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Cattle welfare aspects of production systems in the tropics

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ABSTRACT

There is a growing demand for animal products, especially food for human consumption, including in developing countries in tropical regions of the world. Simultaneously, animal welfare and a reduced environmental impact are increasingly important to modern consumers and non-consumers. Increased efficiency of existing animal production systems is key to meeting the growing demand of animal products without ignoring societal concerns. Adequate animal welfare can play an important role in improving production and addressing consumer demands. This review describes the main cattle production systems in the tropics and considers how they meet the need for transparent animal welfare conditions. Several challenges to overcome are highlighted, including lack of information about the real cattle welfare status in the tropics. Adequate assessment protocols and improvements in animal nutrition, infrastructure, animal health and farming-related education need special attention in the region. Better animal welfare could improve tropical animal production in terms of productivity, and increase the volume of meat and milk delivered. It could also guarantee consumer acceptance and future consumption of animal products, secure incomes, alleviate poverty and reduce migration to urban areas and countryside abandonment.

Keywords: animal welfare, beef, *Bos indicus*, cow, dairy, developing countries, subsistence farming, welfare assessment.

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Introduction

According to the Purchasing Power Parities and the Size of World Economies report from the World Bank (World Bank 2020), low- and middle-income economies account for half of the global economy. As the purchasing power increases, consumers become more aware of the properties of the products they buy, and their origin, demanding better welfare conditions for production animals and, in some cases, are willing to pay a higher price if animal welfare is guaranteed (Vargas-Bello-Pérez *et al.* 2017; Wang *et al.* 2018). Concerns about farmed animal welfare have led to the creation of organisations whose main objective is to prevent cruelty to animals, including those intended for human consumption, creating awareness about the fair treatment of animals during their entire lifetime. As informed and engaged consumers require verification of actual animal welfare levels, research is needed to properly assess animal welfare issues and provide useful tools to improve the lives of farmed animals, consumer knowledge, and the profitability of farming enterprises, especially under specific climatic conditions, such as the tropics.

During the past decades, there has been a surge on the discussion related to livestock production and its environmental impact, both contributing and being affected by climate change (Houghton *et al.* 2001; Pelletier and Tyedmers 2010; Rust 2019). The livestock sector is claimed to be responsible for about 14.5% of the global anthropogenic greenhouse-gas emissions, aside from requiring many natural resources (Grossi *et al.* 2019). Despite these concerns, there is an increasing demand for animal products, especially food for human consumption. The standard of living has increased in many countries, and modern trade agreements, combined with an ongoing globalisation process within agriculture, have increased the accessibility to meat products (Henchion *et al.* 2014). Additionally, the population in developing countries is continuing to grow

(Thornton 2010), and many within this population are experiencing economic growth, which allows them to include a higher amount of animal derivatives in their diet (Delgado *et al.* 2001). Most developing countries lie within the limits of the tropics (Sachs 2001), the area between the Tropic of Cancer at latitude 23° North and the Tropic of Capricorn at latitude 23° South. Beef and dairy production in the tropics is increasing (Fig. 1). According to the Food and Agricultural Organization of the United Nations (FAO), the total beef production in the developing countries from 1997 to 1999 was approximately 28 million tonnes per year and it is now projected that, by 2029, developing countries will account for 80% of the nearly 40 million tonnes of globally produced beef (OECD/FAO 2020).

Some regions are more suitable for beef or milk production than others, based on climate, land availability, land quality, labour and feed costs. Therefore, the impact of production on animal welfare and the environment can vary depending on the region. Establishing the provenance of animal products is essential to meet the demands of consumers and animal welfare organisations. To take account of the ethics of the production method, products must be traceable (Broom 2010). Hence, beef and dairy products must be accompanied by quality information, not only on product excellence but also on production values, including facts about the welfare of the animals. Consequently, the livestock industries in the tropics urgently requires research on various animal welfare aspects of cattle production systems (Herrero *et al.* 2010).

The concept of sustainability now covers producers' livelihood and environmental aspects such as greenhouse gas emissions, biodiversity and animal welfare (Olesen *et al.* 2000). This has captured the public's attention, particularly in countries in the developed world (Cardoso *et al.* 2016; Buller *et al.* 2018). Also, in emerging markets such as China, the public awareness of animal welfare as part of the concept of sustainability is rising (Carpenter and Song 2016). The link between animal welfare and sustainability is not always clear. However, countries such as Denmark and Sweden have created a sustainability index based on indicators for the evaluation of sustainability including animal welfare (Hocquette *et al.* 2014). Keeling *et al.* (2019), having already highlighted the link among animal welfare, poverty and gender inequality in developing countries. Often women are in charge of caring for livestock and, as animal productivity has traditionally been related to animal health and welfare, improving

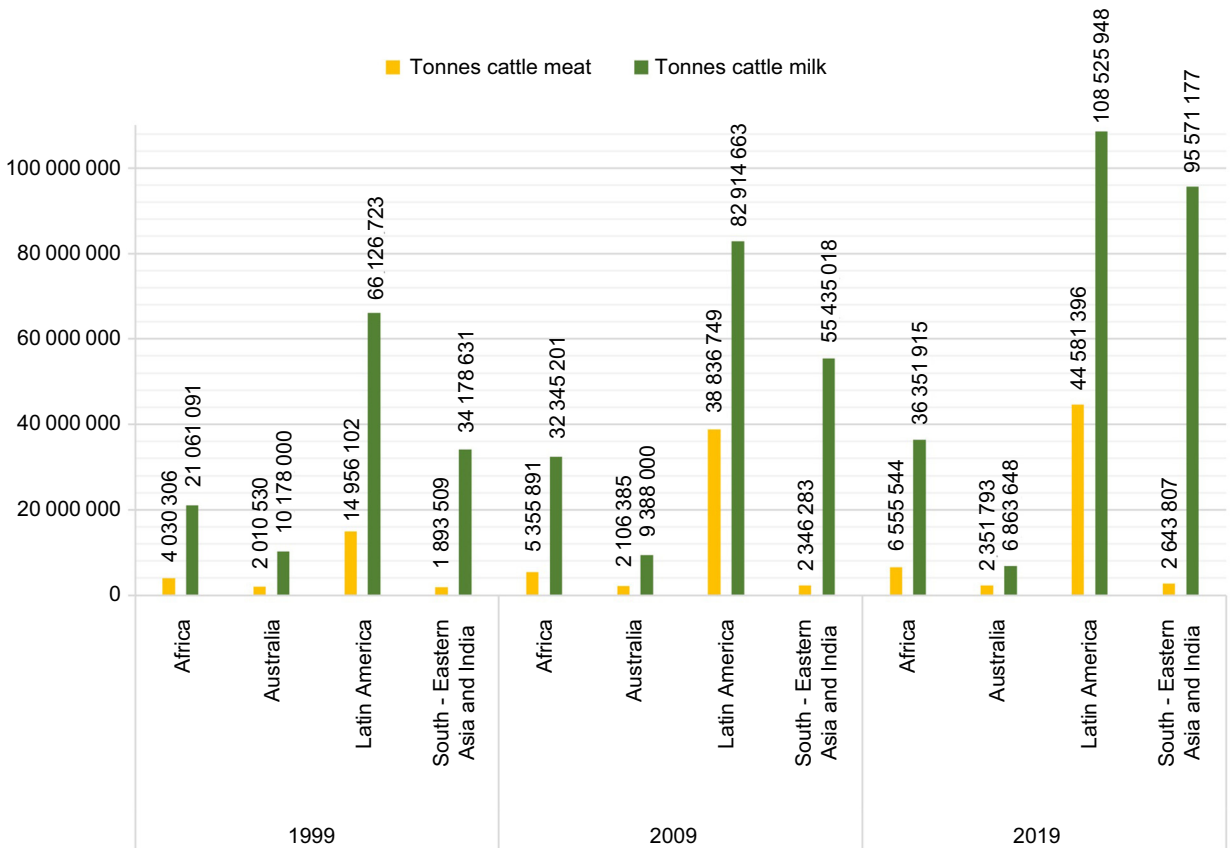

Fig. 1. Cattle meat and milk production in different tropical areas over the past two decades according to data from the FAO (https://www.fao.org/faostat/en/#data/QCL). All regions have registered a production increment for both cattle meat and milk, with the exception of cattle milk in Australia where it has been decreasing.

animal welfare can have a direct or indirect impact on income and sustainability, and the empowerment of women (Keeling *et al.* 2019).

Increasing the numbers of animals in already existing herds or the number of livestock herds to meet consumer demands is not considered sustainable (Steinfield 2006), so working to raise existing herd efficiency is the key to increased production. Developments in genetics, management practices and technology could increase animal welfare without jeopardising production (Dawkins 2016). Additionally, by applying adequate animal welfare measures, a decrease in cattle morbidity and mortality can be achieved (Clark *et al.* 2016). If animal welfare and greenhouse-gas emissions meet consumer standards, the citizens may still show an interest in buying beef and dairy in the future. It is arguable whether animal welfare and environmental impact are a priority for most consumers and stakeholders in developing countries yet. However, meeting these standards is also becoming more relevant for exporting animal products to developed countries, where industries not addressing issues around animal welfare and environmental impact are at risk of losing market access and license to operate (Red Meat Advisory Council (RMAC) 2015; Sinclair *et al.* 2019). Hence, improved animal welfare is of considerable relevance to achieve sustainable development goals (Henchion *et al.* 2014). The evaluation of welfare issues is not necessarily a simple, straightforward task, as different groups may emphasise diverse aspects of welfare (Fraser *et al.* 1997). Some may emphasise physical health and freedom from pain and injury, while others might highlight the affective state of the animal, its possibilities for performing species-specific behaviours, and the absence of stereotypes. Nevertheless, others will focus on the perceived naturalness of the husbandry system (Vaarst and Alrøe 2012; Yeates 2018). The World Organization for Animal Health (OIE) defines animal welfare as 'the physical and mental state of an animal as defined by the conditions in which it lives and dies' (OIE 2011). In this review paper, we use this rather broad definition as our base. Measuring animal welfare is somewhat of a challenge and is usually related to a given standard, taken from, for example, government legislation, private animal welfare standards or labeling schemes, or various research projects. The way in which certain requirements are expressed in these regulations will inevitably influence how they can later be measured and evaluated when assessing compliance (Lundmark 2016). Both the requirements stated in the regulations and the measures chosen can be either animal-based or non-animal-based, where the latter can be further divided into resource and management policies (EFSA 2012). Animal-based measures are also referred to as outcome-based measures (Keeling *et al.* 2013). When analysing animal welfare results, aspects such as the validity, reliability and feasibility of the assessment protocols used must be considered (Veissier *et al.* 2013). In short, assessment protocols must measure the target parameters accurately, thus allowing different individuals to repeat the results over time, and the tests must be practically feasible in on-farm situations (EFSA 2012).

This review describes the main current cattle production systems in the tropical regions of the world, with special emphasis on dual-purpose systems. It also discusses how these systems meet the needs of transparent evaluation protocols on animal welfare established in developed countries and whether these standardised protocols objectively measure animal welfare in the different types of farming systems in the tropics. Furthermore, we aim at illustrating why different indicators, or different weight put on different indicators, might be necessary under distinct geographical and climatic conditions.

Traditional production systems in tropical countries

General considerations

Seré *et al.* (1996) characterised the geography of animal production systems globally, pointing out an array of possibilities in what is generally known as 'tropical conditions' and production systems in those areas. This characterisation indicated that livestock management could be as variable as the geographical locations in which the animals are kept. However, apart from selected examples of specific regions in the tropics, the clear majority of dairy, beef, and dual-purpose cattle in the tropics are raised under extensive pasture-based conditions (Romanzini *et al.* 2020). Another factor to be considered when classifying animal production systems in the tropics is the power to invest in the enterprise. Galina *et al.* (2016) arbitrarily divided farmers into subsistence farmers, medium-income farmers, and farmers with a good budget.

Conditions, such as climatic and socio-economic conditions, in these different enterprises influence product quality and how the animals are treated; so, any methodology used to assess the welfare of the animals needs to be adapted to the specific circumstances. The food safety, environmental impact, and welfare status on these different types of farms will influence how consumers view the final products, depending on whether they align with their values (Fraser 2003; Napolitano *et al.* 2010). Therefore, ensuring that these three requirements are met is essential for better marketing and public acceptance.

Grasslands cover ~26% of the world's total land area, encompassing 80% of agricultural land (Boval and Dixon 2012). More than half of this land area is located in developing tropical countries, where 68% of all grasslands are found (Boval and Dixon 2012). These grasslands provide the feed for grazing livestock, and farming provides many jobs, feed, transportation, and trading services. At least 20% of the working population comprises smallholders who manage

most agricultural land in tropical regions (McDermott *et al.* 2010).

Animals situated in the temperate zones are usually kept on farmland lying on plateaux or hillsides located at 1500–3000 m above sea level. Access to water in these temperate areas is generally reasonable. In contrast, in areas located between 1000 and 600 m, there is a clear distinction between the dry and the rainy seasons, where water resources may be affected. As a result, animal welfare status could be disturbed differently in these two sets of conditions. Fig. 2 presents the distribution of the countries within the tropics related to their geographical site and the three main types of tropical climate. The wet areas or rainforest climate have an average annual precipitation varying between 1500 and 4000 mm. The monsoon tropics are characterised by ~1500 mm rain per year. Tropical wet and dry areas, or savanna climate, have an annual precipitation between 700 and 1000 mm, usually occurring in a short part of the year and presenting no less than 60 mm during the dry season (Kottek *et al.* 2006).

Cattle located in the temperate, tropical zones are usually animals dedicated to milk production, usually *Bos taurus* breeds (González-Padilla *et al.* 2019). A common feature of cattle farms located in these areas is the use of pasture as the primary source of feed, with supplementary concentrate feed (Van Soest 1994). It is rare for these units to be larger than 200 head. By contrast, however, a notable example of milk cattle production systems is the intensive zero-grazing units in some areas of Latin America. This is a somewhat similar approach to those in the United States with usually more than 500 head of Holstein cattle, whose size, production model and pollution are causing concerns for animal welfare (Cardoso *et al.* 2016).

Animal production systems

In the case of beef cattle farming in the tropics, the production units can be divided into two main categories, where the breeding stock is kept in extensive pastoral conditions or rotational systems, usually on improved pastures. The animal welfare status of cattle in temperate zones in the tropics has already been well studied. For example, Petherick (2005) conducted a study in northern Australia and suggested that animal welfare could be significantly improved by

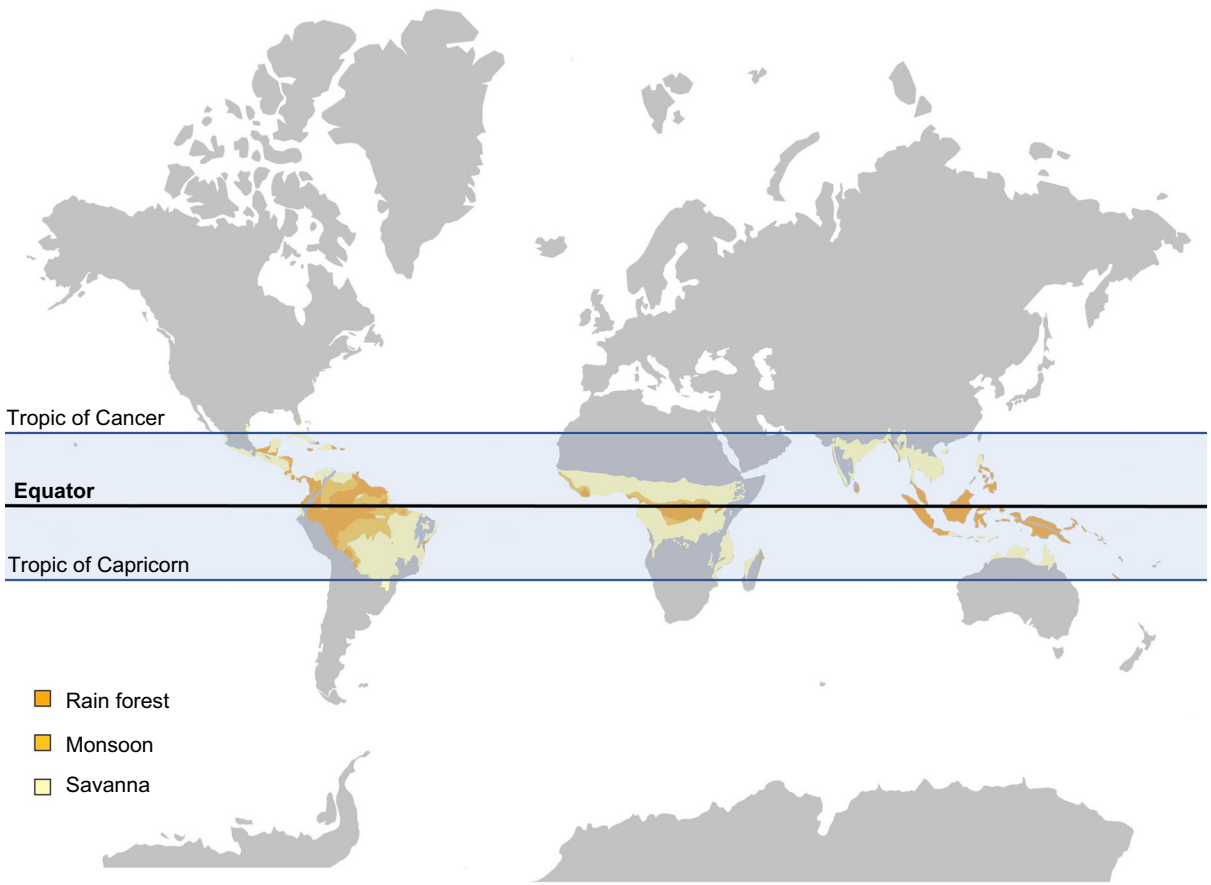

Fig. 2. Distribution of the countries within the tropics related to their geographical site. Tropical regions can also be classified according to the rainfall precipitation per year: above 1500 mm (Rain forest), ~1500 mm (Monsoon) and below 1000 mm (Savanna).

implementing a few straightforward management changes. These included appropriate planning for extended dry periods and drought, wider use of conservative stocking rates, supplementary feeding, and broader implementation of vaccination and weaning programs.

Another husbandry system observed in the tropics is the use of feedlots where steers, or even young heifers, are kept. This is more often found in the lowland tropics, but it is still not very common (Hostiou *et al.* 2006; González-Padilla *et al.* 2019). Some practices in feedlot fattening systems have been widely questioned by animal welfare societies, consumers and scientists (Tucker *et al.* 2015; Macitelli *et al.* 2020) as an example of mistreating animals in the final stages of their lives. Finishing calves in a feedlot usually involves taking them from their native pasture, transporting them, and perhaps selling them at auction (often with negative biosecurity consequences) before arriving at the feedlot. The transportation process often takes a physical and psychological toll on animals, as it involves unfamiliar surroundings, noise, social regrouping, loading and unloading, feed and water deprivation (Nardone *et al.* 2010). A review of animal welfare policies by Ndou *et al.* (2011) concluded that this subject receives low priority due to factors such as traditional customs and beliefs, lack of knowledge of animal handling, housing facilities, and transport, and substandard management facilities. This is exacerbated by the fact that cattle are used for several purposes, such as the production of meat, milk, or both, draft power, and traditional ceremonies. These welfare issues require attention.

A third option gaining increased popularity is to raise fattening steers under pastoral conditions to cater for the increasing demand for beef raised under grazing settings. Extensive systems in the tropics can be subdivided depending on the diversity of the feed given to animals. The most common pasture-based production system depends on monoculture of grass species, which is the main or only food provided to the cattle (Quero *et al.* 2015), sometimes combining grass with legumes. These systems can have native or improved pastures, whose nutritional quality will mostly depend on the season and the grass and legume species present (Kubkomawa *et al.* 2015; Muñoz-González *et al.* 2016). The use of improved pastures has an added advantage in that, with the introduction of exotic species, the quantity and quality of the fodder available for the animals has also improved. For example, in 2019 only 14% of the fattening animals in Brazil, which is probably the largest exporter of beef in the world, came from feedlots (Associação Brasileira das Indústrias Exportadoras de Carne – ABIEC 2020). The question is how much these systems depend on fertilisers and pesticides and what is the impact of these products on the environment for achieving these goals? However, Seré *et al.* (1996) pointed out that pasture improvements only play a limited role in the general goal of improving beef production. Cultivating improved pastures is not necessarily sufficiently economically attractive under the prevailing conditions in the tropics, but has been reported as successful in some regions (Jank *et al.* 2014; Webster *et al.* 2019). There is a pressing need to improve road infrastructure, implement new technologies, and establish suitable grasslands, all from a commercial perspective, to attract investors in mixed farming systems (Seré *et al.* 1996). This type of development is seen in some countries, but is still missing in others.

There is no doubt that the use of pesticides and fertilisers and current grassland management techniques are causing great unease to environmentalists concerned about erosion, water pollution, and depletion of natural bacteria, all being elements necessary for a good equilibrium in the soil (López-Pereira *et al.* 1994). It has become evident that the implementation of alternative production systems with a reduced environmental impact is necessary. In the tropics, the silvopastoral system aims to integrate farming animals with feed resources already available in the environment, such as edible shrubs and trees, combined with native grass species. Therefore, this system helps maintain soil nutrients while providing animals with a wider variety of food and a more balanced diet, among other benefits such as providing shade, shrub cover and climate regulation (Nahed-Toral *et al.* 2013; Améndola *et al.* 2016; Broom 2017). Silvopastoral production units are becoming more popular in the tropics because of the efficient use of space and their potential for sustainable animal production (Tarazona Morales *et al.* 2013). Nevertheless, as Franzluebbers *et al.* (2012) pointed out, impacts are not related to intensification *per se*, but to how well managed the system is. If inappropriately designed, such systems can have a negative effect on livestock performance, as animals tend to concentrate in shaded areas. Thus, shaded points become more susceptible to trampling effects and associated impeded root penetration and reduced soil aeration. This may negatively affect legume growth, thereby nitrogen fixation in the pasture, leading to forage of lower quality that provides fewer nutrients for the animals, compromising animal welfare (Latawiec *et al.* 2014).

Production systems based mostly on purebred animals are common in the dairy industry, particularly in milder climates. These farms, which are mainly based on Holstein cows, can be subdivided into two main husbandry approaches. The zero-grazing system supplies all animal feed on the basis of harvested forages such as alfalfa, which could be given fresh or as silage. Additionally, they are fed concentrates with a high protein and energy content. The other alternative is to put the cows out at pasture and provide additional concentrate feed when the animals are indoors at milking. Systems based on indoor housing in large production units require a closer look at the animal welfare status from other points of view, such as overcrowding and sanitary conditions, than do pasture-based systems. However, indoor systems are not the focus of this review.

Structure of different farming systems in the tropics

Subsistence farms

Subsistence farms are probably the most common system for cattle raised under tropical conditions. Herrero *et al.* (2009) described the role of what is also known as smallholder peasant farming, based mainly on family enterprises. These types of farms have a minimum of facilities and milking is usually undertaken by hand, the use of family labour is common, and cows are a mixture of different breeds. According to Herrero *et al.* (2009), an expected increase in future demand for livestock products in developing countries will provide unique opportunities for small community farmers to improve their livelihoods. In addition to that, a good relationship with the environment could be developed. From the welfare point of view, the animals on such farms are kept as if they were part of the family, but poor nutrition, parasites and heat stress undermine the product quality and quantity (Ndou *et al.* 2011). The animals, mainly males, are often kept as a savings bank and sold in times of need.

Medium-income farms

Medium-income farm enterprises are larger (at least 10 cows per farm) and, by genetic selection, have animals more adapted to the tropics to be more productive (Kamanzi and Mapiye 2012). Practices such as deworming, the addition of supplementary fodder at milking, and better infrastructure (particularly shade areas) are more common. Farmers in this category usually employ workers to assist in the enterprise and may or may not use a milking machine. Some may have another source of income (González-Padilla *et al.* 2019). Average milk production ranges between 6 and 8 L per cow per day, depending on the dairy cow breed and feeding strategy (Hostiou *et al.* 2006). Milk production in tropical and subtropical conditions is indicated to be 40–60% lower than in the temperate zones when using the same breeds, such as Holstein (Usman *et al.* 2013). However, there are huge variations among countries, within countries, and among farming systems. Sales of milk depend on a middle man or are made through cooperatives (Moran 2005). Sanitary measures on medium-income farms are quite reasonable, as is the infrastructure for milk cooling. In a study comparing two production unit representatives of this group, Martinez *et al.* (1988) found that cross-bred cattle raised under poor conditions in Mexico tend to calve in spring, when grazing conditions improve, whereas cattle raised in better settings calve in the cool winter months. For the former, spring calving was the key element for their survival and food supply, while for the latter, winter calving gave a more comfortable environment.

Large-scale farms

As indicated by Seré *et al.* (1996), there is a tendency for farmers in the lowland tropics to move to a more temperate zone, enabling them to increase their livestock; examples of these movements are found in Costa Rica, Colombia and Kenya. These production units are more specialised, with increased quantity and quality of production. In these enterprises, machine milking is the norm and, with the acquisition of milking and container equipment, sanitary conditions and milk cooling are catered for (Usman *et al.* 2013; Ramírez-Rivera *et al.* 2019). One critical aspect is that grazing is the typical source of fodder, with various degrees of supplementation. These units may work on a cooperative basis, and thus their feed supplies and their final product, either milk or meat, are traded through farmers representing the group of individuals. Other farmers are entirely independent and usually sell their products, particularly milk, to established enterprises, which in turn sell the product directly to the consumer. These types of farmers are possibly more aware of new technologies such as organic farming (Müller-Lindenlauf *et al.* 2010) and more interested in developments such as a better price for their products if appropriate welfare practices are performed in their enterprises.

Assessment protocols under the conditions of tropical production systems

The use of standardised protocols, supported by the scientific community, has led to more reliable certification, better opportunities for marketing schemes, and integration of minimum welfare standards for exports (Ellis and Keane 2008). However, the animal welfare concerns addressed in the protocols originated in response to the conditions prevailing in industrialised intensive farming (Hernandez *et al.* 2017). Consequently, the emerging assessment protocols are designed to address the problems of these more high-tech production units, overlooking others such as traditional production systems that work in different conditions, dealing with diverse animal welfare challenges. For example, in extensive pasture-based systems and small traditional farming in developing countries, these protocols are not completely useful due to the diverse characteristics of the production units. Such modifications of the protocols might be useful also to pasture-based systems in developed countries.

Some of the most widespread protocols created to assess animal welfare in a standardised manner are those developed by the Welfare Quality® (WQ®) project. Funded by the European Union and released in 2004, the WQ® protocols are predominantly animal-based, on-farm animal welfare assessment protocols. They aim to integrate four primary areas of concern, denominated as principles, which are ‘good feeding’, ‘good housing’, ‘good health’ and ‘appropriate behavior’. The protocols are specially designed to identify strengths and weaknesses in animal husbandry

and develop strategies to improve animal welfare (Blokhuis 2008). They combine indicators of elementary necessities, infrastructure, health and behaviour. The WQ® protocols have been widely used in research (Knierim and Winckler 2009; Popescu *et al.* 2013; de Graaf *et al.* 2017; Tarazona Morales *et al.* 2017; Wagner *et al.* 2018), including the assessment of farms working under a year-round extensive system, where modifications to the original measurements were suggested (Franchi *et al.* 2014; Hernandez *et al.* 2017; Kaurivi *et al.* 2019). However, to our knowledge, no formal protocol has been created to address the necessities and welfare issues of tropical production systems.

Subsistence farms

Innumerable efforts within the public and private sectors have been devoted to improve the performance of cattle raised in subsistence farms under tropical conditions. It is outside the scope of this review to analyse the different initiatives, as their focus was on the options to improve welfare in tropical animal production where the primary need is an improvement of the sanitary conditions on the farm. Deficient parasite control and inadequate facilities, for example, involving patches of dirty water, mud and inadequate ventilation, jeopardise production (Galina *et al.* 2016). Inexpensive and straightforward measures could be put in place once farmers are willing to accept feasibility on their farms.

Many major animal welfare risks are closely related to how humans perceive animals, knowledge of production procedures, schooling and cultural aspects (Clark *et al.* 2016). Subsistence farmers are particularly vulnerable and generally lack access to better living conditions and opportunities, including access to education, inputs and services (Agus and Mastuti Widi 2018). This may leave animal welfare a low priority. For example, the use of old, outdated and harmful practices, such as whipping, screaming at animals and hot-iron branding, are still common practices. These practices can be seen even on medium-income farms or large-scale farms in the tropics.

Medium-income farms

An objective evaluation of the welfare conditions on medium-income farms could move them towards improving the commercial value of their product. Initiatives such as Latte Nobile (www.lattenobile.it), American Humane (www.humaneheartland.org/about-us), Certified Animal Welfare (https://agreenerworld.org/certifications/animal-welfare-approved/) add value to the products through certification of quality control in the enterprise. The increasing popularity of organic products (Chander *et al.* 2011) has opened a new door to farmers who rear their animals in grazing environments and free from chemicals harmful to the environment, thus avoiding concerns about mistreatment of animals raised under intensive conditions, usually indoors in large units. Organic farms use management practices and alternative remedies to manage animal health (Sutherland *et al.* 2013). Nevertheless, Sutherland *et al.* (2013) also highlighted that these practices in some situations are not enough and most of these remedies lack sound scientific research about how effective they really are. Consequently, the avoidance of more effective treatments could cause other welfare risks, especially when parasites such as ticks reproduce without control. If there is a niche for good publicity, this is probably the area where farmers could improve their income, selling their product at a higher price, without affecting their everyday practices.

Large-scale farms

A study by Hernández *et al.* (2017) evaluated the conditions and welfare of dairy cows on intensive, semi-intensive and extensive farms in Costa Rica. None of the farm groups reached the level of excellent welfare in all three principles of the Welfare Quality® protocol for dairy cows (good feeding, good health and appropriate behaviour). Hernandez *et al.* (2017) found that some of the principles are influenced by the nature of different management systems and might not reflect the actual welfare state of animals, especially in pasture-based systems. These findings indicate a need to revise the protocol, which is designed for intensive systems, or indicate that these three major issues can be a concern to the farmers evaluated, as there seems to be room for improvement. A continuing increase in urbanisation, particularly in developing countries, is already ongoing (Delgado *et al.* 2001; Herrero *et al.* 2009). An advantage of raising cattle in extensive production systems is that most consumers agree that the animals can live in a more natural environment, where they will have the freedom and better welfare standards than for animals in intensive systems, which always remain indoors (Hemsworth *et al.* 1995). Some consumers prefer buying these products because grass-fed animals are believed to be healthier, thus providing more nutritious dairy and meat products. Consumers are also starting to ask whether the food they are buying is produced ethically, taking animal welfare, 'fair trade', and adverse effects of production on the environment into account (Broom 2017). Producers in the tropics could benefit from such consumer preferences, and they could easily move into organic or more sustainable production systems.

Needs and challenges of cattle welfare in the tropics

There are specific challenges that compromise animal welfare in tropical regions, mainly because of the weather and specific animal production systems.

Nutrition

Feeding and welfare in developed countries often have two main issues, i.e. high use of concentrate feed and little time spent in foraging. These two welfare problems barely exist in pasture-based cattle kept in the tropics. Instead, lack of feed may cause undernutrition, which is not unusual and can be a serious problem (Njisane *et al.* 2020). There are predictable seasons in temperate countries such as summer and winter, and farmers store hay and silage for the cold part of the year. It is more difficult to predict when and even if the rainy season will come in tropical, and especially semi-arid, areas. Instead of storing hay or silage, in the dry season, the animals rely on what is left from the previous rainy season, i.e. grass or browsing of often low quality and amount. Traditional nomadic or semi-nomadic grazing systems, especially in Africa, previously compensated for the lack of forage by walking long distances to green areas (Jung *et al.* 2002). Changes in land use, land ownership and population growth have made this option much more difficult today, along with changes in rangeland resources, due to desertification, soil erosion and overgrazing (Ben Salem and Smith 2008).

Quality of feed can be a problem, especially when cattle are kept on grazing areas with high fibre and low protein content. There can be various reasons for this, such as, for example, senesced grasses of lower digestibility and low protein content in the dry season, with a higher lignin concentration. However, the use of fire at the end of the dry season is still common in the tropics and evidence has suggested that this practice increases the quality of native grasslands (Mapiye *et al.* 2008; Flores Ancira *et al.* 2016). It has also been suggested that in the rainy season in the humid tropics, there is a lower nutrient density in the grass, and Muñoz-González *et al.* (2016) claimed this can be due to a higher proportion of water and stem material in the forage. However, Silva *et al.* (2009) found that as swards reach 95% light interception, the quality of tropical C4 grasses decreases because the structure of the sward changes with less leaf material in proportion to stem and dead material. Grassland plant composition in the tropics is also an important matter, as the existing grassland is made up mostly of grass species and few legumes, which are known for their higher protein concentration. Furthermore, it is commonly known that the quality of tropical grasses is lower than that of temperate grass species (Leng 1990; Van Soest 1994). Grass quality can be tackled using fertilisers and grassland management techniques, but this must be undertaken with the right techniques to avoid environmental damage and overgrazing. Year-round feeding programs must be planned and implemented to improve the efficiency of feed resources. Poor cattle nutrition could be compensated for by feeding additional concentrates, but this is often impossible due to high prices, limited access or practical problems. To tackle this problem, farmers can use local agricultural by-products, such as bagasse, corn cobs, citrus peel or others, depending on local availability (Martin 2009; Devendra and Leng 2011). In fact, Costa *et al.* (2019) found that the average daily gain of growing bulls can be increased when using citrus pulp, a feedstuff high in pectin and by-product from the citrus industry. The use of forage conservation techniques and the introduction of leguminous trees and shrubs can also help tackle the lack of feed in seasons with feed scarcity (Devendra and Leng 2011; Agus and Mastuti Widi 2018).

Feeding behavior related to the time of the day is also a crucial aspect affecting nutrition, especially when the animals have no access to food at night. This can be the case when animals spend their night indoors or in small fenced enclosures without feed because of predators or thieves, or they have to be led to pasture. A long walk reduces the available time for grazing, increases energy demands for maintenance, leaves the animals exhausted when arriving at pasture, and limits the available time for grazing to the hottest hours of the day, leading to reduced production (Jung *et al.* 2002). Lower forage intake may be observed in cattle that graze in areas where forage is scattered and heterogeneous, as the animals will spend more time moving to favorite grazing areas than feeding. Natural grazing behaviour in hot areas generally involves grazing in the early morning and late afternoon, which is not possible when these hours are spent walking (Decruyenaere *et al.* 2009). In contrast, in some other tropical regions, animals are kept outside all the time, taking advantage of the coolest times of the day to feed.

Access to water is a problematic issue in tropical countries, especially in semi-arid areas in Africa and Latin America. Water, rather than forage, is often the limiting factor when it comes to livestock density. There are problems with both the quality and the amount of water. If the water is on the surface, it can be muddy and even completely disappear in the dry season, forcing the animals to long walks. Cattle concentrate their grazing activity around water, but the distance animals can travel from pasture to water is variable (Williams *et al.* 2017). In Australia, cattle have been observed grazing on average at 3 km from water points and increasing up to 10 km to reach preferred grazing areas (Low *et al.* 1978). When grass is scarce, cattle may travel from 6 to 13 km to find water (Schmidt 1969; Low *et al.* 1978). However, distances as long as 14–24 km have been observed (Low *et al.* 1978). In this situation, the animals may even get water only sporadically. The combination of very limited access to both forage and water may result in low productivity and death of animals and, of course, reduced animal welfare. The number of cattle may increase, making the situation much more vulnerable in the dry season, when access to forage is limited due to higher stocking rates. The use of boreholes and pans could be a solution if they are managed sustainably, as could managing stocking rates depending on

the season (Masike 2007). However, it is important to note that overgrazing of certain areas could increase by boreholes, as animals would remain together in a limited space close to the water (Dunne *et al.* 2011).

Infrastructure and handling facilities

Depending on the size and type of the farm enterprise, handling facilities and shelters with different levels of technification will be available. Cattle in pasture-based systems rest on the ground, not inside buildings as they do in temperate areas. Soil is an excellent surface to lie on, as long as the soil is dry and stones or thorns are not present. Depending on the country, cattle are kept in enclosures to protect them from being stolen and from natural predators at night. In some other tropical areas, they always rest outside, where shelters are not available for animals to protect themselves from the weather elements. This may lead to heat stress in the hottest months or health-related problems during the coldest season (Tucker *et al.* 2007). The lack of shade on grazing fields, particularly trees or constructed shelters, is a serious threat to animal welfare in hot climates (Silanikove 2000). The onset of the rainy season brings short fresh grass with high protein and low fibre, leading to diarrhoea in cattle ingesting this forage. The combination of cold and wet weather with this short, rich grass may weaken cattle and make them prone to diseases. Options to prevent this are providing shelter and limiting access to pasture or planting trees and shrubs in grazing areas.

Health and disease

A good health status is crucial for the productivity and welfare of animals. During recent decades, the importance of the link between the health of livestock and the health of humans has been increasingly emphasised, and the concept of 'One Health' has been expanded to also include wildlife health and ecosystem health (Gibbs 2014; Lerner and Berg 2015; Lerner and Berg 2017). This is certainly relevant also in a tropical setting, where cattle are kept on pasture and, hence, are an integrated part of the local environment, for example, in relation to exposure to vector borne diseases as mentioned below, and as potential contributors of transmissible diseases to the local wildlife. Grazing cattle are regarded as an important factor for maintaining certain types of flora and small fauna biodiversity, especially in the non-abundance of wild grazing ungulates, and such biodiversity is a relevant part of the One Health approach (Romanelli *et al.* 2014). Furthermore, a concept known as 'One Welfare' has been developed recently, drawing the attention to the fact that the welfare of the animals is closely linked to the welfare of the farmer (García Pinillos *et al.* 2016). If the farmer is confident and making a reasonable living from farming, this increases the chances of good animal management. Similarly, if the animals are sick, emaciated, injured or for other reasons not producing according to standard, this will negatively influence the welfare of the farmer.

In this specific context, various natural elements in the tropics can cause injuries and skin damage. Some of these elements are plant-based, especially thorns on trees or lying on the ground. Others are sharp stones, fighting with con-species, predator attacks and external parasites. These injuries might be very small initially but could easily become infected and cause great suffering.

The incidence of lameness in cows under grazing conditions in the tropics is estimated to be approximately 16% (Moreira *et al.* 2018) compared with a mean of 31.6% lame animals in England and Wales (Griffiths *et al.* 2018). Several factors could be responsible of this relatively low rate in the tropics, such as the low grain feed to the animals, soft grass decreasing pressure on the hoof, and a cleaner surface than pens in intensive production systems, thus reducing the incidence of hoof infections (Bruijnis *et al.* 2012). Compared with cattle in intensive production systems, the welfare and hoof health of cattle reared on grassland is generally better than those of European cattle housed indoors. However, while the numbers of foot lesions may be lower than in temperate intensive production systems, a high percentage of cattle in the tropics suffer impairments of the locomotive system that are frequently not detected and left untreated, becoming chronic problems that compromise animal welfare.

The hot, humid climate of the tropics also provides excellent living conditions for numerous parasites, including several potential vectors, and is favourable for the transmission of pathogens. Gastrointestinal nematodes can be considered one of the most important challenges in cattle production under tropical conditions as there is a high death rate due to parasitic infections and poor nutritional conditions (Molento *et al.* 2011). Ticks and tick-borne diseases, such as bovine babesiosis, east coast fever and anaplasmosis, have also been recognised as an emerging health problem due to growing resistance to acaricides, causing great economic losses (Nene *et al.* 2016; Almazan *et al.* 2018; Hernández-Castellano *et al.* 2019). If ticks appear in large quantities, they impair growth and productivity and cause other long-term problems, affecting animal metabolism and reproduction (O'Kelly *et al.* 1988). East coast fever, a parasitic disease transmitted among cattle or from buffaloes via a specific type of ticks, kills about 1 million heads of cattle in Africa every year (Gachohi *et al.* 2012; International Livestock Research Institute (ILRI) 2021). Farms in the tropics also often have a low level of biosecurity, limited possibilities for isolation of sick animals, and limited training and knowledge about disease prevention, making them vulnerable to infectious diseases (Hernández-Castellano *et al.* 2019).

A good start to improving cattle health and animal welfare conditions would be to focus on reducing disease incidence. Implementation of vaccination and preventive medicine programs can be cost-effective and reduce animal suffering in the long run. Another important action to decrease disease is the application of biosecurity protocols to animals and people entering the farm (Hernandez *et al.* 2017). Depending on the management of the herd, frequency of handling, and whether the animals are sheltered or not, farmworkers and farmers will be able to notice and treat wounds. When animals are kept outside and left by themselves, medical attention might not arrive on time, and sometimes a small problem can evolve into a significant issue, ending in a major infection or death. However, antibiotics, medicines to control parasites, and other drugs must be used carefully to avoid the development of resistance in bacteria and parasites. This is a major problem that is likely to continue in the future, particularly in tropical countries, since the use of veterinary drugs is unregulated in a great proportion of countries in the region. Changes in policy so that drugs can be used and applied only by certified veterinarians have to be put into place to prevent any further increase in antimicrobial and parasite resistance, which are current problems in developing countries (Grace 2015; Roess *et al.* 2015).

Animal welfare education in the tropics

The animal welfare situation in developing countries in the tropics is not optimal. Animal welfare is not a priority due to poverty and food insecurity, which, in turn, are accompanied by a lack of knowledge of animal behavior and inadequate livestock handling facilities. Moreover, traditional customs and beliefs can be detrimental to animal health (Ndou *et al.* 2011; Asebe *et al.* 2016). Animals are sometimes subjected to painful and stressful situations when they must be vaccinated, treated against disease, hot-iron branded, castrated or dehorned. These procedures can be extremely painful, generating fear that can lead to traumatisation and long-term stress, affecting productivity (Grandin *et al.* 1998). This is very harmful to the animal but also increases the difficulties in handling cattle. Treating the animals with a correct pain management strategy might help handle the animals in the future, saving time and money (Hudson *et al.* 2008).

Draft animals are in a different situation. Cattle can be used for pulling carts or plows with poorly adapted tools. They may pull heavy loads, get beaten when working, and must work or rest without shelter from the sun. Better equipment and better treatment of the animals would improve their welfare and performance (Petherick 2005). It is a challenge to change old habits such as beating animals, but once the farmer or worker understands that it is in their interest, they might behave differently. However, regulating draft animal welfare and improving their conditions is restricted by education and financial barriers (Ramaswamy 1994).

Moving animals from one place to another can be hazardous for their psychological and physical integrity due to long transport or waiting times, food and water restrictions, extreme weather and stressful and new environments (Fisher *et al.* 2009; Bulitta *et al.* 2012). If undertaken incorrectly, animals can be injured during transportation or die before arriving at their destination. The conditions in many slaughterhouses do not follow sanitary and food safety guidelines, having dirty surroundings, untrained personnel, and procedures that hurt animals before slaughter (Adeyemo *et al.* 2009). Killing methods can also be very painful. In many cases, the animals are not stunned (Adeyemo *et al.* 2009; Ahsan *et al.* 2014), sometimes because of lack of equipment or because it is not the tradition and sometimes for religious reasons, as many Muslim groups believe that pre-slaughter stunning is not Halal (Khaneghahi Abyaneh *et al.* 2020). In other cases, the stunning technique may be performed incorrectly, failing to render the animal unconscious and involving several attempts to stun the animal before it is slaughtered (Miranda-de la Lama *et al.* 2012). If the procedure is performed on the farm or in the village and is performed by the farmer, this might mean that there is no stress arising from the transportation, but methods used when killing the animals might still cause unnecessary suffering and stress. It is vital to raise awareness of animal welfare and work with the people involved in cattle farming and raising. Reducing transportation, loading, unloading and handling times are necessary to improve cattle welfare in markets and slaughterhouses. Training and education of abattoir workers are also needed, so they understand how to correctly manage, stun and slaughter animals without causing them suffering. This could be driven by governments through the implementation of rules concerning slaughter and transportation. These are urgently needed to improve cattle welfare in the tropics (Petherick 2005; Njisane *et al.* 2020).

Heat stress

The hot and humid climate in tropical regions puts high pressure on animals. In these conditions, the inherent capability of cattle to cool down by sweating and panting is compromised, and heat stress easily occurs. In temperatures above 28°C, even without humid conditions, lactating cows show signs of emerging heat stress (West 2003; Avendaño-Reyes 2012). As pointed out by Silanikove (2000) in an interesting review about the effect of heat stress on animal welfare, despite ruminants having a well developed thermoregulation mechanism, they do not maintain strict homeothermy under heat stress. According to Silanikove (2000), there is unequivocal evidence that hyperthermia is deleterious to any form of productivity, regardless of breed

and adaptation stage to the environment. Heat stress is also regarded as a risk factor for increased susceptibility to disease due to the negative impact on the immune system (Bagath *et al.* 2019). How to grade the welfare of the animals affected by heat stress under the current welfare protocols remains an issue for discussion. Cows with elevated body temperature limit their dry-matter feed intake, and thus milk yield is reduced (West 2003). Heat stress is also reported to alter the affective state of cattle, inducing feelings of hunger and thirst that could be related to feelings of frustration, aggression and pain (Polsky and von Keyserlingk 2017). Heat stress also harms reproductive performance (Jordan 2003) and the immune system (Bagath *et al.* 2019). Under extreme heat stress, animals may even die, especially calves (Stull *et al.* 2008).

The main factor responsible for heat stress in cattle is direct solar radiation; so, the animals seek shade when in hot temperatures (Kamal *et al.* 2018). The degree to which cattle are vulnerable to heat stress depends on various factors. For example, European breeds are often more affected (Hansen 2004). Also, the higher the milk yield, the more heat is produced during the lactation period. Hence, a high-yielding dairy cow is more vulnerable to heat stress and, at the same time, also needs more water to produce a larger amount of milk (Avendaño-Reyes 2012). Providing shade during the hot season is, therefore, an important animal welfare measure. Natural shade from trees is considered highly effective and can provide a microclimate for cattle since the trees reduce temperature and protect from solar radiation (Broom *et al.* 2013; Améndola *et al.* 2016). Trees can confer protection from harsh drying winds. The use of native trees and shrubs in pastures is proposed as a key element in enhancing ecosystem services in tropical pastoral landscapes (Murgueitio *et al.* 2011). Other methods to help cattle dissipate heat can be provided, such creating water baths for their immersion or showers, which is sometimes preferred by some individuals and breeds (Geraldo *et al.* 2012).

Animals often spend the night in enclosures to be protected from predators and thieves. Depending on the distance, when animals arrive to the pasture the next morning, the temperature can be already very hot, making grazing uncomfortable for them. Moving the shelter temporally to the grazing area may improve both animal welfare and production (Ol Pejeta Conservancy 2021).

Nardone *et al.* (2010) discuss possible effects on cattle production raised under tropical settings by arguing that climate change, under more severe conditions, will exacerbate issues such as lack of water in countries with high ambient temperatures, affecting livestock performance. They concluded that there is a need for better information concerning biophysical and social vulnerability, and these matters must be integrated with agriculture and livestock components.

Tropical cattle breeds

For decades, the tendency has been to improve the performance of tropical cattle with European breeds. However, this policy has resulted in animals being more susceptible to the environment and diseases. Increased concerns over chemical residues in food for human consumption, drug resistance and animal welfare are encouraging a change in the methods used to raise animals (Shyma *et al.* 2015). Rearing hardy breeds, more adapted to the conditions of the tropics, can have several benefits, as animals would be less susceptible to heat, parasites and other infections. For example, there is a consensus that Zebu cattle have greater tick resistance than do European or African cattle (Madalena *et al.* 1990; Frisch and O'Neill 1998; Mwangi *et al.* 1998; da Silva *et al.* 2007); therefore, the use of Zebu breeds in areas where ticks are a problem could improve animal welfare and, additionally, reduce the use of chemicals. Nevertheless, Zebu cattle, as well as many of the breeds adapted to the conditions of the tropics, typically manifest a lower performance than do European cattle. Therefore, a controlled cross-breeding should not be completely discarded. A better understanding of the genetic resistance to environmental factors and diseases of tropical breeds could help create breeding strategies to reach a balance between productivity and resistance without jeopardising animal welfare and sustainability.

Conclusions

So as to meet the new challenges and goals of sustainability, there is a global need to improve cattle production within existing herds and pasture provision. Large proportions of consumers and animal production occur in tropical regions of the world, creating a need to address the special conditions in which farming occurs in this region. Improved animal welfare is an increasingly important societal and consumer concern and can also be a way to improve productivity. However, there are several challenges to overcome, including a lack of information about cattle's real welfare status in the tropics. Tropical farming is performed under different management systems, depending on the climate, availability of resources and topography. However, the dominant system in terms of land usage and employment is still subsistence farming, which is largely pasture-based. There is a need for standardised animal welfare assessment protocols for animals in subsistence pasture-based systems, considering the particular conditions of extensive farming.

Additionally, aspects such as animal nutrition, adequate infrastructure, animal health and farming-related education need special attention in the region. Grassland management could be an easy measure to implement, but pasture quality

and water availability vary depending on the geographical area. Access to water might not be an easy issue to solve, so further solutions are needed. The education of farmers on animal welfare could prioritise and improve infrastructure, disease prevention and animal management. Better animal welfare could improve production in terms of volume and guarantee consumer acceptance and future animal product consumption. This would help secure incomes and alleviate poverty and abandonment of primary production.

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