertation, do hereby declare to be the author of this work.

The author hereby declares that she conceived and executed the research presented in this dissertation. Neither the substance nor any part of this dissertation has been submitted in the past or is to be submitted for any other degree at this University or any other University.

The applicable research ethics approval has been obtained for the research described in this work.

The author declares that she has observed the ethical standards required in terms of the University of Pretoria's Code of Ethics for researchers and the Policy guidelines for responsible research.

This dissertation is presented in partial fulfilment of the requirements for the Doctor of Philosophy (PhD) degree in the Department of Production Animal Studies, University of Pretoria.

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Claudia L. Cardoso

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Date

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# LIST OF ABBREVIATIONS

ABSI - Abbreviated Burn Severity Index

Ag - Silver

APIs - Application Programming Interface

BOBI - Belgian Outcome in Burn Injury Score

B - Burn

CIE - Commission Internationale de L'eclairage

CNNs - Convolutional Neural Networks

CO2 - Carbon dioxide

COX-2 - Cyclooxygenase-2

CSS - Cascading Style Sheets

DMSO - Dimethyl sulfoxide

EO - Expert opinion

FLA - First Line Assessment

GP - Good practice

GUI - Graphical User Interface

HR - Highly recommended

HTTP - Hypertext Transfer Protocol

IE - Insufficient evidence

IM - Intramuscular

iNOS - Inducible Nitric Oxide Synthase

iOS - iPhone Operating System

LAB - (L) lightness/darkness, (A) redness/greenness, (B) yellowness/blueness

NGOs - non-governmental organisations

NSAID - Nonsteroidal anti-inflammatory drug

NVT - non-veterinary-trained

OIE – Office International des Epizooties

%TBSA – Percentage of total body surface area

PBI - Prognostic Burn Index

R - Recommended

RGB - Red, Green, Blue

RNNs - Recurrent Neural Networks

ROS - Reactive Oxygen Species

SB - Skin burn

SDGs – Sustainable Development Goals

SGD - Stochastic Gradient Descent

SI - Smoke inhalation

SLA – Second-line assessment

SVM - Support Vector Machines

TBSA - Total burn surface area

3D - Three Dimensional

TNF - Tumour Necrosis Factor

VDM - Veterinary Disaster Management

VT - Veterinary-trained

XML - Extensible Markup Language

YOLO-V3 - You Only Look Once - Version 3

# CHAPTER 1

## EXECUTIVE SUMMARY

Wildfires occur worldwide, affecting farmers emotionally and financially. Beyond the loss of animal life, wildfires also threaten the future reproductive capacity of surviving livestock due to smoke exposure. In determining appropriate interventions, key considerations include animal welfare, clinical prognosis, and cost-effective treatment. Consequently, enhancing clinical assessments to enable prompt and appropriate action is essential for maximising animal welfare.

The incentive for this study was the principal researcher identifying conflict created by the provision of inconsistent advice given to farmers regarding the course of action for animals presenting with burns and/or smoke inhalation in the aftermath of wildfires that occurred during 2020 and 2021 in South Africa.

The first step necessary to understand the scale of the problem and potential sources of conflicting advice was to broaden the researcher's knowledge base concerning wildfires, their causes, areas frequently affected both locally and globally, and the associated losses. The particulars of veterinary disaster management, animal welfare in such situations, and the methodologies applicable for containing veterinary disasters due to fire were also examined. Burn pathology was also researched, including classification, appraisal, prognostication, first aid, and further treatment according to severity. Systemic involvement and smoke inhalation emerged as important considerations in the decision-making process directly related to burn pathology.

The principal objective was to categorise the types of scientific evidence drawn from the available literature, as this would form the foundation for creating evidence-based clinical guidelines for prognostication in cases of burn injuries, thereby reducing uncertainty during decision-making by individuals with varied training levels.

Thus, the focus of this stage of the project was to establish triage guidelines for burn injuries that were evidence-based and tailored to the context of wildfire events, production animals, and field practice, specifically in pre-hospital animal care. Chapter 2 provides a foundational baseline and analysis of the topic, leading to the rationale for the conceptualisation and visual representation of the triage guidelines for burned domestic ruminants.

Three main points were considered when defining the project's objectives. Firstly, there was a need to create an evidence-based system for categorising and clinically evaluating ruminants involved in wildfires to support decision-making. Secondly, the provision of evidence-based, practical, and ethically defensible recommendations aimed at increasing the accuracy of prognosis for burned ruminants in wildfires, and finally, recommendations for further research.

The experimental component of the work is comprised of three parts: 1) a survey of first responders to identify factors affecting decision-making for burned livestock; 2) developing mock-up models of a cow and a sheep for burn categorisation. These models resemble actual animals in size and features and were used to train a computer model; and 3) the development of software to streamline the triage and categorisation of burned livestock based on the most important factors identified for prognostication.

The survey aided in ascertaining the veterinary dynamics of clinical decision-making when evaluating ruminants affected by wildfires. Several clinical and non-clinical factors are involved in the conceptualisation process, and proper prioritisation was crucial to mitigate the possibility of conflicting advice provided by first responders. The main limitation surrounding prognostication in burned animals stemmed from practitioners' differing levels of experience, with a lack of clear understanding regarding the primary prognosticators used in burn pathology or how to accurately prioritise them.

The uncertainty this creates often leads to conflicting advice, inaccurate allocation of resources, and further compromises animal welfare. Hence, it was established that accurate prognosis is a crucial factor guiding decision-making across levels of experience and that a shift in priorities occurs as practitioners gain clinical experience, indicating a more decisive approach, particularly in severe cases, with a tendency to favour animal-centred decisions rather than prioritising economic factors. Chapter 3 provides a thorough explanation of this portion of the work.

Opportunities to improve the accuracy of prognostic indicators in relation to burn severity in domestic ruminants were identified. Therefore, evidence-based triage guidelines have been improved by incorporating recommendations based on stronger scientific evidence derived from controlled trials. The implications of these findings are especially important to improve animal welfare by reducing inaccuracies when diagnosing livestock affected by wildfires.

# CHAPTER 2

# EVIDENCE-BASED GUIDELINES FOR THE CONCEPTUALISATION OF TRIAGE FOR BURNED DOMESTIC RUMINANTS

## 2.1. ABSTRACT

Worldwide, wildfires affect livestock farmers emotionally and financially, and due to global warming, the risk of wildfires is expected to increase in the next thirty years. The losses experienced by farmers include feed, facilities, livestock, and the future reproductive performance of any surviving animals exposed to smoke. Many factors, such as animal welfare, the clinical prognosis of cases, and treatment costs, are all important considerations in decision-making. There is a paucity of data regarding decision-making processes with burn injuries in livestock, and this study aims to derive evidence-based guidelines for decision-making regarding domestic ruminants affected by wildfires in the context of field animal production practice. Most evidence found corresponds to case reports (expert opinion) and observational trials derived from real events. However, scientific controlled trials were widely performed during the eighties and nineties using sheep as a test model for skin burns and smoke inhalation and have significantly contributed to the current understanding of burn injuries in humans and animals. Databases from Web of Science, Medline, and Google Scholar were searched with chosen keywords connected with burn injuries in livestock in publications in both English and Spanish. A research matrix was populated with relevant information according to inclusion criteria and strength of evidence, and as a result, triage guidelines were synthesised and integrated for both sheep and cattle in a visual, instructional format. Key clinical factors such as burn depth and extent, anatomic localisation of burns, and smoke inhalation were considered when categorising animals according to clinical severity. Additionally, core indications for decision-making were summarised, including non-clinical factors, implying that the lack of resources affecting their provision will severely compromise animal welfare, leading to the consideration of euthanasia as a strong recommendation.

KEYWORDS: ruminants, burns, triage, prognosis, welfare, wildfires.

## 2.2. Introduction

The devastating occurrence of wildfires affects farmers emotionally and financially (Rethorst *et al*., 2018). Clear guidelines for quick decision-making regarding injured livestock must be based not only on clinical prognosis but also on accessibility to the area, the value and number of animals involved, and the availability of adequate human and financial resources. Decisions need to be ascertained unequivocally as the context requires timely actions to limit losses and optimise animal welfare (Rogers *et al*., 2015).

Common losses resulting from wildfires amount to land, feed, facilities, animals, and future performance of surviving livestock exposed to smoke (O'Hara *et al*., 2021); moreover, according to recent studies in South Africa (Forsyth *et al*., 2019), and at a global level (UNEP, 2022) the risk of wildfires is expected to increase in the next thirty years due to global warming exposing animals and farmers to fire risk during more than half of the year.

As a measure of clinical severity, the extent and depth of burns have classically been used as predictors for mortality to guide prognosis and decision-making processes (Wohlsein *et al.,* 2016; Willson, 1966). Hence, burn injuries have historically been assessed according to the extent of the body surface or total body surface area (TBSA) affected and the depth of lesions with variable outcomes based on the subjective judgment of the evaluator (Moore *et al*., 2021).

There is consensus in the literature that animals affected by more than thirty per cent TBSA (>30% TBSA) of any depth must be euthanised immediately because of the severity of systemic effects, further complicated by delays in veterinary assistance due to accessibility to the disaster area, rendering a hopeless prognosis (Nielson *et al*., 2016; Cowled *et al*., 2022).

When dealing with severe burn injuries, the body immediately starts an inflammatory response comprised of massive release of mediators and cellular peroxidation, leading to extensive tissue damage and systemic compromise (Nielson *et al*., 2016; Jeschke *et* al., 2020). Further consideration must also be given to injuries of the respiratory tract due to smoke inhalation, especially in sheep due to their proximity to the ground, which exacerbates both the inflammatory and the hypermetabolic response, decreasing survivability (Cox *et al.,* 2003). Moreover, recent studies contemplate the long-term consequences for livestock exposed to smoke during wildfires in the US. Pneumonia and infertility have been frequently reported as common consequences. Impacts on reproduction include decreased conception rates, uterine-growth retardation, and abortions with sheep being mostly affected. These findings open a wider range of considerations, especially for the future performance of breeding stock exposed to wildfires (O'Hara *et al*., 2021).

With wildfires, animal welfare should be at the forefront of the decision-making process. However, the welfare of the people involved also needs to be considered. Treatment usually starts under severely resource-limited conditions, so the decision-making process needs to integrate several factors, including clinical presentation depending on systemic involvement, prognosis based on the extent and severity of the burn injury, availability of skilled personnel to care for the animals, ability to provide adequate shelter, feed, and water, the availability of and the cost of treatment, and the long-lasting consequences on livestock due to exposure to smoke (Vaughan, 2007; Lara *et al*., 2017; NSW-DPI, 2018; O'Hara *et al*., 2021). Therefore, decisions should not be made on any one-time point assessment unless the severity is such that euthanasia is the only option. Less severe cases should be monitored for at least 7 to 10 days to account for the dynamicity of burn injuries (Madigan *et al*., 2008).

Experimental work on ovine models related to smoke inhalation alone, and smoke inhalation in combination with tissue burns has contributed to the current understanding and treatment recommendations used in human medicine and extrapolated to veterinary medicine (Soejima *et al.*, 2001; Traber *et al*., 2007). Various studies (Pierson *et al*., 1969; McAuliffe, 1980; Morton *et al*., 1987; Lee *et al*., 2014; Kaita *et al*., 2020) have defined and classified burn injuries, describing their evolution and the severe clinical signs that provide the basis for prognosis and decision-making. Observational studies and case reports have also provided guidelines for farmers and are relevant regarding important recommendations for decision-making when considering animals burned in wildfires (Willson, 1966; Carroll, 1981).

The definition of important concepts and practices that safeguard animal welfare is at the forefront of the conceptualisation process that guides decision-making and is frequently described in the literature related to veterinary disaster management (Rethorst *et al*., 2018; Knight, 2002). Accounting for the loss of machinery, feed, crops, and property (fencing, handling facilities, etc.), alterations of water quality after the fire, and the logistics of sourcing supplementary feed for surviving livestock is an important part of the analysis process to follow when making individual decisions (Knight, 2002).

Offering prognostic hope for animals with minor burns, without neglecting animal welfare could mitigate the sense of loss that the farmer experiences in these situations. It is at this point that conflict arises due to contradictory advice given, especially for animals undergoing treatment, which are re-evaluated by the multidisciplinary group involved in the aftermath of fire events and are given a different course of action. These practice promotes distrust amongst stakeholders (Squance *et al*., 2021). Especially for animals undergoing treatment, which re-evaluated and advised a different course of action. For the most part, animal welfare is often paralleled by emotional perceptions and anthropomorphic considerations that lead to decisions based not on evidence but on human perception of suffering (Korte et al., 2007; Fordyce, 2017). Hence, clear guidelines to be followed by the transdisciplinary team involved in veterinary disaster management will contribute to generating solutions for the recovery of the community, providing a better outcome for both the animals and the humans involved (NSPCA, 2015; Salaberry-Pincheira and Vera Oliva, 2018; Squance *et al*., 2021).

### 2.2.1. Veterinary Disaster Management

The United Nations Sustainable Development Goals (SDGs) specifically focus on the link between wildfires and the loss of livestock through SDG 15, “Life on Land” (UN, 2024). Degradation of forests due to unsustainable agricultural practices destroys animal habitats, displaces wildlife, disrupts food chains, and increases fire vulnerability. It also impacts food security and disrupts livelihoods. A cascading effect of the loss of livestock and farmland due to wildfires is the increased pressure on the remaining land, which further strains the ecosystem (Khatri, et al., 2023).

Injured livestock due to wildfires constitutes a veterinary disaster. Preparedness for such situations can greatly contribute to increasing the social and economic recovery of the community (OIE, 2016). Figure 1 depicts the disaster management cycle. Within this cycle, veterinary services/professionals play fundamental roles at both national and local levels. Firstly, by establishing frameworks for mitigation and prevention strategies, secondly, by establishing a hierarchy of communications; and thirdly, at ground level when responding to the fire disaster event, by doing veterinary triage to match needs and resources. Working with affected farmers/farm managers complements decision-making as only the farmer/farm manager will know what resources are available or attainable to make sustainable decisions and continue these actions over the recovery phase. Lastly, a lessons-learned phase after the event is of great value for constant improvement (OIE, 2016).

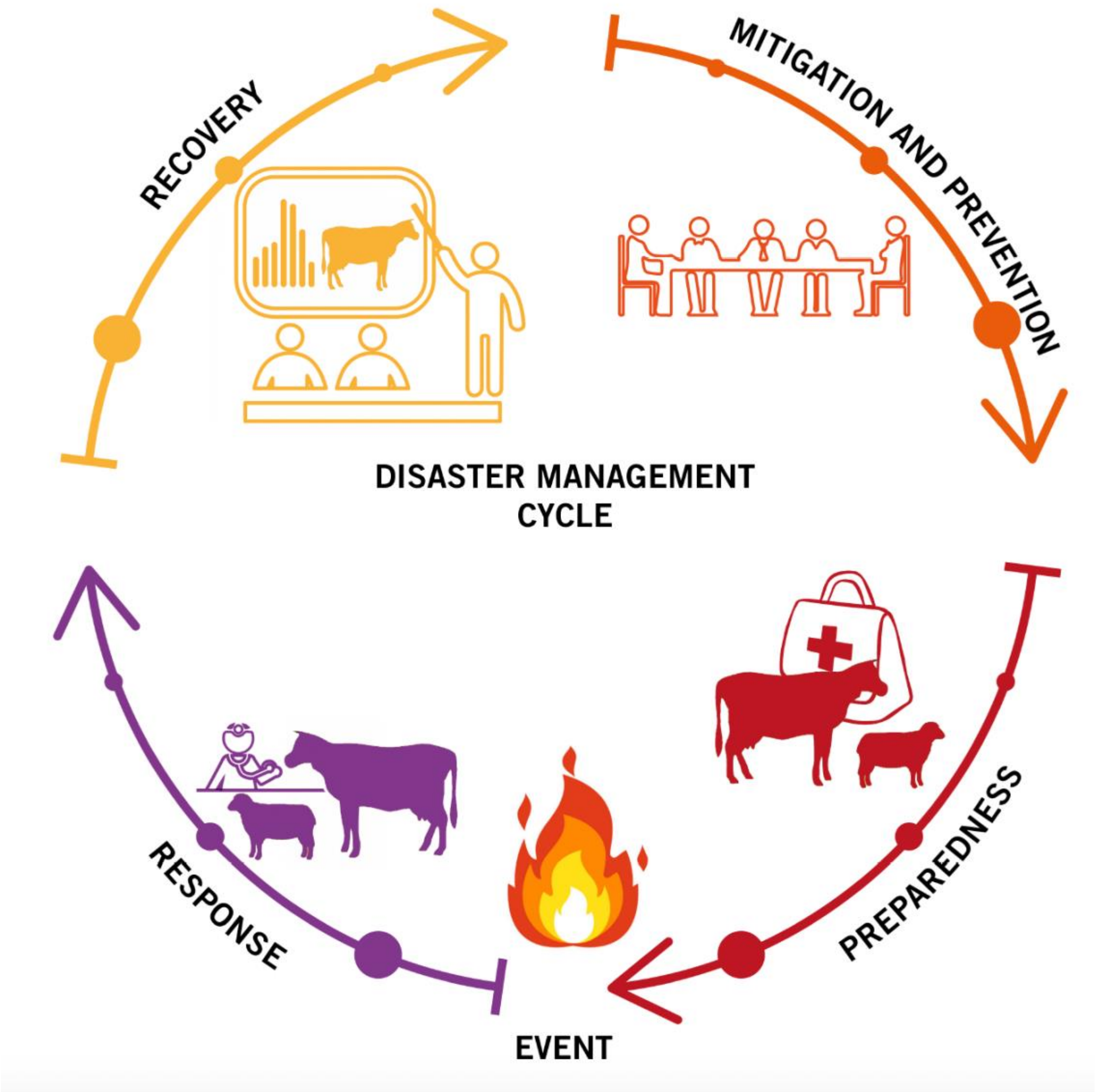



Figure 1. Disaster management cycle. Adapted from OIE guidelines, 2016.

Fires have severe social and economic impacts by affecting the life, health and expected production gain from livestock. During these events, their habitat is destroyed and needs to be recovered. A key factor affecting recovery is depleted financial resources that add to the sense of loss experienced by the affected community (Knight, 2002). Furthermore, conflicting assistance contradicts the core goal of an emergency management plan, which is primarily collaboration to safeguard animal welfare and in the long-term, community recovery (Squance *et al*., 2021).

### 2.2.2. Animal Welfare in Disaster Situations

Animal welfare can be defined simply as the internal state of the animal at any given time (Mellor and Beausoleil, 2015). This state affects how the animal responds to its environment based on changes in behaviour, physiology, health status, cognition, and productive outputs (Hemsworth *et al*., 2015).

The Five Domains is a widely used model in the evaluation of animal welfare in livestock, which classifies welfare opportunities and threats into five overlapping categories: environment, behaviour, nutrition, health, and mental state (Mellow and Beausoleil, 2015). The emotional or cognitive experience of production animals is often overlooked, with livestock welfare goals focusing mainly on production indicators such as feed intake, low disease prevalence, and low mortality (Cardoso *et al*., 2016).

An objective assessment of welfare status is measured by determining if the animal is under physiological stress through deviation on homeostatic levels of certain indicators for which the animal elicits a biological response due to a threat to its well-being (Narayan *et al*., 2021). However, this notion is challenged by the allostatic welfare approach, which states that the physiologic ‘Allostasis Concept’ should be at the centre of animal welfare evaluation instead of that of physiologic homeostasis. The allostasis approach advocates for a comprehensive assessment of animal welfare that incorporates negative and positive welfare states, recognising the sentient status of animals. Good animal welfare is not only the absence of stress as classically determined by the homeostatic approach but also involves the capacity for adaptive change (Korte, et al., 2007). This perspective aligns best with the Five Domains model of Mellor and Beausolleil (2015).

In disaster situations such as wildfires, the affected livestock's immediate and future needs are a core concern (Knight, 2002). Animal welfare in this context has been uniformly negatively affected, and each animal will respond with different intensity to this environmental stressor that destroys their home range, social structures and their physical state. Triaging of burned stock then constitutes the first step towards animal welfare care within the disaster management framework. The aim is to categorise animals using a multifactorial conceptualisation guide, which includes triage principles of resource allocation to stabilise the animals' allostatic overload and bring the animal back to health whenever possible by applying available resources.

After the fire, there will be severely injured animals that will need immediate euthanasia (animals that cannot move, cannot travel and are in severe respiratory distress) and others that are mildly injured with a good chance of recovery in terms of health and productivity (Rogers et al., 2015). Minor and mildly injured animals that are mobile and alert can be retained provided that veterinary treatment is immediately instituted and that animals are re-assessed by a veterinarian to ensure the continuity of welfare and health care, resulting in further treatment or euthanasia if no improvement is observed or the patient deteriorates (Cowled *et al*., 2022). Major and severely affected animals have a poor prognosis and will need careful individual consideration. Animal owners should seek professional advice at this stressful time to make appropriate decisions.

## 2.3. Burn Lesions Due to Wildfires in Domestic Ruminants

Skin burns occur due to direct contact with flames and/or radiation from the heat of flames and are often concomitant with smoke inhalation, especially in sheep (Madigan *et al*., 2008). Management of severe burn lesions is extremely difficult in the context of production animal practice due to the type of dedicated medical care and resources needed, the costs involved, and the protracted healing time (Cowled *et al*., 2022).

Fluid and electrolyte depletion, hypovolemic shock, and hyperdynamic states often follow major burns; smoke inhalation, although not detectable over the first days following the insult, can severely affect the respiratory system and contribute to the severity of the burn injury (Cox *et al*., 2003).

Therefore, according to general disaster triage methodology (Wingfield, 2009) burned animals need to be evaluated firstly in terms of neurological state and mobility, followed by respiratory and cardiovascular involvement; secondly, regarding the localisation of injuries as this may impair vision, foraging/ingestion, movement, nursing and urination/defecation by being localised in the head (ocular and mouth), limbs, genitals (including udder), and perineal involvement respectively; and thirdly by evaluating the total body surface area involved (TBSA) and the depth of lesions as determinants of compatibility with function. Combinations of these parameters will be used to determine the overall severity of the injury and its relation to mortality outcomes; hence, they will be used as prognosis predictors for decision-making.

### 2.3.1. Classification of Burn Lesions

#### 2.3.1.1. According to Body Surface Extent

Historically, the "Wallace rule of 9 Principle" is used in human medicine to define the extent of body surface area burned with partial-thickness burns and deeper burns. Superficial burns are not considered in %TBSA because these do not require fluid therapy (Thom, 2017). However, in veterinary medicine, Pierson (1969) described the following body surface percentages for cattle as a more accurate allocation: head 7%, back 7%, left costal wall+ left abdominal wall 24%, right costal wall + right abdominal wall 24%, udder 4%, ventral thorax and abdomen 7%, each foreleg 4% (8%), each hindleg 6% (12%), perineal area 6% and tail 1% (Figure 2). To the authors' knowledge, no specific description of the extent of burn lesions has been published for sheep.

Survivability is inversely correlated to %TBSA and depth of burn lesions; moreover, survivability substantially decreases with smoke inhalation and severe burns (full-thickness burns) in critical anatomic locations. Cut-offs defined for humans are drastically reduced for animals affected by wildfires because the care conditions and the possibility of transporting affected animals in time ("golden hour") to specialised care units are scarce to null (Rogers *et al*., 2015; Cowled *et al*., 2022). Experts report a 100% survivability for 10-20% TBSA superficial to deep partial-thickness burns, approximately 87% survivability for 20-30% TBSA deep partial-thickness burns, with adequate care; while only 27% survivability is correlated with 30% or higher combined partial-thickness and full-thickness burns, under specialist care. Survivability substantially decreases with smoke inhalation and critical location burns that impair functionality (Pierson, et al., 1969). This highlights the limited possibilities for the application of proper indications for burn treatment in the field, prompting a reduction in the proposed cut-offs to cater for the reduced availability of clinical and non-clinical resources.

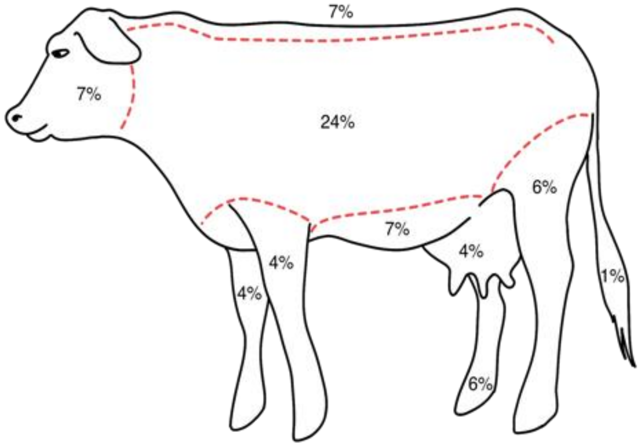



Figure 2: Schematic depiction of total body surface area (TBSA) appraisal in ruminants. Adapted from Pierson et al., 1969.

#### 2.3.1.2. According to Depth

The latest approach to the classification of burn injuries (Noorbakhsh, 2021) considers the need for surgical treatment for complete healing and is as follows (Table 1):

- **Superficial burns** affect the superficial layers of the epidermis: animal shows pain, erythema, oedema, and peeling of the skin. Not contemplated on TBSA appraisal.

- **Superficial partial-thickness burns** can reach the basal layer of the epidermis, pain is evident and the capacity to recover is preserved, showing improvement in a period of two weeks with proper care.
- **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. Pain in these lesions is less than in the above-described lesions because the pain receptors are destroyed.
- **Full-thickness burns** destroy the epidermis, dermis, and supportive structures. Extensive fluid loss and tissue reaction with eschar formation are observed. These burns are considered not as painful, because pain receptors have been destroyed. These lesions are highly susceptible to infection, repair often involves surgical procedures and specialised care. More than 5% TBSA of this type of burns are considered to have a poor prognosis in ruminants.
- **Deep full-thickness burns** involve all layers of skin, underlying muscles, bones, ligaments, fat, and fascia (Noorbakhsh, 2021; Rice and Orgill, 2023).

Table 1: Classification of burn wounds according to depth (Noorbakhsh *et al.,* 2021).

| 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 |

## 2.4. Veterinary Triage

The main objective of performing veterinary triage in disaster situations is to adequately pair available resources with patients' needs. Veterinary triage in production animal practice needs to take into consideration factors such as overall owners' low tolerance for long treatments, the difficulty of animal loading and transportation, low availability of skilled personnel, facilities, supplies, and/or equipment to care for the animals, and the possibility of euthanasia (Wingfield, 2009). Moreover, affordability and the provision of adequate space, food, and water for the safe-keeping of in-treatment animals constitute important non-clinical decision drivers as part of the five domains of animal welfare (Mellor and Beausoleil, 2015).

Accessibility to the affected area, followed by means to move affected animals to safer ground, is the first challenge faced in wildfires. Hence, the initial approach needs to be to quickly identify those animals that would benefit from being moved to safer ground to receive care and those that need to be euthanised immediately (Madigan et al., 2011).

The next step is to assess animals by performing a physical examination of respiratory and cardiovascular parameters, starting with the most critically affected. According to general triage guidelines, immediate attention needs to be given to animals showing a depressed respiration rate and/or cardiovascular rate and in hypo/hyperthermia (these animals are considered critical and are usually labelled as code ‘red’) (Wingfield, 2009). In burn cases, cooling of burn lesions to stop their progression and needing intravenous (IV) therapy are labelled as requiring urgent attention and coded ‘orange’. Mild injuries and unaffected animals are of lower priority, labelled code ‘yellow’ and ‘green’, respectively, and their evaluation is delayed until the red and orange categories have been attended to. A new priority categorisation may result after a physical assessment.

Thereafter, proper evaluation of the burn lesions will render adequate categorisation and prognostication according to %TBSA, depth and anatomic location in connection with severity and compatibility with function (Wingfield, 2009).

Animals with detaching claws or severely affected coronary bands require frequent re-assessment as these are in considerable discomfort and are prone to fly strike or secondary infection. For all in-treatment cases, progression of the burn injury, pain management, antibacterial therapy, fly strike prevention, and consistent nursing care are mandatory (Rogers *et al*., 2015).

#### 2.4.1. Prognosticators of Burn Mortality

In humans, prediction of mortality is conducted by applying scores such as the Baux score, Belgian Outcome in Burn Injury score (BOBI) and the Abbreviated Burn Severity

Index (ABSI) as well as the Prognostic Burn Index (PBI). Across these scores, age, burn surface area, and inhalation injury are the most important parameters for prognostication of mortality (Kaita, et al., 2020). Image-based automated burn diagnosis has been used in human medicine for decades to properly identify the depth of burn injury, which presents a great challenge even to experienced practitioners (Boissin & Laflamme, 2021).

In animals, severe burn injury, defined as a burn on >30% TBSA or full thickness burns on >5% TBSA, can be fatal hence, prediction of mortality becomes important in the decision-making process for these patients. Visual appraisal of burned animals has been utilised as a predictor of mortality, often focusing more on the burn injury and its response to treatment than on the clinical state of the patient. Weight loss, seen as a decrease in body condition score, and development of burn wound infection are used as decision-making parameters during case re-assessment (Rogers *et al.,* 2015).

Scores for the prognostication of mortality in animals and/or the possibility for recovery in burned animals have not been established. These can be established after adopting unequivocal methods for determining %TBSA in the different species and establishing age correlations with clinical severity, allowing for the development of advanced technological tools, readily available in human medicine, for predicting burn outcomes by combining crucial parameters, such as common prognosticators of burn, including anatomic location and smoke inhalation. Quickly obtaining adequate fluid therapy volumes, add-ons to fluid therapy, and diet needs for supporting animals in recovery may aid treatment success.

### 2.4.2. First Aid in the Disaster Treatment Area

In most cases of wildfires, the treatment of burned ruminants will be based on veterinary resources available in a mobile setting, which, in the context of triage implies identifying cases that will respond best to the available intervention (Surowiecka-Pastewka *et al*., 2018).

Within two hours of the insult, stabilising the patient and stopping the progress of the thermal injury must be the priority; sedation may be necessary, as well as pain medication, preferably non-steroidal drugs. Ensure venous access is obtained early, as the ongoing edematous process could impair access later. The burn lesions must be cooled down with abundant cool water; avoiding the use of very cold water or ice as this will increase vasoconstriction and lead to tissue hypoxia.

Burn injuries present three distinct areas: the coagulation area, located centrally, followed outwardly by the stasis/ischemic area and the hyperaemic area in the periphery of the lesion, characterised by inflammatory vasodilation (Karpelowsky & Rode, 2008). During the healing process, these areas will undergo consecutive and overlapping phases, which will trigger wound healing aimed at restoring tissue perfusion and remodelling and re-epithelialization, resulting in varying levels of skin pliability and/or scar contraction, which could be movement and/or functionality restrictive (Jeschke, et al., 2020) (Morton, et al., 1987)

In general, mild burns, defined as >10 % TBSA but <20% TBSA partial-thickness, with mild involvement of anatomic critical locations and no respiratory involvement, require light treatment starting with stabilisation and stopping the progress of the thermal injury, securing intravenous access and fluid therapy if needed. Plasma transfusion or vitamins E or C may be required as add-ons to fluid therapy. Burn wounds should be covered with topical antibiotics and dressings while planning wound healing optimisation through nutritional support and perfusion. Monitoring of body weight is used in production animals as an indicator of survivability in connection to the hypercatabolic state that follows burn injury; hence, targeted nutritional support is needed. Common catabolism-reducing agents, such as propranolol, can be considered to reduce the loss of body condition.

Lastly, planned rehabilitation of in-treatment patients to prevent tissue contractures should be implemented. This can be achieved by active range of motion exercises. Patients should be reassessed to detect those not responding to treatment and require a change in therapeutic intervention.

Treatment recommendations for >20%TBSA partial-thickness skin involvement leading to major burns advocate for the preservation of the characteristic fluid-filled vesicles for the first few days to prevent infection. Pain medication is highly recommended. Clear the surrounding fur/wool and regularly debride devitalised tissue, flush the lesions with water and antiseptic solutions, and frequently apply water-based topic antibiotic cream. The lesions must be covered with antibacterial (propolis/medically graded honey) bandages and allow eschar formation.

The eschar will prevent tissue contraction, allowing time for re-epithelization; once the eschar falls off, wound constriction will begin to close the lesion unless the surface area is too big, in which case skin grafting will be required.

Severe burns are difficult to treat, and eschar formation is prominent. In addition to the standard burn treatment protocol, occlusive moist antibacterial bandages and frequent excision of devitalised tissue are required. This often necessitates skin grafting and results in protracted healing time of full-thickness burns and higher costs. These cases cannot be treated in the field.

In summary, superficial and deep partial-thickness burns in <20% TBSA (depending on location) respond best to treatment and therefore carry the best prognosis (Lara, et al., 2017) (Efimova, et al., 2019) (Pierson, et al., 1969) (Morton, et al., 1987).

Animals with full-thickness burns on >5% TBSA require costly and lengthy treatment and require careful consideration regarding prognosis, taking into account animal welfare concerns.

### 2.4.3. Burn Shock and Fluid Therapy

Burn shock is a systemic reaction that occurs in severe burn injury when >20% TBSA is affected, although it can happen especially in young animals with >10% TBSA and will require intensive veterinary care. The systemic reaction is divided into two stages: resuscitation (first 24-72 hours) and a hyperdynamic/hypermetabolic state ensuing 3-5 days after the insult (Vaughn and Beckel, 2012).

During stage one, fluid therapy is often lifesaving, contributing to the stabilisation of the patient by controlling vascular permeability, oedema formation and the release of inflammatory mediators. During stage two, where the increased metabolic rate leads to the loss of body mass, enteral nutrition is paramount to mitigate the concomitant immune suppression that contributes to the high risk of developing sepsis (Vaughn and Beckel, 2012).

The fluid therapy most often recommended is Ringer's lactate solution administered at a dose rate of 2 to 4 ml/kg per %TBSA, according to the Parkland formula used to calculate resuscitation fluid volumes in correlation with %TBSA involvement Half of the volume is administered during the first 8 hours and the other half in the next 16 hours (Alvarado, et al., 2009). To counteract part of the pathophysiologic changes that occur with skin burn (SB) and smoke inhalation (SI) injuries, certain add-ons can be administered in combination with fluid therapy. In two studies conducted by Morita and others (2006 a, b), a correlation between vitamin E depletion and higher mortality of B and SI injury patients was postulated. Forty merino sheep previously supplemented with vitamin E and exposed to SB and SI showed a lower total reduction in tocopherols and a higher recovery rate from their injuries than non-supplemented sheep (Morita *et al.,* 2006 a, b). Traber and others (2007) corroborated these findings and showed that tocopherol had a 1.5 times greater decrease in B and SI injured animals than non-supplemented sheep (Traber *et al*., 2007). Furthermore, Shimoda and others (2008) measured plasma, lung, trachea, heart, and liver tocopherols/lipids and found that, except for the heart, tocopherols were markedly depleted due to the severe oxidative stress experienced with SB and SI; hence, suggesting that supplementation during the resuscitation period would be beneficial (Shimoda *et al.*, 2008).

Lung oedema is more severe in combined injury (B and SI) due to the augmentation of pulmonary microvascular permeability to fluid (Lalonde *et al.*, 1992; Soejima *et al.*, 2001). Dubick and others (2005) postulated that reducing the number of reactive oxygen species (ROS) involved in oedema formation associated with burn hypovolemia by adding a free radical scavenger to the resuscitation fluid, would reduce the total fluid requirements and improve cardiovascular recovery. A vitamin C infusion used as an add-on scavenger led to a reduction of the net fluid balance and a 30 and 50% reduction in the total fluid requirements. Their findings showed that initial cardiovascular dysfunction due to hypovolemia as well as the secondary phase of contractile dysfunction due to SI improved (Dubick *et al*., 2005).

#### 2.4.4. Smoke Inhalation

Animals severely affected by smoke inhalation should be immediately euthanised for welfare reasons. Treatment is intense, costly, and often unsuccessful. Complications such as infection often occur, requiring intensive antibiotic treatment that should be preceded by a complete erythrogram and leukogram, respiratory tract sampling, culture and antibiogram. In mild cases, long-acting penicillin can be administered intramuscularly (IM) at a dose rate of 1ml/20kg of body weight every three days with a withdrawal period of at least 21 days from the last injection. Alternatively, when there is no possibility of repeat injections, tulathromycin at a dose rate of 1ml/40Kg BW IM can be used as a once-off injection, with an 18-day and a 16-day withdrawal period for cattle and sheep, respectively. Dimethyl Sulfoxide (DMSO) acts as an anti-inflammatory and reduces oxidative stress by inhibiting inflammatory mediators such as Cyclooxigenase-2 (Cox-2), inducible Nitric Oxide Synthase (iNOS), and Tumour Necrosis Factor (TNF) (Tsung *et al*., 2016).

In cases with pulmonary bronchopneumonia, which impairs tissue oxygenation and ventilation, furosemide (0.5 to 2 mg/Kg intravenously every 6 hours) has been indicated (Lara *et al*., 2017). In these cases, fluid therapy should be carefully monitored, avoiding the use of crystalloids because they potentially increase oedema formation.

#### 2.4.5. Pain Management

Flunixin meglumine is a cost-effective non-steroidal anti-inflammatory drug (NSAID) that may be used to alleviate the pain associated with superficial and deep-partial thickness burns. It is recommended to be administered intravenously for quicker effect at a dose rate of 0.25 to 1 mg/Kg twice daily (1 ml/45 Kg body weight) or once daily (2 ml/45 Kg body weight) for a duration of 3 to 5 days. However, Chigerwe and others (2020) do not fully recommend its use in haemodynamically unstable animals. Other NSAIDs used are Meloxicam (0.5 mg/kg, PO, q 24 h) for all species or carprofen (2.2 mg/kg, PO, q 12 h) for pigs (Chigerwe et al., 2020).

### 2.4.6. Antibiotic Therapy

Administration of systemic antibiotics is mostly recommended when there is involvement of the respiratory tract with pneumonia or in the case of mastitis (Morton *et al*.,1987). The efficacy of systemic antibiotic therapy with skin burn injury is controversial, as circulation is known to be compromised, hindering the delivery of the drug in therapeutic amounts to the infected site through the systemic route. Hence, topical medication appears to be more appropriate. The topical medication must be capable of penetrating eschars and have antibacterial action against biofilm and common environmental contaminants such as Enterobacteriaceae species (Maslova *et al*., 2021). Silver sulphadiazine and Aloe vera are often combined as topical emollients due to their antibacterial, anti-inflammatory, and moisture-preserving capabilities (Lara *et al*., 2017). For the same reasons, propolis compounds and medical-graded honey have also been suggested by Lara and others (2017) as promoters of cellular repair. Sensitive structures such as palpebral and corneal tissues should be examined regularly, and topical medication should be applied twice daily. Atropine should be used for pain relief when there are evident corneal ulcers, some cases may require protection of the cornea from necrotic palpebral tissue; necessitating fixation of the third eyelid as protection (Lara et al., 2017).

## 2.5. Materials and Methods

This work conducted a scoping systematic review according to the updated six steps of Arksey and O'Malley framework (Levac *et al*., 2010; Munn *et al*., 2018; Westphaln *et al*., 2021) to synthesise the most important combination of factors to consider when triaging burned domestic ruminants and determine their category of evidence. Publications in English and Spanish were searched in databases such as Web of Science, Medline, Google Scholar, government agencies, and non-governmental organisations (NGOs) websites (expert-opinion-based publications). Two independent researchers revised the publications to fulfil the purpose of delineating evidence-based guidelines for categorising burned domestic ruminants. Inclusion criteria were decided upon labelled topics, and the category of evidence was allocated according to international frameworks for the development of clinical guidelines.

Labelling was determined using relevant topics connected with the objectives of the study, such as 'animal welfare' and 'assessment of burn severity' to define factors involved in the determination of the prognosis in general and ruminants in particular and 'systematisation of assistance' and 'triage in disaster situations'. A database was created, which included the year of publication, authors, country of affiliation of principal author, title of article and category of evidence.

The newer approach to the categorisation of scientific evidence corresponds to the Totality of Evidence-Based Medicine (T-EBM) Wheel, which has been proposed as a substitution for the traditional EBM pyramid or Quality of Evidence (QoE) Pyramid (Aldous *et al*., 2024).

The QoE approach was found to be appropriate in this case due to the type of literature selected. The categories of evidence ranged from C1 to C4 on a decreasing level of strength. C1 corresponds to highly recommended to recommended actions derived from evidence gathered from systematic reviews of randomised clinical trials; C2 corresponds to experts' opinions derived from evidence gathered from cohort studies, case studies and controls, and non-randomized trials. C3 and C4 correspond to good practice recommendations based on evidence derived from descriptive studies, case series, case reports and evidence derived from experts' opinions (Bhaumik, 2017).

Hence, triage guidelines for the proposed categories of burn severity in production animals were delineated within the context of field production animal practice and disaster management/pre-hospital premises, and 2) using the level of recommendation connected to the strength of scientific evidence currently available in the literature as a baseline. When deciding on burn prognostic indicators, factors related to the estimated length of treatment, resources available in a mobile service setting and the possibility of a return to normal production were considered.

## 2.6. Results

These results are divided into two parts. The first part analyses the scientific evidence in the published literature on veterinary disaster management and animal welfare, burn injuries, and the second part integrates these findings into clear triage guidelines for the transdisciplinary team involved in veterinary disaster management.

### 2.6.1. Analysis of Scientific Evidence

More than one hundred (180) publications surfaced on a preliminary search according to labelled topics. When categorised concerning the strength of evidence, 38 publications complied with the criteria, as seen in Figure 3.

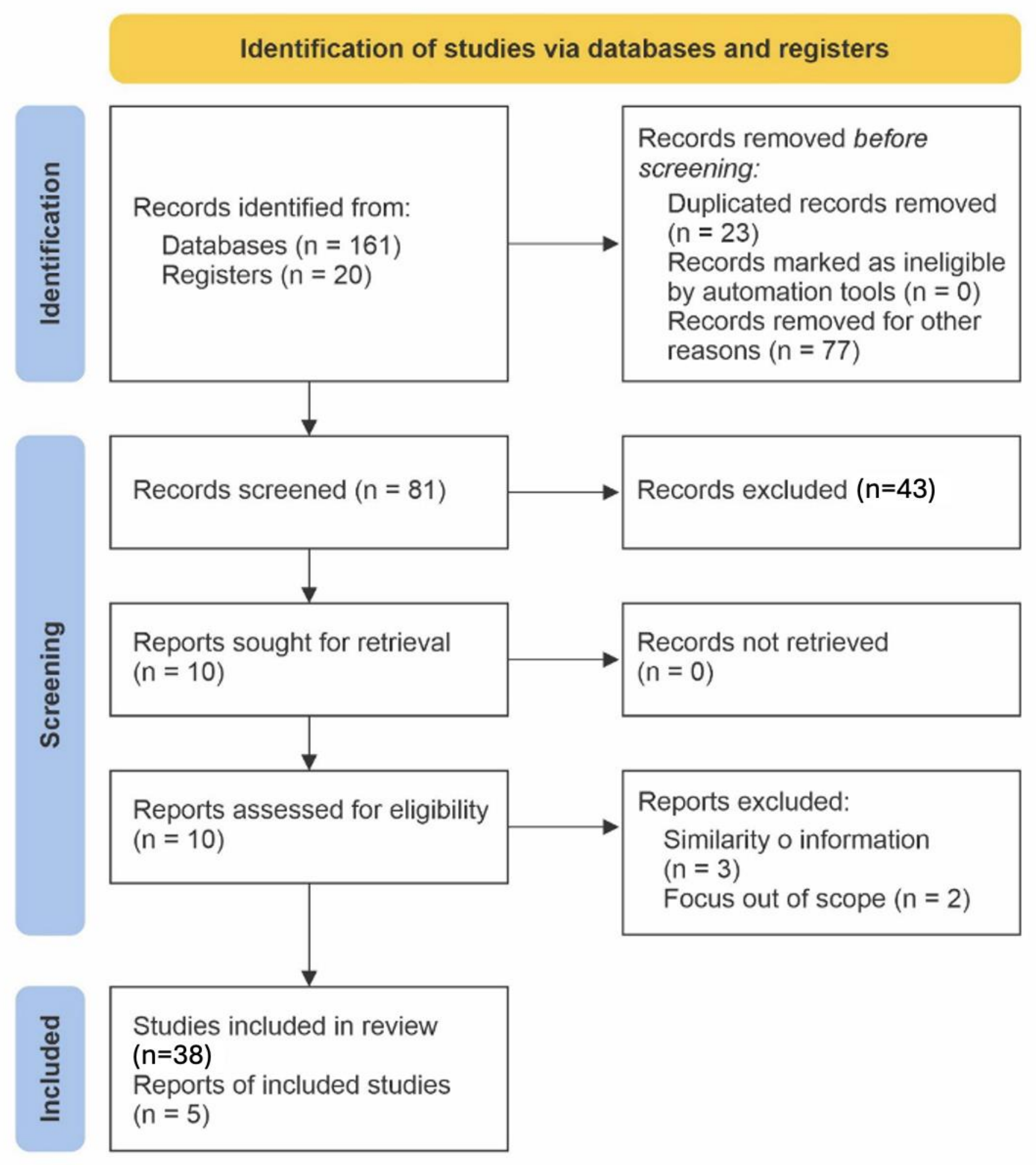



Figure 3: Prisma chart for reporting systematic reviews.

Labelling was decided upon relevant topics in connection with the objectives of the study, such as ‘animal welfare’, and ‘assessment of burn severity’ to define factors involved in the determination of the prognosis in general and ruminants in particular and ‘systematisation of assistance’ and ‘triage in disaster situations’. A database was then created with the year of publication, country of affiliation of the principal author, authors, title of article and evidence classification shown in Table 2.

Table 2: 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 | Assesing 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.* | Pahophysiological 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: Assesing 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 |
| 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, 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.

Figure 4 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.

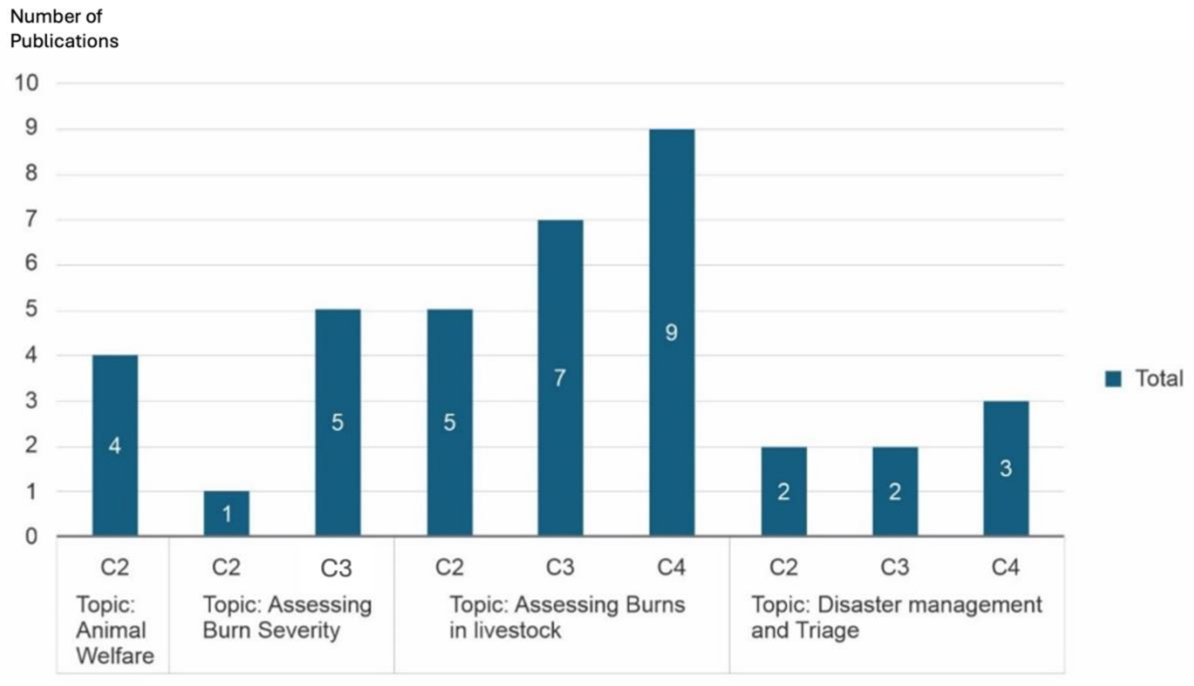



Figure 4: Distribution of literature included in the review according to classification of scientific evidence.

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.

According to this framework, the level of recommendations for clinical decision-making could be divided into highly recommended (HR) and recommended (R) actions based on systematic revisions of randomised clinical trials, other systematic reviews with or without metanalysis (C1) and randomised studies with methodologic limitations (C2) respectively. Recommendations based on experts' opinions (EO) included descriptive studies, case reports, and other non-randomized studies with bias risk (C3 and C4). Certain actions fell into a category for which there was insufficient information or evidence available, and others fell within good practice (GP) recommendations based on the experience of experts and general criteria applied in the field of practice (C4). Most of the literature referring to burn severity and prognosis in ruminants was derived from cohort studies without multivariate analysis and case studies (a few of them with controls). Hence, due to the particularity of the topic, the recommendations used for the conceptualisation of the triage guidelines were mainly allocated within the C2, C3 and C4 categories corresponding to R, EO, and GP recommendations.

An initial visual inspection of casualties has been recommended (R) as a measure to reduce stock losses, followed by an examination of clinical parameters and proper categorisation of burn severity regarding skin burn, systemic involvement, and possible smoke inhalation (Madigan et al., 2011). Specifically, regarding respiratory and cardiovascular considerations, as well as smoke injury, which can take up to two weeks to manifest. Burn lesion appraisal regarding % TBSA, depth and its potential increase in severity in the following hours and days after the insult are widely mentioned, 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.

The degree of head and front limb oedema in ovine within the first 24 hours after the insult and its association with the occurrence of smoke inhalation and the prognosis related to survivability have been noted in both well-controlled and lower strength trials. 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 in heavy respiratory distress with evidence of burn/smoke injury compromising the respiratory tract
- completely blind animals
- animals that are not able to walk
- sheep with major swelling of the front limbs and head within the first 24 hours after injury
- animals with severe burns (deep-partial and full-thickness) in the oral cavity and genital areas, compromising functionality
- cattle with severe foot burns due to the difficulty and extended healing time for these injuries

Various non-clinical parameters which factor in decision-making for burned animals are mentioned at the EO/ GP level. Considerations such as who will provide animal care, the ability of a farmer to care for the animals under treatment, financial considerations, the complexity of the treatment plan, and the feed, shelter, and pain management required. Long treatment periods are usually not considered in production animals due to cost and varied convalescence periods depending on burn severity and whether there were complications during treatment. Expected convalescence periods span anything from 3 weeks for minor/mild cases up to two years in severe cases with the associated financial costs (Cowled, et al., 2022).

Hence, when focusing on how decisions are currently made regarding production animals affected by wildfires, the strength of evidence falls in categories C3 and C4, corresponding to case reports supporting experts' opinions.

Current literature reports a general difficulty in accurately assessing burned animals, which hinders the proper allocation of resources and lacks a clear rationale for prioritising the various factors involved in decision-making.

### 2.6.2. Triage Conceptualisation

From the analysis of the evidence, the triage conceptualisation was delineated as follows:

A first-line assessment (FLA) is necessary when arriving at the scene, whereby; injured animals are mainly evaluated regarding neurological state (comatose vs alert) and mobility (cannot walk versus cannot rise/cannot walk). Comatose sheep have been reported to have a hopeless prognosis, especially if combined with severe burns on lower legs and hooves, with swelling and dry, leathery skin. In general, burned animals with an inability to stand and move show poor survivability hence, euthanasia is indicated (McAuliffe *et al.*, 1980; Cowled *et al*., 2022). Different considerations can be made depending on the species, but, as a rule, it is recommended to euthanise sheep that show severe swelling of the head and front limbs in the first 24 hours, as this has been correlated with lung involvement (Lalonde *et al*., 1992).

The FLA will render four colour-coded categories as shown in Table 3.

Table 3. Colour-coded grouping after first-line assessment (FLA – visual assessment) of ruminants injured in wildfires.

| PRIORITY Colour code | Observation | | Plan/Treatment |
|---|---|---|---|
| | Mentation | Locomotion | |
| GREEN | Alert | Able to walk | Appears not to need assistance. Observation. |
| RED | Comatose | Unable to rise/walk | Need immediate assistance if resources are available. Euthanise if no resources are available. |
| ORANGE | Alert | Able to walk | Likely to survive with adequate treatment. If resources are not available, welfare will deteriorate rapidly. |
| BLACK | Dead/dying | Unable to rise/walk | Euthanise |

Thereafter, a second-line assessment (SLA) comprised of a clinical examination focussing on respiratory and cardiovascular parameters must be performed on the animals allocated to the red, orange and green categories during FLA. A new categorisation may ensue as shown in table 4.

Table 4: Re-categorisation of animals according to priority for treatment from red, orange and green first-line assessment (FLA) categories following the second-line assessment (SLA).

| FLA Colour code | Clinical examination - SLA | | | | Plan/ Treatment following SLA |
|---|---|---|---|---|---|
| | Temperature | Cardiovascular parameters | Respiratory parameters | Burn injury assessment | |
| RED | Hypo/ hyperthermia | Depressed | Depressed | Major burns | Immediate attention: Treat if full resources available/Euthanise if not |
| ORANGE | Normal | Normal | Normal | Mild burns | Urgent attention: Stop progression of burn depth/ IV fluid if needed, pain management. Treat only if full resources are available. Euthanise if not. |

| | | | | | |
|---|---|---|---|---|---|
| YELLOW | Normal | Normal | Normal | Minor burns | Delayed attention: Pain management |
| GREEN | Normal | Normal | Normal | Appear unaffected | Observation |

Key: FLA=First-line assessment; SLA=Second-line assessment, SI=Smoke inhalation

During SLA, lesions must be evaluated, focusing primarily on burn prognostic indicators such as the extent and depth of the burns, which must be conducted to determine the severity and aid in the prognostication of the case. As a rule of thumb, the larger the body surface affected and the greater the depth of lesions, the worse the prognosis.

Cut-offs for %TBSA and depth related to burn survivability were defined based on available scientific evidence and in direct consultation with paediatric burn experts (personal communication by Drs H Nauhaus, paediatric internal medicine specialist at Edendale Hospital, Durban, KwaZulu-Natal).

Animals affected by >20% of partial-thickness burns on their body surface and >5% full-thickness burns (code black) have a hopeless prognosis due to complications such as infection/sepsis and the specialised care required with associated high cost. The decision to treat these cases needs to be carefully considered and most often will depend on the value of the animal and whether it is insured (Cowled *et al*., 2022).

The anatomical location of burn injuries also influences prognosis. Therefore, it is recommended to evaluate their location in terms of the possibility of healing and future functionality (Rogers et al., 2015). Burn injuries are commonly found in the face, eyes, ears, mouth, and lower body (limbs, feet, genitals, and udder) in ruminants. The presence of erythema, slight oedema and pain is indicative of the viability of the tissue involved, without proper treatment, this can quickly evolve into eschar, ampullae and infection in a few hours.

In sheep, burns to the legs are considered an important indicator of survivability and if severely affected have been associated with poor prognosis. However, burned legs in restricted areas and not associated with severe swelling were reported to heal with appropriate care in approximately 30 days (McAuliffe *et al*., 1980).

Experts consider cattle foot burns to be more serious than ovine foot burns. Cattle with burnt feet will not move to eat, hence nursing cattle with burnt feet can be costly, lengthy, emotionally, and physically draining. Euthanasia is indicated in most cases (NSW-DPI, 2018).

Moreover, burns on the perineum, genitals (including udder - especially in cows), and rectum require special consideration as they may restrict normal function and future performance (Morton *et al.,* 1987). Cattle often get burned on their feet, limbs, and ventral parts of their bodies, including the udder.  Morton and others (1987), reported on dairy cows affected by teat burns and concluded that mature cows heal quicker and more satisfactorily, with less anatomic distortion and a more successful return to normal lactation than heifers. Healing time for severe burns in adult cows (75% of teat area + superficial burns) is at least four months, and although it usually has a good prognosis, the length of treatment and consistent care needed must be considered when deciding the course of action. Partial-thickness burns have a poorer prognosis when the time for recovery before the subsequent lactation, especially on heifers, is three months or less; prognosis becomes poorer as bending of the teat and obstruction of the teat canal were seen as common complications in young animals. Topical treatment with emollients and antibiotics is advocated, and systemic antibiotics are only used in case of complications such as mastitis (Morton *et al.,* 1987).

Movement-restrictive lesions on the limbs prompt the need to provide feed and water within reach, such lesions can eventually be further movement-restrictive for the animal in the future, owing to scaring constriction. Proper evaluation and alignment with available resources need to guide decision-making. If animals in treatment cannot be provided with adequate conditions to safeguard animal welfare, euthanasia shall be considered. When considering sheep, one limb affected could be manageable only with adequate resources, more than one limb affected will decrease treatment success (Noorbakhsh et al., 2021).

A visual representation of the severity categories was developed for cows and sheep (Figures 5 and 6).

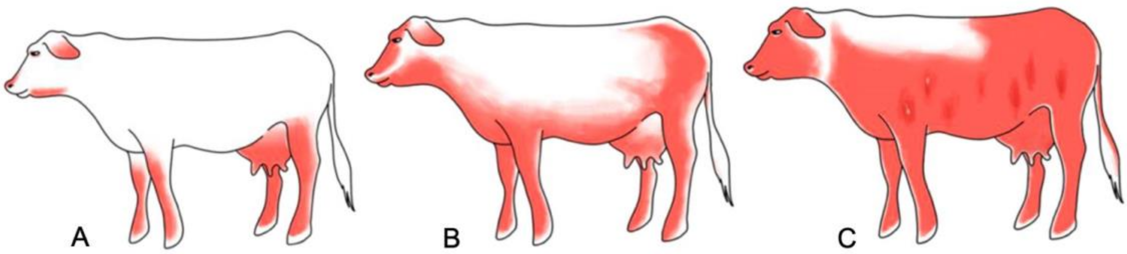



Figure 5: Categorisation of bovine burn severity.

**A) Mild burns** affecting > 10% but <20% TBSA with partial-thickness burns, SLA code **Orange**; **B) Major burns** affecting >20% TBSA, including the face, udder and feet with partial-thickness burns, SLA code **Red**; **C) Severe burns** affecting >20% TBSA including the face, udder and feet with partial-thickness and >5% affected by full-thickness burns (darker red areas), SLA code **Black**. Adapted from Pierson et al., 1969.

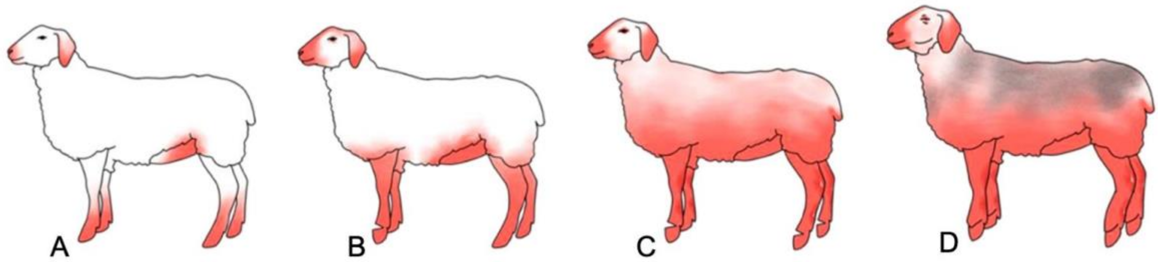



Figure 6: Categorisation of ovine burn severity.

**A) Mild burns** affecting >10% but <20% TBSA with partial-thickness burns, SLA code **Orange**; **B) Major burns** affecting >20% TBSA including the face, udder/prepuce and feet with partial-thickness burns, SLA code **Red**; **C) Severe burns** affecting >20% partial-thickness and <5% full-thickness burn, SLA code **Black**; **D) Severe burns** affecting >5% TBSA full-thickness burn with highly suggestive signs of smoke inhalation (swollen head and front limbs within first 24 hours of injury), SLA code **Black**. C Cardoso, 2022.

The triage categorisation and ranking of severity, the action required for each category and the preliminary prognosis are presented in Table 5.

Table 5: Categorisation of burned animals after second-line assessment (SLA), including priority, burn lesion evaluation, presenting signs, prognosis and action to be taken. C Cardoso, 2022.

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

A full visual representation of the conceptualised triage methodology comprising the first-line assessment, second-line assessment, factors considered, prioritisation, categorisation and prognosis is presented in Figure 7.

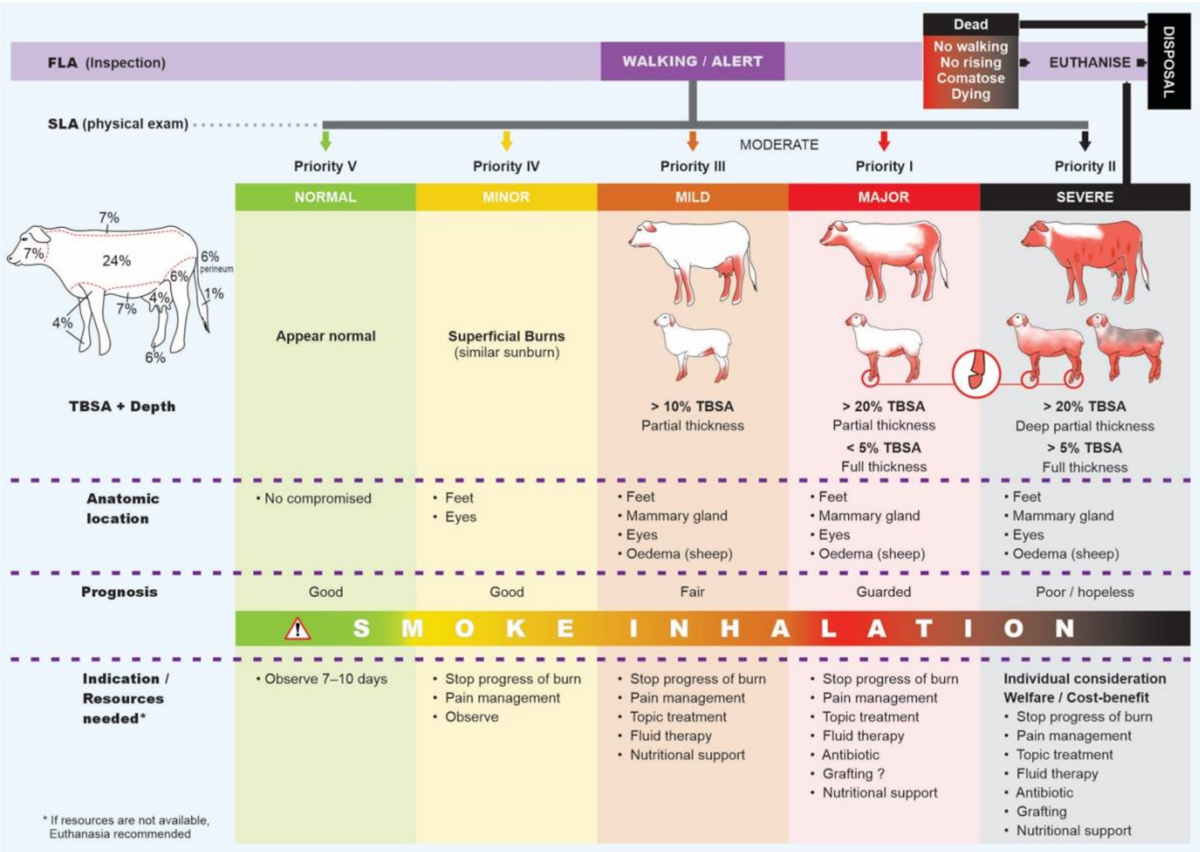



Figure 7: Proposed triage flow diagram for burns considering commonly used predictors of survivability in domestic ruminants: percentage total body surface area (%TBSA), depth of burns, oedema location on the first 24hrs (sheep), limbs/feet affectation (sheep and cattle), respiratory affectation/smoke inhalation (sheep most affected), mammary gland/age (cow). *FLA: First-line assessment. *SLA: Second line assessment. C Cardoso, 2022.

## 2.7. Discussion

Various publications present conflicting advice on assessing farm animals and wildlife burned in wildfires. While Butkus and others (2021) concluded that the survival rate of burned wildlife presented to rehabilitation centres does not significantly differ based on the involvement of a veterinarian, Cowled and others (2022) emphasized the need for regular clinical reassessment of injured livestock to manage the progression of burns and to facilitate accurate prognostic assessment.

Chigerwe and others (2020) described the treatment of burned small ruminants and pigs in a hospital setting in the United States, highlighting the common anatomic locations of burns in these species. They and others (McAuliffe *et al*., 1980) have suggested that survival may be more guarded for sheep and pigs when compared to goats, while other authors stated that pigs and goats impacted by fires have a poor prognosis because of their higher susceptibility to stress (NSW-DPI, 2018) (RSPCA, 2024).

Bolcato and others (2023) emphasize the challenges of treating burned cattle due to the lack of clinical evidence in managing bovine burn patients and recognise the importance of identifying the systemic effects of severe burn injuries for the correct allocation of resources, while other authors only focused on anatomic presentation and topical treatment options for decision-making (Morton *et al*., 1987). This latter approach fails to consider the full effects of wildfires on animals and resource limitations for in-field treatment.

Madigan and others (2011), and Cowled and others (2022), based on experience drawn from mass casualty veterinary response teams in the United States and

Australia, highlighted the importance of preparedness and coordinated efforts to improve the outcome for animals and humans affected by fires.

The proposed triage guidelines presented in this thesis concur with these authors and others (Rogers *et al*., 2015; Rethorst *et al.*, 2018; Salaberry-Pincheira *et al*., 2018) who have reported mass casualty events in which the main aims are containment and mitigation. Madigan and others (2011) described the implementation of a simple measure, such as luring animals with food and water to decide on their level of awareness and mobility. This allowed the prioritisation of animals to be assessed and treated and a reduction in mass casualties. Following this test, the team went from initially considering euthanasia for 90% of the stock affected to a total of 65% receiving treatment and showing progress over the study period of 42 days.

Current guidelines regarding decision-making for livestock affected by wildfires are based mainly on observations from case reports presented by professional experts (Carroll, 1981; Madigan *et al*., 2008; Rogers *et al*., 2015) and are considered low-strength evidence but still valid for the context of production animal field practice. Important discoveries related to burn injury classification, systemic involvement, and treatment have been made through research on ovine animal models (Lalonde *et al*., 1992; Soejima *et al*., 2001; Cox *et al*., 2003; Traber *et al*., 2007) which are applicable to support clinical prognosis and decision-making on higher strength of evidence.

It has been reported that fires will unavoidably become a more frequent occurrence worldwide (Forsyth *et al*., 2019; UNEP, 2022); hence, disaster management preparedness is necessary to mitigate losses. A transdisciplinary group of trained professionals should all work together towards the recovery of the affected community.

A common thread among scoped publications is the need to better understand burn injuries in livestock for more accurate decision-making and to predict recovery time for different severities of burn injury. However, burn injury is only one of the considerations for decision-making in production animal field practice, because other factors play an important role in the quality and success of the decision. Animal welfare has evolved to be an important consideration in cases of disasters involving livestock, with pain management being paramount in the treatment. Categorisation of burned animals on the First-line Assessment must follow welfare and cost-effective principles because these are among the core considerations in the context of production animal practice.

Contradicting recommendations lead to unnecessary losses and increase the recovery period of the community (Squance *et al*., 2021). Within the first- and second-line assessments proposed in this work, pre-hospital practices in field animal production prevailed in the definition of the parameters and actions. Where a rationale behind a recommendation was lacking, stronger evidence to support the inclusion of the action was sought (Soejima *et al*., 2001; Traber *et al.,* 2007), providing a practical, evidence-based model for triage of burn-affected animals.

Veterinarians were consulted on the rationale behind prioritising factors involved in burn clinical decision-making as part of the ground theory work demarcated within the last step of the Arksey and O'Malley framework. This portion of the work further informed the conceptualisation of the triage and is reported in Chapter 3.

# CHAPTER 3

# DYNAMICS OF VETERINARY DECISION-MAKING REGARDING RUMINANTS AFFECTED BY WILDFIRES

## 3.1. ABSTRACT

Wildfires pose a significant threat to livestock. Field assessment of the affected animals is crucial for effective decision-making. However, this evaluation is frequently subjective and reliant on the experience of the evaluator, leading to potential misdiagnosis and inefficient allocation of resources. To better understand the dynamics of the decision-making processes when applied to wildfire burn cases in domestic ruminants, a survey was sent to veterinary-trained individuals with varying clinical experience. The findings of this study showed that novice practitioners prioritise prognosis and cost of treatment when making decisions for burned ruminants. However, as the practitioner's level of experience increased, there was a tendency to place less emphasis on economic factors and more on the animals' welfare, especially concerning their systemic involvement and the possibility of recovery with treatment intervention, and this ultimately guided the decision-making process.

Keywords: Clinical experience, burns, decision-making, ruminants, wildfires

## 3.2. Introduction

Decision-making in veterinary practice encompasses a multifaceted interplay of ethical considerations, emotional influences, and professional development. Recent studies have underscored the importance of structures, frameworks, and supportive multidisciplinary and collaborative environments in enhancing decision-making processes among veterinary practitioners (Ashall, 2023). Such frameworks are essential for addressing complex clinical situations, where decisions often involve ethical dilemmas and the welfare of animals. These considerations underscore the importance of emotional well-being as a pivot in shaping decision-making capabilities (Arbe Montoya, et al., 2021).

Veterinary students are taught to consider various factors, including financial implications and the human-animal-bond, when making difficult decisions regarding animals in critical condition (Littlewood, et al., 2021). The influence of financial constraints on clinical decisions is crucial, as veterinarians often face pressures related to client expectations and the cost associated with treatments, which may skew decision-making (Lavigne, et al., 2021) and present practitioners with a moral dilemma. This highlights the need for veterinarians to balance clinical judgment with economic realities in all contexts of veterinary practice.

Veterinarians with clinical experience are better equipped to balance various considerations and engage the client in shared decision-making, leading to more ethical decisions, improved animal welfare and better client compliance (Cary, 2021).

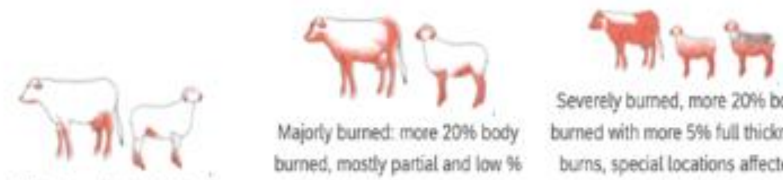
The primary objective of this portion of the project was to survey both veterinarians and lay people (farmers, farm managers) on factors affecting their decision-making processes when dealing with burned livestock in the aftermath of a wildfire. The second objective was to request images of burned animals from survey participants to create a database which could then be used to train software to categorise burned animals (see Chapter 4) by depicting burn severity according to the defined cut-offs from the triage guidelines.

## 3.3. MATERIALS AND METHODS

This study was approved through the Research Ethics Committee of the Faculty of Veterinary Science and the Humanities Faculty [REC 055-22 (1)]. Qualtrics XM-certified solutions ™ (Silver Lake, Seattle, Washington, United States) were used to design and partially deliver the questionnaire to two cohorts, veterinary and non-veterinary individuals. In remote areas and amongst more senior individuals, digital access proved difficult, therefore, a hard copy of the survey was delivered to interested participants. A total sample size of 107 was proposed to be adequate for the study (split into 54 veterinary-trained and 53 non-veterinary-trained respondents), and analysis and reporting have been done based on this division. A link to the questionnaire was also distributed through popular publications on four internet websites related to farming, through veterinary groups and associations, and at a veterinary congress.

### 3.3.1. Veterinary-trained Respondents

The questionnaire directed at veterinary-trained (VT) individuals (Figure 8) was designed based on a marketing consultation strategy where a scenario is proposed, and the respondents give their opinion (treatment, slaughter or euthanasia) regarding the different triaged categories of burned ruminants. The participants were also asked to prioritise the factors (most important, second, third and fourth) they had considered in their decision-making process.



## Question 1

VETERINARIANS: Your client requires advice on animals burned in wildfires. The fire has affected the farm devastating fencing and some of the breeding stock (cows and sheep). 75 of a total of 100 animals were affected at different levels of severity, 10 of which have died. After your evaluation, these are the groups you will have to advise on. What would your advice be for the different groups?

| | Mildly burned: 10-15% body burned, partial thickness burns, no smoke inhalation detected. Recovery with treatment approx 1 month. 45 animals affected. | Majorly burned: more 20% body burned, mostly partial and low % full thickness burns, special locations affected but recoverable, no smoke inhalation detected. Recovery with treatment approx 4 months. 10 animals affected. | Severely burned, more 20% body burned with more 5% full thickness burns, special locations affected, signs of smoke inhalation. Your valuable bull/ram is in this category. Recovery with treatment more than 4 months. 10 animals affected. |
|---|---|---|---|
| Treatment | ○ | ○ | ○ |
| Slaughter | ○ | ○ | ○ |
| Euthanasia | ○ | ○ | ○ |

## Question 2

VETERINARIANS: In your opinion, from the list of factors below, choose according to importance the factors to consider for the advice given above.

Write the number on the corresponding block.

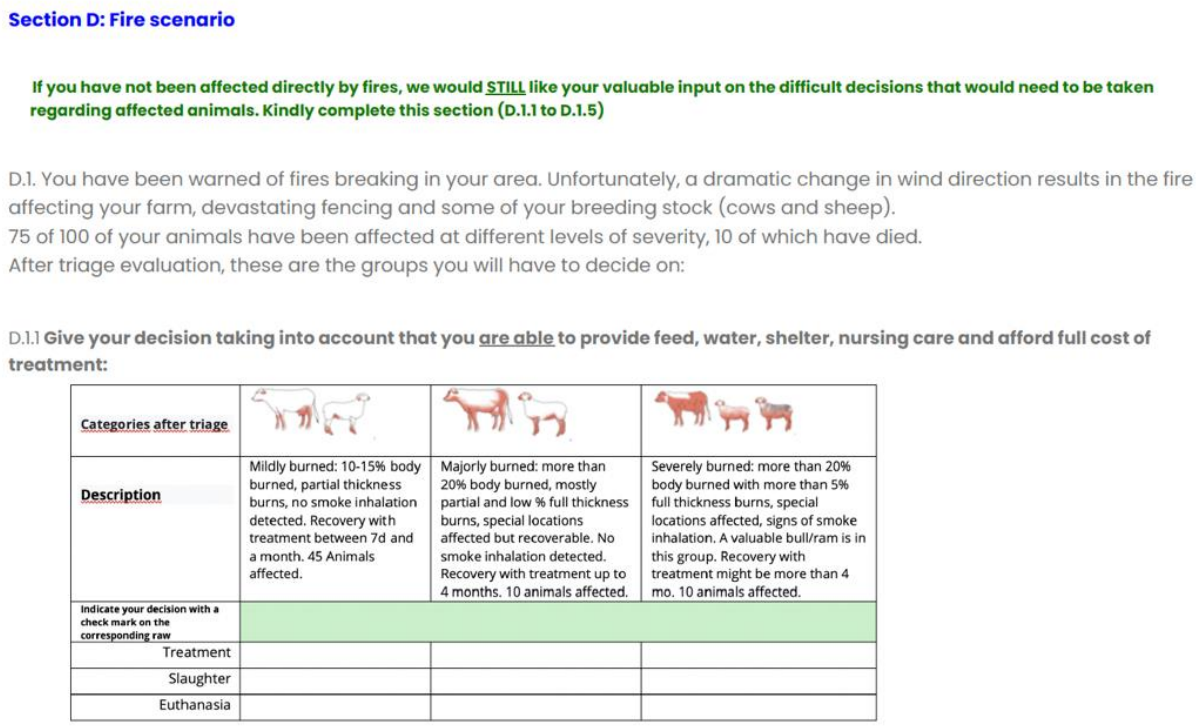
1. Prognosis
2. Systemic affectation
3. Degree of nursing care needed
4. Length of treatment
5. Cost of treatment
6. Shelter availability
7. Food/water availability
8. Welfare
9. Return to normal production
10. Foreseen complications
11. Value of the animal
12. Insurance
13. Other (add your factor)

Most important [ ] 1
Second [ ] 2
Third [ ] 3
Fourth [ ] 4

Figure 8: Questionnaire for veterinary-trained responders consulting on their decision-making process regarding different categories of severity of burned sheep and cows (Question 1) and the prioritisation of factors involved in their final decision (Question 2).

### 3.3.2. Non-veterinary-trained Respondents

The questionnaire directed at non-veterinary trained (NVT) individuals (Figure 9) aimed to collate information regarding the type of farming, geographic area, and whether the individual had experienced fires on their farm. In both cases, questions were formulated to gather information regarding the farmer's decision-making process regarding burned livestock. A case-scenario modality was used in cases where the individual had not personally experienced a wildfire on their property. Four situations were presented to these participants for which they needed to make decisions regarding livestock affected by fires based on different factors related to animal health, welfare, economics and human well-being. Unfortunately, no participation was achieved, and no responses were obtained for this category of respondents despite having widely promoted participation through rural organisations, popular publications, interviews in farming programs and the survey being presented in English and Afrikaans. The main reason given for no participation was no internet connection and/or not having a smartphone. Hard copies were provided for these cases, but still no responses were received. The data from this portion of the survey would have complemented the data obtained from VT respondents and would have highlighted further challenges surrounding wildfires experienced by farmers in South Africa. Unfortunately, it could not be included in this work.



**Section D: Fire scenario**

**If you have not been affected directly by fires, we would STILL like your valuable input on the difficult decisions that would need to be taken regarding affected animals. Kindly complete this section (D.1.1 to D.1.5)**

D.1. You have been warned of fires breaking in your area. Unfortunately, a dramatic change in wind direction results in the fire affecting your farm, devastating fencing and some of your breeding stock (cows and sheep).
75 of 100 of your animals have been affected at different levels of severity, 10 of which have died.
After triage evaluation, these are the groups you will have to decide on:

D.1.1 **Give your decision taking into account that you are able to provide feed, water, shelter, nursing care and afford full cost of treatment:**

| Categories after triage | | | |
|---|---|---|---|
| Description | Mildly burned: 10-15% body burned, partial thickness burns, no smoke inhalation detected. Recovery with treatment between 7d and a month. 45 Animals affected. | Majorly burned: more than 20% body burned, mostly partial and low % full thickness burns, special locations affected but recoverable. No smoke inhalation detected. Recovery with treatment up to 4 months. 10 animals affected. | Severely burned: more than 20% body burned with more than 5% full thickness burns, special locations affected, signs of smoke inhalation. A valuable bull/ram is in this group. Recovery with treatment might be more than 4 mo. 10 animals affected. |
| Indicate your decision with a check mark on the corresponding raw | | | |
| Treatment | | | |
| Slaughter | | | |
| Euthanasia | | | |

Figure 9: Questionnaire design – NVT. Fire scenario presented on the survey with different burn severity categories requesting a joint decision with the veterinarian.

### 3.3.3. Image Database for Training Neural Network

No photos were received with the survey, and only a few videos of fire events occurring during the period of data collection were provided by colleagues and the public but, unfortunately, not of adequate quality to be used for the purpose of neural network training.

### 3.3.4. Statistical Analysis of Survey Data

Descriptive statistics were used to summarise the data collected with the survey as described above. The Kruskal-Wallis non-parametric test was conducted to compare various groups with ordinal dependent variables. The correlation between variables was tested with Spearman's (rho) test. The Dunn-Bonferroni test was used for further pairwise comparison of factors as a methodology involved in decision-making regarding different variables. It did not substantially add to the results. Hence, it has been included in Appendix 2 and not in this chapter.

## 3.4. Results

The survey consulted veterinary-trained individuals with varying clinical experience on 1) their decision-making process concerning animals with burn injuries of varying severity and 2) the factors influencing their decision-making process. A provision was made for ‘other’ factors to be included by the participant, but no additional factors were added by any participant.

Based on years of experience, the participants were divided into three cohorts: <1 year; 2-5 years and 6-10 years.

The first question was scenario-based and presented the participant as a veterinary consultant advising a client who had suffered a wildfire on their farm. The scenario included three categories of burn severity (mild, major, severe) with differing numbers of animals affected per group. The participant was required to decide on options for the burned animals (treatment, slaughter, euthanasia) (Table 6).

Table 6: Treatment decisions of each cohort based on the proposed burn severity groups (<1 year, 2-5 years and 6-10 years of clinical experience) presented as a proportion of the total number of participants in the cohort.

| | **Proportion of categories' decision over experience % (N)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **<1 year (n=11)** | | | **2-5 years (n=6)** | | | **6-10 years (n=24)** | | |
| | **Treatment option** | | | | | | | | |
| **Burn Severity** | **T** | **S** | **E** | **T** | **S** | **E** | **T** | **S** | **E** |
| **Mild** | 90.9 (10/11) | 9.09 (1/11) | 00.0 (0/11) | 100.0 (6/6) | 00.0 (0/6) | 00.0 (0/6) | 100.0 (24/24) | 0.00 (0/24) | 0.00 (0/24) |
| **Major** | 18.1 (2/11) | 81.8 (9/11) | 00.0 (0/11) | 00.0 (0/6) | 83.3 (5/6) | 16.6 (1/6) | 00.0 (0/24) | 66.6 (16/24) | 33.3 (8/24) |
| **Severe** | 00.0 (0/11) | 18.1 (2/11) | 81.8 (9/11) | 00.0 (0/6) | 00.0 (0/6) | 100.0 (6/6) | 0.00 (0/24) | 4.1 (1/24) | 95.8 (23/24) |

Key: T: Treatment, S: Slaughter, E: Euthanasia. Mild: 10-15% TBSA, partial-thickness, no smoke inhalation detected; Major: >20% TBSA partial-thickness, <5% full-thickness burns, some critical anatomic locations affected, no smoke inhalation detected; Severe: >20% TBSA partial-thickness, >5% full-thickness burns, critical anatomic locations severely affected, signs of smoke inhalation.

A consistent and overwhelming preference for treatment across all experience levels indicated a clear consensus on the decision regarding mild burns.

For the category of major burns, most of the cohort with < 1 year experience decided on slaughter (81.8%, 9/11) and very few considered treatment (18.1%, 2/11). The dominant choice for the cohort with 2-5 years of experience was also slaughter (83.3%, 5/6) with some consideration given to euthanasia (16.6%, 1/6). Most of the 6-10 years of experience cohort also favoured slaughter (66.6%, 12/24), while a third considered euthanasia (33.3%, 8/24) as an option.

For the severe category, the <1 year of experience cohort predominantly considered euthanasia (81.8%, 9/11). In comparison, minimal (18.1%, 2/11) to no consideration was given to slaughter or treatment options. In the 2-5 years of experience cohort, all decisions favoured euthanasia (100%, 6/6), and this was also the dominant choice (95.8%, 23/24) in the 6-10 years of experience cohort.

The second question asked participants to consider the factors from the list provided involved in their decision-making for question one (most important factor, second, third and fourth).

Table 7 shows how each factor was considered by the different cohorts (<1 year; 2-5 years, and 6-10 years of experience).

Table 7**:** Factors considered by each cohort (<1 year; 2-5 years and 6-10 years of clinical veterinary experience) in the decision-making process when considering treatment options for burned livestock.

| **Factors involved in decision-making** | **Years of clinical veterinary experience** | | |
|---|---|---|---|
| | **< 1 year (n=11)** | **2-5 years (n=6)** | **6-10 years (n=24)** |
| Prognosis | 81.8 (9/11) | 100.0 (6/6) | 75.0 (18/24) |
| Cost of treatment | 90.9 (10/11) | 83.3 (5/6) | 66.6 (16/24) |
| Welfare | 36.3 (4/11) | 66.6 (4/6) | 66.6 (16/24) |
| Return to production | 54.5 (6/11) | 50.0 (3/6) | 29.1 (7/24) |
| Value of animal | 54.5 (6/11) | 16.6 (1/6) | 41.6 (10/24) |
| Systemic affectation | 27.2 (3/11) | 16.6 (1/6) | 37.5 (9/24) |
| Length of treatment | 27.2 (3/11) | 00.0 (0/6) | 33.3 (8/24) |
| Nursing care needed | 18.1 (2/11) | 16.6 (1/6) | 20.8 (5/24) |
| Complications | 9.0 (1/11) | 33.3 (2/6) | 12.5 (3/24) |
| Feed/water availability | 00.0 (0/11) | 16.6 (1/6) | 4.1 (1/24) |

| | | | |
|---|---|---|---|
| Shelter availability | 00.0 (0/11) | 00.0 (0/6) | 8.3 (2/24) |
| Insurance | 00.0 (0/11) | 00.0 (0/6) | 4.1 (1/24) |

When analysing key factors related to decision-making, all cohorts prioritised prognosis (81.8, 100 and 75%, respectively), which indicates its importance in guiding clinical decision-making. Cost of treatment was considered a significant factor amongst less experienced practitioners, while diminished in importance with experience, suggesting that as practitioners gain expertise, they may prioritise other factors over cost. Welfare was considered less significant amongst less experienced practitioners but became more important as clinical experience increased, reflecting a shift towards a more holistic view of animal care with experience, this will be expanded on in the discussion section.

Regarding return to production, a decline in importance over time was noted as experience was gained, again indicating a shift in focus from economic factors to more clinical or welfare-related concerns, also to be expanded on in the discussion section.

The factor value of the animal fluctuated considerably amongst cohorts, suggesting again that less experienced assessments may consider economic value more heavily, but later experience brings a broader perspective.

Systemic involvement increased in importance as years of experience increased, with only 27.2% in the < 1 year of experience cohort considering it important compared to 37.5% of the 6-10 years of experience cohort. This reflects an increased recognition of systemic issues with experience, which suggests a growing awareness of the complexities of burn pathology with increased experience. The same was indicated regarding the length of treatment and degree of nursing care needed to manage major to severe burn wounds.

Experienced practitioners (6-10 years of experience cohort) were the only ones who considered non-clinical factors such as feed/water/shelter availability and insurance in their decision-making process. In comparison, minimal consideration across all experience levels was given to these factors, indicating they are currently not prioritised during decision-making related to fire disasters.

The data was then collated following an ‘importance scores’ distribution where the most named factor received a higher value (4) and subsequent factors were assigned reduced values according to answer frequency (3, 2, 1) with (0) designated for factors not considered in the answer.

Table 8 shows the ranking of factors involved in the decision-making process for burned livestock according to cohort (< 1 year; 2-5 years and 6-10 years of clinical veterinary experience). When each decision-making factor was compared to years of clinical veterinary experience, all three cohorts ranked prognosis as the most important factor, while the cost of treatment was inversely related to the level of experience and welfare was considered more important as the years of experience increased. Value of the affected animal and return to production were the other two most frequently included factors for decision-making across cohorts, but they also appeared as less important as experience increased.

Table 8: Ranking of factors involved in the decision-making process for burned livestock according to cohort (<1 year; 2-5 years and 6-10 years of clinical veterinary experience).

| **Factors involved in decision-making** | **Years of clinical veterinary experience** | | |
|---|---|---|---|
| | **< 1 year (n=11)** | **2-5 years (n=6)** | **6-10 years (n=24)** |
| Prognosis | 2.909 | 3.166 | 2.541 |
| Cost of treatment | 2.181 | 1.666 | 1.291 |
| Welfare | 1.090 | 2.666 | 2.083 |
| Return to production | 1.090 | 0.833 | 0.458 |
| Value of animal | 1.363 | 0.333 | 0.750 |
| Systemic affectation | 0.454 | 0.500 | 1.125 |
| Length of treatment | 0.454 | 0.000 | 0.500 |
| Nursing care needed | 0.181 | 0.166 | 0.416 |
| Complications | 0.272 | 0.333 | 0.333 |
| Feed/water availability | 0.000 | 0.000 | 0.125 |
| Shelter availability | 0.000 | 0.000 | 0.250 |
| Insurance | 0.000 | 0.000 | 0.125 |

The data showed an increased emphasis on prognosis and welfare as the level of experience increased. A shift towards prioritising prognosis and animal welfare suggests either a more compassionate approach or a more careful consideration of veterinary care with greater awareness of treatment failures and possible complications when managing burns. Cost considerations become less important as experience increases, possibly reflecting increased awareness of animal welfare. The fluctuation in value assessment and return to production indicates again that economic factors may initially influence decision-making but become less relevant as practitioners gain experience. Lastly, with increased experience, practitioners show a greater understanding of systemic health issues and complications, demonstrating a depth of knowledge that influences decision-making. This analysis highlights the evolving priorities in veterinary decision-making, emphasising a trend toward holistic and welfare-oriented approaches as practitioners gain experience.

Table 9 shows the correlation coefficient analysed with Spearman's (rho) test and corresponding p-values for each decision factor. Negative or positive rho values suggest the type of correlation for the factors considered; low p-values (<0.05) indicate that the correlation is statistically significant.

Table 9**:** Factors involved in the decision-making process for burned livestock correlated with years of clinical veterinary experience analysed with Spearman's correlation and ranked according to statistical significance (<0.05).

| **Decision factor** | **Spearman's rho (95% CI)** | **p-value** |
|---|---|---|
| Cost of treatment | -0.349(-0.599, -0.037) | 0.025 |
| Return to production | -0.262 (-0.534, 0.059) | 0.098 |
| Welfare | 0.189 (-0.135, 0.477) | 0.237 |
| Shelter availability | 0.184 (-0.140, 0.473) | 0.248 |
| Systemic affectation | 0.176 (-0.148, 0.466) | 0.271 |
| Feed/water availability | 0.129 (-0.195, 0.428) | 0.422 |
| Insurance | 0.129 (-0.195, 0.428) | 0.422 |
| Value of animal | -0.122 (-0.422, 0.202) | 0.448 |
| Prognosis | -0.125 (-0.424, 0.199) | 0.437 |
| Length of treatment | 0.117 (-0.207, 0.418) | 0.467 |
| Nursing care needed | 0.071 (-0.251, 0.378) | 0.661 |
| Complications | -0.010 (-0.325, 0.307) | 0.953 |

The interpretation of the values obtained for prognosis indicates that the negative rho (-0.125) suggests a slight tendency for the prognosis factor to decrease in priority with experience, but it does not indicate statistical significance (p-value: 0.437).

The factor cost of treatment shows a statistically significant (p-value: 0.025) negative correlation (rho: -0.349), indicating that as experience increases, the emphasis on the cost of treatment tends to decrease. Welfare, in turn, shows a positive rho (0.189), indicating a slight tendency for welfare considerations to increase with experience, but the result is not statistically significant (P-value: 0.237). Factors such as return to production and value of animals suggest that as experience increases, the emphasis on these decreases while the consideration of systemic involvement increases with experience for decision-making, although none of them showed statistical significance.

### 3.5. Discussion

The degree of clinical experience has been highlighted as one of the factors influencing accuracy when evaluating the most important prognostic indicators of burn, such as %TBSA and depth of burn, which are directly related to survivability and will determine the need and volume of fluid therapy to be administered for resuscitation having an incidence on cost and skills needed for effective treatment.

A high degree of subjectivity surrounds the evaluation and decision-making processes concerning animals burned in wildfires. This not only affects production animals but also concerns companion animals, wildlife, and even human medicine, underscoring the overall difficulty practitioners experience with the evaluation of burn cases. The added challenge of evaluating animals in a disaster setting may prompt prioritising value preservation efforts, which founders as the pathology evolves and complications ensue, leading to fruitless efforts and hope-wrecking experiences for farmers when animals undergoing treatment do not progress as expected.

The survey results indicated that novice veterinarians place more importance on prognosis and economics as decisive factors in their decision-making process. Hence, the 'cost of treatment' had major weighting, as discussed by Lavigne and others (2021). Regardless of experience level, a strong and consistent preference for treating mild burns was found across cohorts. Our findings showed that slaughter, with an increasing tendency towards euthanasia as clinical experience increased, was the preferred option for major burns. Treatment was largely disregarded for major burns.

Euthanasia was the dominant decision across cohorts to manage animals with severe burns, and this tendency increased with clinical experience. These trends indicate that as experience increases, there is a clear shift towards more aggressive decision-making for severe cases, reflecting a deeper understanding of the phenomenon and protocols required in burn management among seasoned practitioners.

The decision to slaughter major and severely affected animals was mostly seen amongst novice practitioners, who appeared to fail to contemplate welfare considerations such as fitness for transportation and the spectacular systemic involvement in severely affected ruminants. Furthermore, these animals cannot receive any pain relief medication due to drug withdrawal contemplations.

Meat safety from livestock affected by wildfires is a growing concern. Recent research (Depenbrock *et al*., 2023) has explored various aspects of this topic, including the potential contamination of the meat, the implications for animal health and welfare, and the regulatory frameworks regulating meat inspection.

One significant potential concern is heavy metal contamination in meat from animals grazing on pastures affected by wildfires (Depenbrock, et al., 2023). Wildfires can deposit ash contaminated with metals, and Nkosi and others (2021) have postulated that heavy metals can accumulate in both wild and domestic animals, raising concerns about meat safety and public health. Moreover, current protocols for abattoir inspections may not be suitable for animals affected by environmental stressors such as wildfires (Auplish, et al., 2023) (Nkosi, et al., 2021)

Overall, the survey results indicate that the cost of treatment is the only factor that shows a statistically significant negative correlation with experience, which reinforces the notion of a shift in priorities as practitioners gain expertise. Many factors, such as prognosis, welfare, and return to production show no significant correlations, indicating that these factors may not be as influenced as much by experience as others. Hence, most factors remain stable across different levels of experience, suggesting that certain decision-making factors are entrenched in practice regardless of how long a practitioner has been in the field.

This research may help inform younger practitioners' decision-making, training and educational approaches by highlighting the importance of considering cost, welfare and ethical implications when dealing with animals burned in wildfires.

Experience informs decision-making, and it is shaped through exposure and the application of critical thinking and problem-solving skills. This process starts during educational training and further develops through professional practice (Wainwright, et al., 2011). This evolution is critical for improving patient outcomes and enhancing the quality of care provided to animal patients.

Veterinary practitioners, particularly those who are newly graduated, rely on established protocols and guidelines taught during training to inform their clinical decisions. As practitioners gain experience, they begin to internalise these guidelines and adapt them based on individual patient needs and contexts, as seen in this instance. This shift is supported by the concept of evidence-based veterinary medicine, which encourages the use of the best available evidence in conjunction with clinical expertise and patient care values (Janicke, et al., 2020) (Hadoock, et al., 2023).

Experience also enhances the ability to engage in shared decision-making with owners. Research indicates that experienced veterinarians are prone to facilitate discussions that incorporate client preferences and values into the decision process (Ito, et al., 2022). This approach increases client satisfaction and conformity with the decision (Ito *et al*., 2022). Janke and others (2021) highlight the importance of implementing shared decision-making in leading to improved outcomes in veterinary practice, especially supported by communication skills that develop with experience (Janke, et al., 2021).

The ethical dimensions of clinical decision-making become more pronounced with experience. As ethical dilemmas present themselves in practice, such as balancing client desires and animal welfare, the practitioner develops a more sophisticated understanding of ethical frameworks which guide their decisions (Grimm, et al., 2018). For example, ethical decision-making tools have been proposed to help veterinarians prioritise the welfare of the patient while considering the broader context of client relationships and economic factors (Gibson, 2023). This is crucial for managing complex scenarios and aligning decisions to professional standards and client expectations.

Moreover, the integration of technology, such as computerised decision support systems, is becoming increasingly relevant in veterinary practice. These systems assist the practitioner in making informed decisions based on individual patient data, thereby enhancing decision-making processes (Fox, et al., 2021).

Our findings also highlight the need to widen undergraduate knowledge regarding fire veterinary disaster incidence, welfare assessment in disaster situations, burn pathology specifically concerning systemic involvement, fitness for transportation and welfare implications, and the strong effects of stress on meat quality, which impacts fitness for consumption.

Hence, clinical decision-making in veterinary practice is a dynamic process that evolves with experience, as confirmed by the results of this survey. As practitioners transition from novices to experienced veterinarians, they develop a more comprehensive understanding of evidence-based practices, enhance their communication skills for shared decision-making, tackle ethical dilemmas more effectively and gradually adopt the use of technology to support their judgement while improving patient care and outcomes in veterinary practice.

Figure 10 incorporates the survey results regarding decision-making for the proposed categories of severity into the evidence-based triage guidelines considering the availability of clinical and non-clinical resources.

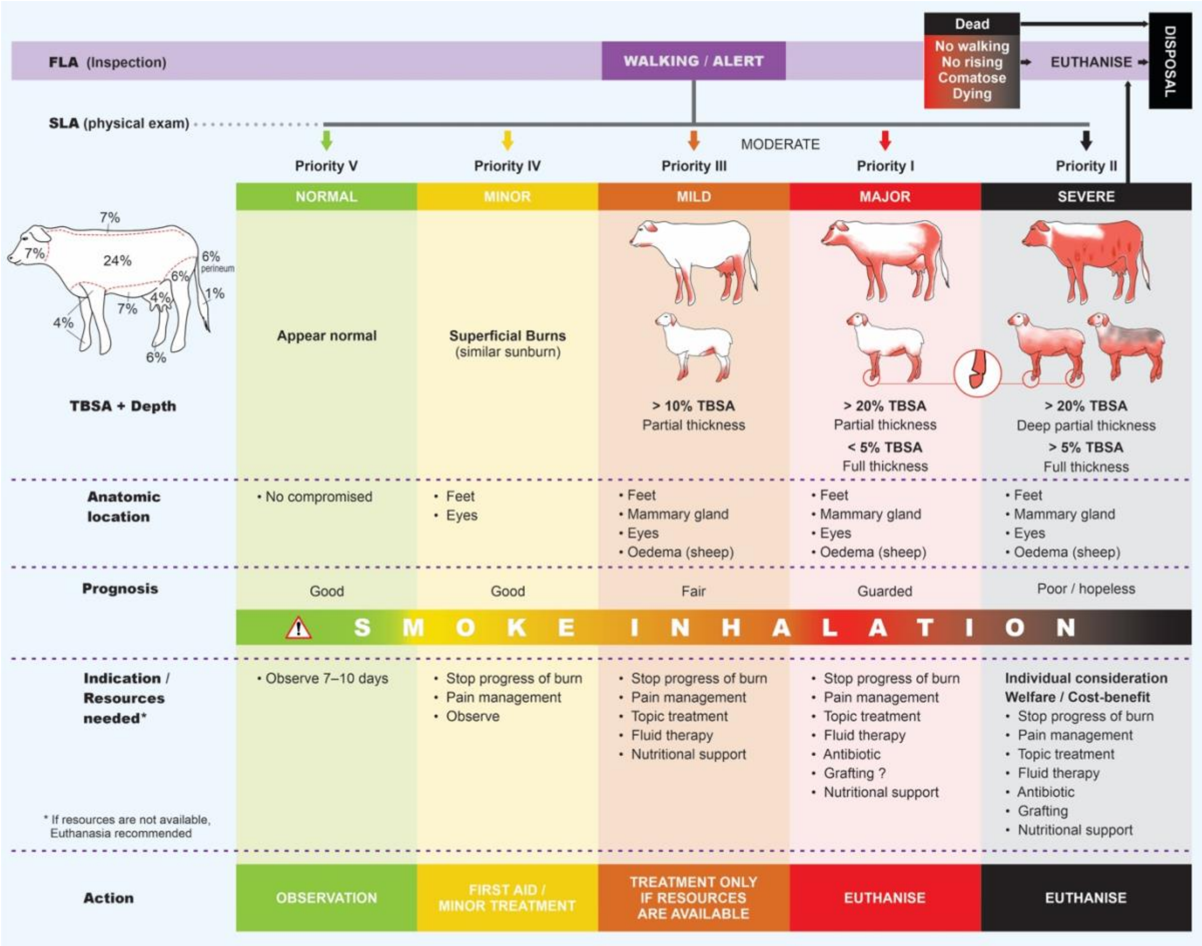



Figure 10. Triage diagram updated with vet-trained inputs regarding decisions for different categories of severity. Proposed triage flow diagram for burns considering commonly used predictors of survivability in domestic ruminants: percentage total body surface area (%TBSA), depth of burns, oedema location on the first 24hrs (sheep), limbs/feet affectation (sheep and cattle), respiratory affectation/smoke inhalation (sheep most affected), mammary gland/age (cow). *FLA: First-line assessment. *SLA: Second line assessment. Action corresponds with the results of the vet-trained survey for the different categories. C Cardoso, 2024.

# CHAPTER 4

# USE OF AI IMAGE ASSESSMENT FOR TRIAGING BURNED LIVESTOCK: SOFTWARE DEVELOPMENT

## 4.1. ABSTRACT

Commonly used prognostic indicators for burns carry evaluator subjectivity related to the level of training, general clinical experience and overall time from original insult. Level of experience increasing evaluation subjectivity leads to unsound decision-making and represents the biggest constraint in evaluating burned animals. Furthermore, mismatching resources and animals' needs halters the community's recovery after fire events by either ineffectively instituting treatment on non-recoverable animals or unnecessarily euthanising animals on the assumption of animal suffering.

Several efforts have been made in human patients to reduce the subjectivity when evaluating the percentage of total body surface area (%TBSA) and depth of burns, using automation to swiftly calculate %TBSA, burn depth, fluid resuscitation volumes

and to reach trained professionals with specialist knowledge to assist with decision-making in real-time and across borders. To the authors' knowledge, no similar efforts have been developed for animals. A transdisciplinary group developed a prototype mobile application using the NativeScript framework. Four images of an affected animal (mock-up model) were taken from different angles, inputted into the system, and sent to a processing platform. These images were contrasted to built-in cut-offs of prognostic indicators for burn severity connected to survivability in domestic ruminants previously defined by the veterinary triage guidelines. Despite limitations regarding sample numbers, a first step has been taken towards connecting the practitioner in the field to skilled advice and potentially reducing timeframes for assistance during fire disasters involving domestic ruminants.

## 4.2. Introduction

Wildfires will become more severe and frequent in the coming decades (Forsyth *et al*., 2019; UNEP, 2022). Animals are often trapped by fences and burned at different levels of severity, the farmer and the veterinary practitioner must then face the difficult task of deciding what to do with these injured animals (Madigan *et al*., 2011).

Burn injuries are dynamic and can become more severe if left untreated (Jeschke *et al.*, 2020). Therefore, delays in veterinary diagnosis and initiation of care increase burn severity, leading to poorer prognoses and worsening the negative welfare state in which burned animals are commonly found (Narayan *et al*., 2021).

A proactive approach to categorising the affected animals may reduce delays and allocate more animals to the treatment category. This process could be streamlined by an established triage plan, which could be initiated by the farmer/farm workers while the veterinary practitioner is on the way. However, currently, the farmer/farm workers do not have the expertise or resources to be able to initiate this process. The automated triage system proposed in this chapter can be used to overcome this problem by allowing anyone to take photos of the animals from certain angles and start categorising affected sheep and cows.

When the veterinarians reach the farm, they can then physically examine these animals and offer further advice on the necessary course of action, therefore reducing the time animals must wait before receiving veterinary care improving the welfare status of the affected livestock.

The prognosis for the patient will be determined by the degree of burn severity as it is directly correlated to survivability. Burn severity is a function of the combination of the extent of the body surface area affected (%TBSA) and the depth of the burn (Thom, 2017).

According to the proposed triage guidelines in this thesis, burn categories will be defined based on these two factors with additional consideration of the anatomic location of the burn, the degree of systemic involvement, the possibility of smoke inhalation and the potential for returning to full productive performance as a measure of treatment success (Chapter 3).

The defined categories follow a scarce-resources availability logic, meaning that the %TBSA cut-offs, depth of burn and location of burn were ruled as treatable on a field setup with scarce resources available and needing minimal use of surgical intervention.

The objective of this segment of the project was to develop an automated software system designed for universal use, aimed at triaging animals with burn injuries. This system provides evidence-based treatment options for various categories, facilitates communication between practitioners in the field and expert advisors, and reduces the time required for assistance concerning ruminants affected by wildfires.

## 4.3. Materials and Methods

A series of systems were used to establish the theoretical basis of the burn severity estimation system which is constituted by image processing:

The NativeScript framework was used to build an application for the categorisation of burn severity. The NativeScript framework allows the building of native mobile applications for iOS and Android using JavaScript, TypeScript, Angular, or Vue.js. This framework provides direct access to native application programming interfaces (APIs), each of these applications or software communicates with each other by using requests and responses. NativeScript's key features comprise cross-platform development, enabling the code to be written once and deployed to both iOS and Android, as well as native performance, with platform-specific APIs for optimal efficiency. It also utilises familiar web technologies, employing JavaScript, CSS, and XML for development. A hot module replacement allows for quick changes without full reloads and is supported by a large community and ecosystem that benefits from extensive resources. Hence, NativeScript is a powerful tool for building high-quality, performant mobile apps with a single codebase (NativeScript, 2024).

A graphical user interface (GUI) is an intuitive system that offers the user symbols and visual metaphors to interact with an application or software. This communication tool replaced the command-line interfaces of earlier computing systems. The key elements of a GUI comprise icons, which are small pictures representing files, folders or actions. Windows, which are seen as rectangular areas on the screen that enable the display of information and allow for interaction. Menus, showing lists of options that can be selected. Buttons, on which a click triggers actions. Scrollbars, which are used to navigate content that does not fit on one screen, and pointers which are controlled by a mouse or trackpad and are used to manipulate elements. The user interacts with a GUI through a mouse or touch screen; the program will interpret the actions (input processing) and send commands to the computer, which in turn will perform the requested actions (command execution). Lastly, the GUI displays the results of the actions on the screen to inform the user. Examples of everyday GUIs with which users interact are operating systems such as Windows, applications such as Google Chrome and a wide range of mobile apps such as banking apps.

A modified version of YOLOv3 (You Only Look Once version 3) was used. YOLOv3 is a convolutional neural network for object detection. YOLOv3 has gained popularity due to its speed and accuracy for object detection in real-time, mostly used in video surveillance and automated vehicles and robotics. YOLOv3 is capable of multi-scale predictions by using three different scales to identify objects of different sizes. Furthermore, it uses the Darknet 53-backbone, which employs a deep convolutional neural network architecture. Identifying objects requires robust feature extraction capabilities based on accurate object detection against a background, for achieving this, high layering and residual connection capabilities are needed, the Darknet 53-backbone was developed with these capabilities in mind to support the YOLOv3 system (Huang, et al., 2019). Hence, the YOLOv3 network is fed an image, the Darknet 53-backbone extracts feature at different scales, the network then predicts class probabilities for objects at each scale, the algorithm eliminates redundant bounding connections, selects the most confident predictions and outputs a set of class labels and confidence scores. These systems have been applied mostly in automated vehicles to detect pedestrians, other vehicles and traffic signs, video surveillance and medical image analysis to aid in identifying tumours or other abnormalities in medical images.

For the optimisation of these functions, Stochastic Gradient Descent (SGD) has been used to adjust the neural network weights based on a loss function's gradient (Zheng, et al., 2019). The SGD is a popular optimisation algorithm used in machine learning to minimise a cost function. It is particularly useful for large datasets where the calculation of exact gradients of data points can become computationally expensive. The SGD randomly selects a single data point or a batch of data points, and the gradient of the loss function is calculated for this subset of data. An iterative process ensues until a stopping criterion is met. This system is applied for the training of neural networks such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and optimises the parameters of support vector machines.

Human eyes and brain work together to interpret light as colour. Light receptors in the eyes send signals to the brain, which then creates the sensation of colour. Objects reflect certain wavelengths of light and absorb others. In general, white objects reflect all light wavelengths and black objects absorb all light wavelengths. A practical example is thinking about a strawberry, which reflects red light and absorbs all other colours. Red, green and blue are the primary colours, and all of them combined form white light while mixing varied intensities of them, creates the visible spectrum of light colours.

The feature extraction function of the proposed burn software uses colour space transformation to convert images from RGB (red, green, blue) to CIELAB colour space to mimic human vision. Colour space is a model used to understand, categorise and define reproducible representations of colours. An example would be a Pantone Collection. Adobe RGB and CIELAB are structured mathematical systems of colour spaces. These are used to understand the capabilities of a particular digital file. RGB colour space refers to the primary colours of light: red, green and blue, used in digital cameras. The CIELAB colour space is a mathematically mapped version of the way we see colour. Three values indicate where a colour falls within the colour space. LAB describes the lightness/darkness (L), redness/greenness (A); or yellowness/blueness (B) of a colour, constituting an opponent-type colour system. CIELAB is a device-independent colour space recommended by the International Commission on Illumination or CIE by its French name, Commission Internationale de l'eclairage) ("PANTONE® UK | Understanding Different Colour Spaces"). ("PANTONE® UK | Understanding Different Colour Spaces")

Finally, the data transfer and output functions utilise Hypertext transfer protocol (HTTP) requests for communication between the mobile application and the backend database. This constitutes the backbone of how a user interacts with the web. A 'POST' request sends image data from the mobile app to the database, and a 'GET' request retrieves image data for processing. Processing entails running the object detection and feature extraction algorithms and storing results in the database. The output displays the animal type, classification confidence, objectness score, and the bounding box coordinates for testing and demonstration.

#### 4.3.1. Mock-up Models and Backgrounds

An adult life-size model of Merino sheep and a Hereford-type cow (60kg and 400kg, respectively) belonging to the Clinical Skills Laboratory at Onderstepoort, Faculty of Veterinary Science (Figure 11; Figure 12 respectively) were used as mock-up models for software and neural network training. Photographs of the respective models were taken with an iPhone mini 13 camera (specifications in Appendix 1) from four views (cranial, caudal, right lateral, left lateral) and software (Adobe Photoshop, Adobe Inc. 2019) was used to create images of digital models of the different proposed categories of burned sheep and cows with differing backgrounds, including shade and sunlight. Moreover, an open burn database (BIP Group-Signal Theory and Communications Department, University of Seville, Spain) was used for guidance regarding the depth of burn colour according to the current scientific classification (Table 1, Chapter 2).

Figure 11. Mock-up adult Merino sheep. Clinical Skills Laboratory, Onderstepoort, Faculty of Veterinary Science.

Figure 12. Mock-up Hereford-type Cow. Clinical Skills Laboratory, Onderstepoort, Faculty of Veterinary Science.

## 4.4. RESULTS

The project aimed to integrate a mobile application with advanced machine learning algorithms to estimate burn severity in animals based on the main prognostic indicators of %TBSA, burn depth, and the anatomical location of burns.

### 4.4.1. HARDWARE AND SOFTWARE COMPONENTS OF THE PROPOSED SYSTEM

The system is comprised of two main components: the input device and the base station. The hardware components contained in these two components are comprised of an input device represented by a camera, wireless data transmitter, processing chip and data storage/memory. The base station contains a microprocessor, a chassis/housing unit, a display/output device and a wireless data receiver.

For the real-time animal detection interface to function properly, the input device needs a camera to capture the images and a processing chip to determine which images are valid and which are not. Temporary data storage is required to hold previously captured images before data transmission takes place. Finally, a wire data transmitter is required to send the captured images to the base station once all four images have been captured and validated.

The base station is where most of the processing takes place. It requires a wireless data receiver to receive the four images sent by the input device. These images are then processed to determine the triage priority for the animal in question. This priority is then outputted by the display/output device. Finally, a chassis or housing unit is needed to contain and house all hardware components of the base station into a single object.

The software is represented in the GUI design for the burn's software and includes five image boxes: four for photos, one for detailed viewing, a capture button and a submit button, as seen in Figure 13. It ensures that all four images are taken and are of sufficient quality to provide the system with the necessary data to accurately estimate burn severity.


Figure 13: Graphical user interface (GUI) screen display. Image courtesy of T Fogwill, 2023.

Training of the burns network involves a composite loss function, which includes coordinate, dimension, objectness and classification loss components. Coordinate loss includes the accuracy of the animal's predicted location. Dimension loss includes the accuracy of the animal's predicted size. Objectness loss includes confidence in the presence of an animal in the image and classification loss, the accuracy of the predicted animal type.

#### 4.4.1.1. Software Functional Block Diagram

The system is comprised of the main functional units or subsystems of the system (Figure 14).

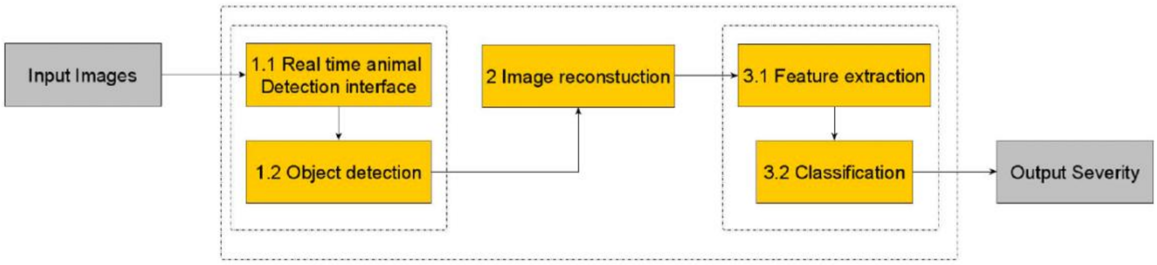



Figure 14: Software functional block diagram. Conceptualisation and Design: T Fogwill, 2023.

The four images of the affected animal are inputted into the system: one lateral image from the right and left of the animal, one cranial, and one caudal. The object detection (FU1.2) will determine which portion of the image contains the animal and which contains the surrounding environment, as well as inform the user which images are valid inputs. If no object (animal) is detected in the image, then image reconstruction cannot be done. Hence, a new image should be inputted.

A real-time animal detection interface (FU1.1) that runs on the photographic input device is used to perform the image validation and ensures that even untrained users can take valid pictures and will also prevent inputs when heavy vegetation obscures most of the animal. These images are sent wirelessly to the base station where further processing will take place. The isolated animal portions of the images are combined into a single 3D model using image reconstruction techniques (FU2).

This 3D model is used as a representation of the animal from all sides and is created by combining all available surfaces of the animal as seen from the input images into a single 3-dimensional model of the animal, allowing for feature extraction (FU3.1) to be done on the animal model. The feature extraction subsystem (FU3.1) will determine the percentage of the animal's surface area that has been burned as well as what type of burns are present. Discrimination between superficial partial-thickness, deep partial-thickness, and full-thickness burns will be done according to distinctive presenting features such as colour. These features can be used to determine which parts of the animal are burned, as well as to estimate the surface area of each type of burn wound. This information can then be used to determine exactly what category the animal falls under to be classified (FU3.2), according to the proposed triage system. This classification of priority is then outputted by the base station for triage purposes.

#### 4.4.1.2. Neural Network Flow Diagram

Figure 15 depicts the general flow of the software system. The flow is based on the triage guidelines proposed for ruminants affected by wildfires. The animals are preliminarily captured in images and scanned by the system to categorise them according to priority for assistance. When the veterinary team arrives, it will conduct an SLA, and a final decision will then be made regarding prognostication for the animal.

The categories are defined as normal, minor, mild, major and severe as presented in Table 5 and Figure 7 in Chapter 2.

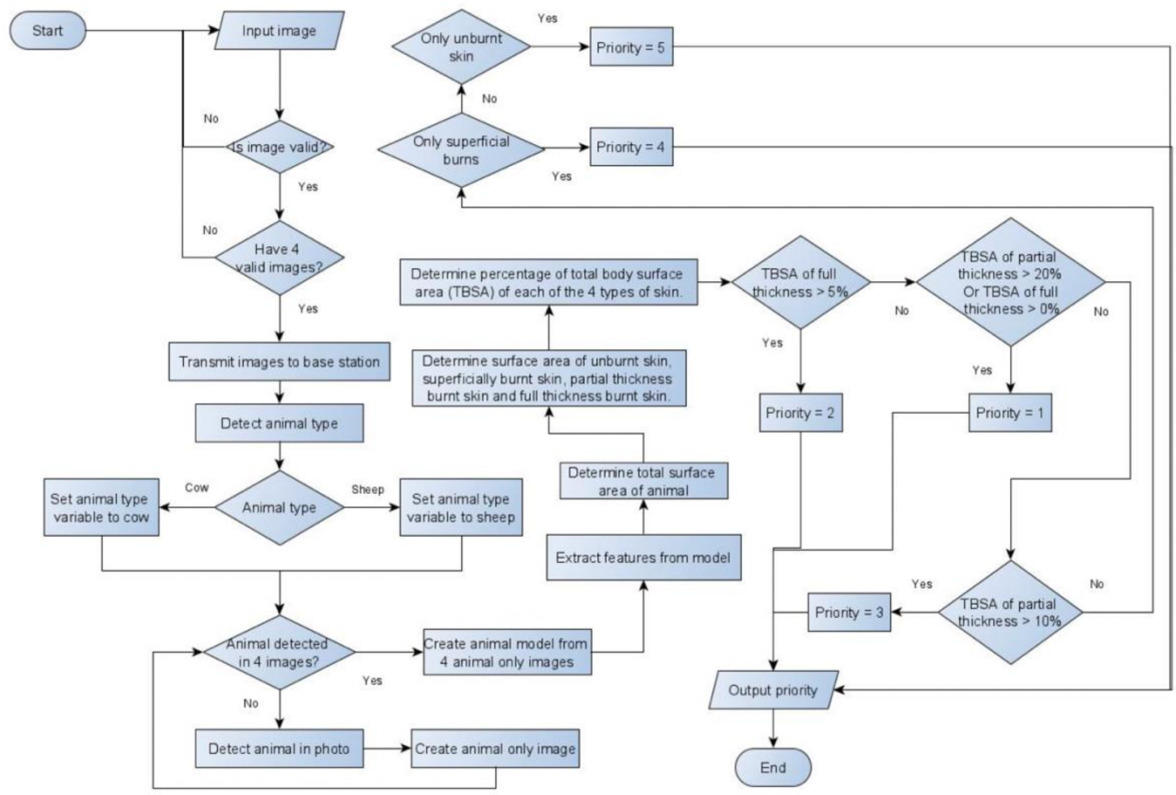



Figure 15: Neural network flowchart symbology diagram. Conceptualisation and Design: T Fogwill, 2023.

Key: Oval = represents the start or end of a process; Rectangle = denotes a process or operation step; Arrow = indicates the flow between steps; Diamond = signifies a point requiring a yes/no; Parallelogram = used for input or output operations.

The algorithm used Support Vector Machines (SVMs) to classify skin burns. SVMs are machine learning algorithms that are used for classification and regression tasks in high-dimensional spaces. Binary classifiers find the hyperplane separating data points of different classes in the CIELAB colour space. Moreover, multiple-SVMs fuse to handle multiple classes of burn severity (Cirillo, et al., 2019). An SVM finds the optimal hyperplane that separates data points into different classes with a maximum margin of confidence. A larger margin leads to optimised generalisation performance. Hence, the support vectors are the data points that define the decision boundary. These vectors handle non-linearly separable data, mapping the data into higher-dimensional spaces using kernel functions. In this way, SVMs handle complex patterns. The most common application of this technology is in image classification, bioinformatics and financial analysis to detect fraud and predict stock markets. The photographs of the mock-up models mimic a live burned ruminant that is standing in the field as it would be considered in the proposed First Line Assessment (FLA) and to fit the different categories proposed in the triage concerning % TBSA, burn depth, and anatomic location of burn as per the proposed Second Line Assessment (SLA) (Figure 16).

Figure 16: Composite image of mock-up models with differential burn severity and backgrounds. C Cardoso, 2023.

The final output in the proposed burn software estimates the percentage of each type of burn on the animal and aids in triage according to triage guidelines for domestic ruminants (Table 10).

Table 10: Training of the convolutional neural network using mock-up images of sheep and cows with differing burn severity against a background. C Cardoso, 2024.

| Priority | Cut-offs | Image input | Category |
|---|---|---|---|
| I<br>Major burns | > 20 % TBSA<br>Partial thickness<br>< 5 % TBSA<br>Full thickness |  | Critical |
| II<br>Severe burns | > 20 % TBSA<br>Deep partial thickness<br>> 5 % TBSA<br>Full thickness |  | Euthanasia |
| III<br>Mild burns | > 10 % TBSA<br>Partial thickness |  | Urgent |
| IV<br>Minor burns | Superficial burns | | Stable |
| V<br>Normal | No burn injuries seen | | Apparently unaffected |

Hence, the multilayered software system performs five main functions: 1) detects the validity of the image, 2) identifies which portion of the image contains the object (animal), 3) combines all animal portions of the four images into a single model, 4) extracts feature such as skin colour from the animal model and lastly, 5) calculates the percentage of total body surface area (%TBSA) of all depth types using the extracted features. Furthermore, it classifies priority for treatment based on said %TBSA using the proposed triage cut-offs correlated to priority.

For the first and second functions, object detection constitutes the theoretical foundation. The first function of the real-time animal detection interface attempts to detect an animal, and failing to do so will render the image as 'invalid input'. If an animal is detected, the image is valid and saved for transmission. The second function detects the animal and further isolates the portion from the surrounding environment.

The third function uses image reconstruction to create a 3-dimensional (3D) animal model. Since each image only contains a portion of the animal (i.e. the left leg may not be seen in an image of the lateral right view), data from multiple images are used to reconstruct a 3D model of the animal. The fourth function uses feature extraction to process the data into numerical features that can be used to determine certain features of said data, which are then used to determine what portions of the animal have red skin or blackened skin. The data is then used by the fifth function to calculate the %TBSA of the colour types, which informs the category of priority classification for the animal.

The proposed system is currently human-handheld operated, improvements are being explored to mount the input device onto a remote-controlled drone, or onto an autonomous vehicle that automatically classifies animals once activated. Improving the current specifications can also lead to improvement of the overall system. The system works on a priority estimation accuracy of 75% and a processing time of under 120 seconds. Human accuracy has been situated at about 60% with classic %TBSA methods and differing skill training levels, image-based diagnostic tools applied to the diagnosis of burn wounds greatly increase accuracy (above 85%) and consistency (Boissin and Laflamme, 2021) (Huang, et al., 2021) (Abubakar, et al., 2020)

## 4.5. Discussion

Telehealth refers to the broad use of technology to collect and share health information, care, advice, and education remotely. Telemedicine is a specific area within telehealth that involves using electronic tools to transmit information about a patient's health status from one location to another. In addition, teleconsultation involves communication via technology between a primary care veterinarian and a veterinary specialist, like a dermatologist. In this scenario, the primary veterinarian seeks expert insights while remaining accountable for all information gathered during the teleconsultation. Lastly, teletriage is implemented in urgent situations requiring immediate or specialised care, such as during wildfires. The goal of teletriage is to support owners and patients in potentially life-threatening situations by facilitating prompt access to specialists and offering professional consultation and guidance (Cushing, 2022).

In the case of wildfires, teletriage will assist the owner in addressing the primary problem of which animals can potentially be saved and which have hopeless prognosis while the veterinarians are on their way to the affected area. Prioritisation of certain categories will allow veterinarians to concentrate their efforts on animals that can be saved.  Several factors may delay veterinary teams from reaching the area of disaster, this itself further compromises the welfare and health of affected animals as time is of paramount importance in the case of burn pathology (Adonis Nasr, 2020).

Various limitations were encountered in achieving the development of a field-ready application. The main detected issue is the current unreliability of the software to consistently remove the background of the animal from the images, with the proposed solution being to revise the implemented algorithms. Moreover, a decision was taken to use colour as the determining factor to detect burn depth, but colours in the background of the image that were within the range of "burn colours" caused inaccuracies in the identification of the burn depth. Hence, the triage classifier partially failed due to background information that was not properly removed. Burn wound categories use colour and texture characteristics for proper classification (Acha, et al., 2005), and it might be necessary to include both to improve extraction capabilities. Due to time constraints and the availability of models, the system was only tested on a single mock-up model, i.e. not on multiple sheep or cows. It is, therefore, not possible at this stage to extrapolate the performance of the system to other animals, whether of the same or different species.

However, success was achieved regarding the development of an application that allows imaging of an animal from four sides, and the application indicated whether the image that would be captured was acceptable for processing or not, validating the captured images. The software is capable of sending the images wirelessly to a computer for processing, and the neural network has been trained to fully recognise the silhouette of a sheep from the captured images so that the correct triage parameters can be used for the subsequent classification.

Recommendations for further research relate to algorithm refinement on background removal and incorporating texture as a parameter, which the system will analyse alongside colour in order to improve its accuracy in classifying burn wounds. This is possible because different burn depths exhibit distinctive textural properties, hence, incorporating this information can enhance the system's ability to differentiate between them even when colour information is ambiguous. Furthermore, training the system on a larger real-world dataset is crucial to improve performance and generalisability. Integrating the application into an existing telehealth platform to facilitate real-time consultation with veterinarians would also be enormously beneficial.

A general discussion follows in Chapter 5, which summarises the efforts, achievements and future directions that this work has yielded.

# CHAPTER 5

# GENERAL DISCUSSION AND CONCLUDING REMARKS

This research highlighted the scarcity of high-level evidence in the form of randomised controlled trials specific to burn severity assessment and prognosis in production animals. The sources indicated that the recommendations to support decision-making regarding burned livestock due to wildfires are based on expert opinions and good practice, representing the lower levels of scientific evidence. The reliance on lower-level evidence limits the strength and generalizability of recommendations. Although some high-strength evidence derived from research in ovine models was available in the literature regarding skin burn and smoke inhalation, these are not generally mentioned in subsequent research. Incorporating this evidence can greatly improve the recommendations for this species.

The triage guidelines developed in this study included recommendations applicable to a field setting, such as the correlation between head and front limbs swelling and smoke inhalation within the first 24 hours of injury, giving a prognostic indication which will reduce the decision-making timeframe for animals presenting these signs and eliminate the need to maintain the animal under observation without action for seven to ten days as previously recommended. Another example would be the incorporation of scavengers into the initial fluid therapy to reduce the systemic buildup of inflammation factors and reactive oxygen species (ROS), which improves the response to treatment in burned ovine. This would be applicable only in cases where these resources are available and provided that the number of animals to be treated does not exceed the capacity of the skilled team.

At this point of the research, it was important to consult veterinary-trained respondents on the factors that influence their decision-making processes when confronted with a large number of animals affected by wildfires. All experience groups prioritised prognosis as a key factor in decision-making, underscoring the need to enhance its accuracy when evaluating cases of burned animals. The cost of treatment was a significant consideration for novice practitioners, and its importance diminished with experience, reflecting a shift in priorities towards an animal-centred modality of veterinary care in disaster scenarios. In turn, welfare concerns become more prominent as experience increases. Analysis of the survey data revealed variations in how practitioners with different experience levels approach decisions for burned animals, highlighting the need for more standardised, evidence-based guidelines to improve the consistency of decision-making across experience level and the need for further training of undergraduates in burn pathology and clinical decision-making.

Assessing the severity of burns in the field is crucial for effective triage and resource allocation. However, in line with the above exposition, this evaluation is often subjective and reliant on the experience of the evaluator for accuracy, leading to potential misdiagnosis of severity and an inefficient related decision. This is particularly problematic in burn pathology, where time is of the essence in reducing the severity and further complications, which leads to poorer prognosis and worsening of the negative welfare state in which burned animals are commonly found.

The proposed solution for this crucial gap in veterinary decision-making capabilities was the development of a prototype mobile application that utilised image processing and machine learning to provide a more objective and efficient method for triaging burned livestock.

Certain limitations were identified in the mobile application, principally related to image background removal, which in some cases led to inaccuracies in burn severity estimation. The reliance only on colour to determine burn depth was identified as being susceptible to errors, especially in cases of animals with dark coats and when background colours were similar to burn colours. However, based on the outcomes of the pilot project, we have shown that it is possible to create a system that autonomously estimates burn severity on an animal. Proof of concept has been established with a small sample of real data; however, a larger sample of real data would be necessary to produce a system that may be deployed in the field.

It is important to acknowledge the limitations of prognosis in the dynamic and unpredictable environment of a disaster. Factors like limited information, psychological stress, and unforeseen complications can all impact the trajectory of events. Therefore, it is crucial to combine prognosis with other factors like ethical principles and human compassion when dealing with animals from affected areas while still categorising them according to severity and constantly monitoring treatment progress. There is a need to continuously update and refine the course of action as new information becomes available.

By acknowledging the importance of accurate prognosis and its limitations, we can strive for more efficient, equitable, and ultimately, cost-effective resource allocation in the face of disaster. The triage guidelines established in this study will help the veterinarian and others assessing livestock to integrate the most important clinical (%TBSA, burn depth, anatomic location) and non-clinical (resources needed for treatment, comfort, nutrition and patient monitoring) considerations to make holistic decisions for animals caught in wildfires.

Recommendations regarding burn prognostication and bias related to the practitioner's clinical level of experience are two-fold. Firstly, this work highlights the need to widen undergraduate knowledge regarding fire veterinary disaster incidence, welfare assessment in disaster situations, burn pathology specifically concerning systemic involvement, fitness for transportation and welfare implications, and the strong effects of stress on meat quality, which affects fitness for human consumption. Secondly, within adequate ethical considerations, a need for more randomised clinical trials and other high-quality studies to strengthen the evidence base for burns affecting production animals, especially in relation to smoke inhalation and systemic involvement and how these influence skin burn severity. Moreover, there is a need to further investigate the impact of various non-clinical factors on burn outcomes and treatment decisions, especially in connection to adequate nutrition during the treatment and recovery period, to provide more comprehensive guidance to affected farmers and practitioners.

The concluding remarks highlight the significant improvement that the use of the proposed triage and supporting technology can bring to the welfare of animals caught in wildfires:

- Reducing decision-making delays by providing a faster and more objective burn severity estimation allowing for quicker triage and treatment decisions.
- Optimise resource allocation by accurately identifying animals with the highest chances of survival, ensuring that limited resources are used effectively.
- Minimising unnecessary suffering by providing tirage accuracy, animals with high burn severity may promptly be euthanised, and animals with good prognosis may receive adequate care.
- The design of visual instructional material (severity images for cows and sheep, tables and diagrams) during the project, which was provided to producers' organisations and also distributed through popular publications to be used in triage by veterinarian and non-veterinarian individuals to better understand the wide range of clinical and non-clinical considerations applied to decision-making tending to enhance the animal welfare of ruminants affected by wildfires.

# CONFLICT OF INTEREST DECLARATION

The author, Claudia L Cardoso, and her supervisors, Prof. R. Leask and Dr K. May declare that no conflict of interest has biased the integrity of the research results reported herewith.

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# APPENDIX 1

## Specs /Images/Further tests

### Camera Specs: iPhone 13 Mini (https://www.apple.com/za/iphone-13/specs/ )

- Dual 12MP camera system: Main and Ultra-Wide cameras
- Main: ƒ/1.6 aperture
- Ultra-Wide: ƒ/2.4 aperture and 120° field of view
- 2x optical zoom out
- Digital zoom up to 5x
- Portrait mode with Focus and Depth Control
- Portrait Lighting with six effects
- Sensor-shift optical image stabilisation (Main)
- True Tone flash
- Panorama (up to 63MP)
- Sapphire crystal lens cover
- 100% Focus Pixels (Main)
- Night mode
- Deep Fusion
- Smart HDR 4
- Photographic Styles
- Wide colour capture for photos and Live Photos
- Lens correction (Ultra-Wide)
- Advanced red-eye correction
- Auto image stabilisation
- Burst mode
- Photo geotagging
- Image formats captured: HEIF and JPEG

# Dunn-Bonferroni Test (pairwise comparison)

| Factor | Test Statistic | Std Test Statistic | p | Adj. p |
|---|---|---|---|---|
| welfare-prognosis | -65.33 | -2.49 | .013 | .846 |
| welfare-systemic | 81.4 | 3.1 | .002 | .127 |
| welfare-cost | -11.67 | -0.44 | .657 | 1 |
| welfare-value | 67.3 | 2.56 | .01 | .682 |
| welfare-return/prod | 77.76 | 2.96 | .003 | .201 |
| welfare-nursing care | 120.78 | 4.6 | <.001 | <.001 |
| welfare-length ttm | 106.26 | 4.05 | <.001 | .003 |
| welfare-shelter | 148.83 | 5.67 | <.001 | <.001 |
| welfare-feed/water | 155.33 | 5.92 | <.001 | <.001 |
| welfare-complications | 127.82 | 4.87 | <.001 | <.001 |
| welfare-insurance | 155.33 | 5.92 | <.001 | <.001 |
| prognosis-systemic | 146.73 | 5.59 | <.001 | <.001 |
| prognosis-cost | 53.66 | 2.04 | .041 | 1 |
| prognosis-value | 132.63 | 5.05 | <.001 | <.001 |
| prognosis-return/prod | 143.09 | 5.45 | <.001 | <.001 |
| prognosis-nursing care | 186.11 | 7.09 | <.001 | <.001 |

| | | | | |
|---|---|---|---|---|
| prognosis-length ttm | 171.59 | 6.54 | <.001 | <.001 |
| prognosis-shelter | 214.16 | 8.16 | <.001 | <.001 |
| prognosis-feed/water | 220.66 | 8.41 | <.001 | <.001 |
| prognosis-complications | 193.15 | 7.36 | <.001 | <.001 |
| prognosis-insurance | 220.66 | 8.41 | <.001 | <.001 |
| systemic-cost | -93.07 | -3.55 | <.001 | .026 |
| systemic-value | -14.1 | -0.54 | .591 | 1 |
| systemic-return/prod | -3.65 | -0.14 | .89 | 1 |
| systemic-nursing care | 39.38 | 1.5 | .134 | 1 |
| systemic-length ttm | 24.85 | 0.95 | .344 | 1 |
| systemic-shelter | 67.43 | 2.57 | .01 | .673 |
| systemic-feed/water | 73.93 | 2.82 | .005 | .32 |
| systemic-complications | 46.41 | 1.77 | .077 | 1 |
| systemic-insurance | 73.93 | 2.82 | .005 | .32 |
| cost-value | 78.98 | 3.01 | .003 | .173 |
| cost-return/prod | 89.43 | 3.41 | .001 | .043 |
| cost-nursing care | 132.45 | 5.05 | <.001 | <.001 |
| cost-length ttm | 117.93 | 4.49 | <.001 | <.001 |
| cost-shelter | 160.5 | 6.11 | <.001 | <.001 |

| | | | | |
|---|---|---|---|---|
| cost-feed/water | 167 | 6.36 | <.001 | <.001 |
| cost-complications | 139.49 | 5.31 | <.001 | <.001 |
| cost-insurance | 167 | 6.36 | <.001 | <.001 |
| value-return/prod | 10.45 | 0.4 | .69 | 1 |
| value-nursing care | 53.48 | 2.04 | .042 | 1 |
| value-length | 38.95 | 1.48 | .138 | 1 |
| value-shelter | 81.52 | 3.11 | .002 | .125 |
| value-feed/water | 88.02 | 3.35 | .001 | .053 |
| value-complications | 60.51 | 2.31 | .021 | 1 |
| value-insurance | 88.02 | 3.35 | .001 | .053 |
| return/prod-nursing care | 43.02 | 1.64 | .101 | 1 |
| return/prod-length ttm | 28.5 | 1.09 | .278 | 1 |
| return/prod-shelter | 71.07 | 2.71 | .007 | .447 |
| return/prod-feed/water | 77.57 | 2.96 | .003 | .206 |
| return/prod-complications | 50.06 | 1.91 | .056 | 1 |
| return/prod-insurance | 77.57 | 2.96 | .003 | .206 |
| nursing care-length ttm | -14.52 | -0.55 | .58 | 1 |
| nursing care-shelter | 28.05 | 1.07 | .285 | 1 |
| nursing care-feed/water | 34.55 | 1.32 | .188 | 1 |

| | | | | |
|---|---|---|---|---|
| nursing care-complications | 7.04 | 0.27 | .789 | 1 |
| nursing care-insurance | 34.55 | 1.32 | .188 | 1 |
| length-shelter | 42.57 | 1.62 | .105 | 1 |
| length-feed/water | 49.07 | 1.87 | .062 | 1 |
| length-complications | 21.56 | 0.82 | .411 | 1 |
| length-insurance | 49.07 | 1.87 | .062 | 1 |
| shelter-feed/water | 6.5 | 0.25 | .804 | 1 |
| shelter-complications | -21.01 | -0.8 | .423 | 1 |
| shelter-insurance | 6.5 | 0.25 | .804 | 1 |
| feed/water-complications | -27.51 | -1.05 | .295 | 1 |
| feed/water-insurance | 0 | 0 | 1 | 1 |
| complications-insurance | 27.51 | 1.05 | .295 | 1 |

The Dunn-Bonferroni test revealed that the pairwise comparisons that include prognosis, welfare and cost of treatment are mainly the ones that have an adjusted p-value <0.05. Thus, reaffirming the notion that these factors are the ones most frequently considered across experience.

# APPENDIX 2

## Dissemination: Articles/drafts/Presentations

Submitted May 2024 / accepted with changes

### 1) Guidelines for domestic ruminants burned in wildfires

Claudia L Cardoso* 1, Catherine E May 2 and Rhoda Leask 1

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**ABSTRACT**

Worldwide, wildfires affect livestock farmers emotionally and financially and due to global warming, the risk of wildfires is expected to increase exceptionally in the next thirty years. The losses experienced by farmers include feed, facilities, livestock, and the future performance of any surviving animals. Many factors such as animal welfare, clinical prognosis of cases, and treatment costs are all important considerations in decision-making when allocating resources and facilitating community rehabilitation. There is a paucity of data regarding decision-making processes with burn injuries in livestock and this study aims to derive evidence-based guidelines for decision-making regarding domestic ruminants affected by wildfires in the context of field animal production practice. Most of the evidence found corresponds to case reports (expert opinion) and low-strength observational trials derived from real events. However, high-strength scientific trials were widely performed during the eighties and nineties using sheep as a test model for skin burns and smoke inhalation and have significantly contributed to the current understanding of burn injuries in humans and animals.

Databases from Web of Science, Medline, and Google Scholar were searched with chosen keywords connected with burn injuries in livestock in publications in both English and Spanish. A research matrix was populated with relevant information according to inclusion criteria and strength of evidence and as a result, triage guidelines were synthesised and integrated for both sheep and cattle. Opportunities to improve the accuracy of prognostic indicators related to burn survivability in domestic ruminants were identified and are currently being developed by an interdisciplinary research team.

KEYWORDS: ruminants, burns, triage, prognosis, welfare.

# 2) Approximation to reducing burn clinical evaluation subjectivity when triaging domestic ruminants burned in wildfires

Draft

Claudia L Cardoso* 1, Catherine E May 2, Rhoda Leask 1, Tania Hanekom 3

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Acknowledgement: Timothy Fogwill

## Abstract

Commonly used prognostic indicators for burns carry evaluator subjectivity related to the level of training, general clinical experience and overall time from original insult. Subjectivity leads to unsound decision-making and represents the biggest constraint in evaluating burned animals. Furthermore, mismatching resources and animals' needs halters the community's recovery after fire events.

Several efforts have been made to reduce the subjectivity when evaluating the percentage of total body surface area (%TBSA) and depth of burns in human patients which involve the use of automation to swiftly calculate %TBSA, burn depth, fluid resuscitation volumes and to reach trained professionals with specialist knowledge to assist with decision-making in real-time and across borders. To the authors' knowledge, no similar efforts have been developed for animals. A transdisciplinary group developed a prototype mobile application built using the Native script framework. Four (4) images of an affected animal (mock-up model) were taken from different angles, input in the system and sent to a processing platform. These images were contrasted to built-in cut-offs of prognostic indicators for burn severity connected to survivability in domestic ruminants previously defined by veterinary triage guidelines. Despite limitations regarding sample numbers inherent to the topic, a first step has successfully been laid into connecting the field to skilled advice and potentially reducing timeframes for assistance during fire disasters involving domestic ruminants.

KEYWORDS: software, burns, triage, ruminants, welfare.

## 3) Dynamics of Veterinary Clinical Decision-making Concerning Domestic Ruminants Affected by Wildfires

Submitted February 2025

Claudia L Cardoso* 1, Catherine E May 2, Rhoda Leask 1

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### Abstract

Wildfires pose a significant threat to livestock, often leading to burn injuries. Assessing the affected animals in the field is crucial for effective decision-making. However, this evaluation is frequently subjective and reliant on the experience of the evaluator, leading to potential misdiagnosis and inefficient allocation of resources. This work consulted veterinary-trained individuals with varying clinical experience to better understand the dynamics of their clinical decision-making processes when applied to wildfire burn cases in domestic ruminants. This study concluded that novice practitioners prioritise prognosis and cost of treatment when making decisions for burned ruminants. However, as the practitioner's level of experience grows, there is a tendency to place less emphasis on economic factors and more on the animal's welfare, especially concerning their systemic affectation and possibility of recovery despite treatment intervention.

Keywords: burns, ruminants, triage, veterinarians, decision-making.

4) 2022 - Oral presentation: Domestic ruminants injured in wildfires: digital evaluation of burn prognostic indicators. Second Southern Africa – Spain Research Forum: *Southern perspectives for global challenges*. Pretoria – South Africa. November 2022.
5) 2023 - Oral presentation: Triage of Sheep Injured in Wildfires. 10th International Sheep Veterinary Congress, Seville, Spain. 6-10 March 2023.
6) 2023- Triage of Sheep Injured in Wildfires. Animal, Science Proceedings 14 (2023), 180-181, O-167. Principal Author. Science Direct, Elseviere. https://doi.org/10.1016/j.anscip.2023.01.243


# CERTIFICATE OF PARTICIPATION

This is to certify that:

**Claudia Cardoso, Rhoda Leask**

contributed with the Oral Presentation titled

**Triage of Sheep Injured in Wildfires**

in the **10th International Sheep Veterinary Congress**,
held in Seville, Spain,
from 6th to 10th March, 2023.

And as evidence thereof,
we hereby issue this certificate.



**Jesús-Félix Barandika**
Co-president Organizing Committee

**María-Jesus Alcalde**
Co-president Organizing Committee

**Delia Lacasta**
President Scientific Committee

7) 2023 - Popular articles:

- https://agriorbit.com/veld-fires-burn-triage-in-ruminants/
- https://maroelamedia.co.za/landbou/landbouproduksie/veldbrande-en-vee-upgee-raad/
- https://journals.co.za/doi/full/10.10520/ejc-farmweek_v2023_n23019_a12

- https://www.up.ac.za/faculty-of-veterinary-science/news/post_3157858-veld-fires-and-livestock-up-faculty-of-veterinary-science-experts-advise-on-animal-treatment-decisions

8) 2023 Interview: https://www.youtube.com/watch?v=jlLvxbZ_tsk&t=704s

# APPENDIX 3

## Approvals

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Veterinary Science
**Research Ethics Committee**

6 June 2022

**CONDITIONALLY APPROVAL**

| | |
|---|---|
| **Ethics Reference No** | **REC055-22** |
| **Protocol Title** | **Triage and treatment of livestock injured by veld fires in South Africa** |
| **Principal Investigator** | **Dr CL Cardoso Camaiti** |
| **Supervisors** | **Prof R Leask** |

Dear Dr CL Cardoso Camaiti**,**

We are pleased to inform you that your submission has been conditionally approved by the Faculty of Veterinary Sciences Research Ethics committee, subject to other relevant approvals.

Please note the following about your ethics approval:

1. Please use your reference number (REC055-22) on any documents or correspondence with the Research Ethics Committee regarding your research.
2. Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.
3. Please note that ethical approval is granted for the duration of the research as stipulated in the original application for post graduate studies (e.g. Honours studies: 1 year, Masters studies: two years, and PhD studies: three years) and should be extended when the approval period lapses.
4. The digital archiving of data is a requirement of the University of Pretoria. The data should be accessible in the event of an enquiry or further analysis of the data.

Ethics approval is subject to the following:

1. The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.
2. **Applications using Animals:** FVS ethics recommendation does not imply that AEC approval is granted. The application has been pre-screened and recommended for review by the AEC. Research may not proceed until AEC approval is granted.

NOTE: REC approval only granted for the scoping review (also as requested by the applicant after consultation).

REMINDER: Any further work such as questionnaire survey and MCDA will need to be described in more detail, together with sample size justification, more detailed methodology, copy of questionnaire, ICFs, etc. The application is still set to be rerouted to the Humanities ethics committee – without the additional information mentioned, approval will not be granted. Please the Humanities ethics committee to not review the application at this stage.

We wish you the best with your research.

Yours sincerely

**PROF M. OOSTHUIZEN**
**Chairperson: Research Ethics Committee**

100 YEARS OF VETERINARY EDUCATION

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Faculty of Veterinary Science
Fakulteit Veeartsenykunde
Lefapha la Disaense tša Bongakadiruiwa

UNIVERSITEIT VAN PRETORIA
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Faculty of Humanities
Fakulteit Geesteswetenskappe
Lefapha la Bomotho

Humanities 100.
Since 1919

17 April 2023

Dear Dr CL Cardoso Camaiti,

| | |
|---|---|
| **Project Title:** | Triage and treatment of livestock injured by veld fires in South Africa |
| **Researcher:** | Dr CL Cardoso Camaiti |
| **Supervisor(s):** | Prof R Leask |
| **Department:** | Production Animal Studies |
| **Reference number:** | 28493185 (REC055-22 Line 1) (Amendment) |
| **Degree:** | Doctoral |

Thank you for the application to amend the existing protocol that was previously approved by the Committee.

The revised / additional documents were reviewed and **approved** on 17 April 2023 along these guidelines, further data collection may therefore commence (where necessary).

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the amended proposal. Should your actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

We wish you success with the project.

Sincerely,

**Prof Karen Harris**
**Chair: Research Ethics Committee**
**Faculty of Humanities**
**UNIVERSITY OF PRETORIA**
**e-mail: tracey.andrew@up.ac.za**



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