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Ministry of Environment Water & Agriculture

Characterization and assessment of small-scale livestock production, husbandry, health, and technology practices in the Kingdom of Saudi Arabia LIV/051/2021/1

Strengthening MoEWA's Capacity to implement its Sustainable Rural Agricultural Development Programme (2019-2025) (UTF/SAU/051/SAU)

Food and Agriculture Organization of the United Nations

Riyadh, Kingdom of Saudi Arabia

ABBREVIATIONS AND ACRONYMS

BCS	Body condition score
CO2-e	Carbon dioxide equivalent
CW	Carcass weight
GCC	Gulf Cooperation Council
GDP	Gross domestic product
GHG	Greenhouse gas
FAO	Food and Agriculture Organization of the United Nations
KSA	Kingdom of Saudi Arabia
LGA	Grassland-based arid/semi-arid tropics/sub-tropics production system
LLR	Landless ruminant production system
MoEWA	Ministry of Environment, Water and Agriculture
MI	Mixed irrigated agriculture production system
MR	Mixed rain-fed agriculture production system
NLIP	National Livestock Improvement Plan
NTP	National Transformation Programme
SDG	Sustainable Development Goal
SO	Strategic objective
SRAD	Sustainable Rural Agriculture Development Programme
SWOT	Strengths, weaknesses, opportunities, and threats
TMR	Total mixed ration
USD	United States dollar

EXECUTIVE SUMMARY

The aim of this report is to map, characterize, and assess small-scale livestock production, animal husbandry and management systems, technologies, and practices currently used in Jazan, Aseer, Makkah, Northern Borders and Eastern Region of the Kingdom of Saudi Arabia (KSA). Understanding current practices in the targeted regions is key to supporting Sustainable Rural Agriculture Development Programme (SRAD) project component 6 on "*Strengthening the capacity of small-scale livestock holders*".

In describing livestock productions systems in the targeted regions of KSA, the classification system of Seré and Steinfeld (FAO, 1996) is complemented with country-specific variables to achieve a livestock description system that is valuable to the objectives of the SRAD programme.

Targeted livestock farms develop their activities in an arid or semi-arid agro-climate context, with particular welfare problems linked to high temperatures and high prevalence of endemic animal diseases. Current livestock production systems are characterized by limited possibilities of access to pasture, high feed costs, limited technology use, traditional husbandry practices, very low productivity, high environmental impacts, and high meat prices linked to religious events.

To improve sector productivity there is a need to address three key challenges: 1) poor animal health; 2) unsustainable feeding practices and poor nutrition; and 3) traditional husbandry techniques. Improvements need to be made mainly through strengthening education and extension services, improving disease surveillance and introducing regulations targeting positive practices.

INTRODUCTION

In 2016, the Kingdom of Saudi Arabia (KSA) adopted Vision 2030, an ambitious plan to transform the KSA economy away from its dependence on oil. To help achieve the ambitious goals of Vision 2030, KSA has developed and launched several national programmes, including the National Transformation Programme (NTP).

Vision 2030 has five key strategic objectives in the areas of the environment, water, and agriculture (specifically the reduction of pollution in all its forms), protection of the environment from natural hazards, protection and rehabilitation of the natural environment, rural development, food security, and sustainable use of water resources. To operationalize these strategic objectives, the Ministry of Environment, Water and Agriculture (MoEWA) has formulated 73 initiatives under 18 strategic pillars.

Sustainable Rural Agricultural Development (SRAD) 2019-2025 is a programme, jointly formulated by FAO, and MoEWA within the context of Vision 2030, that aims to diversify agricultural production, improve income and living standards for small-scale holdings, create job opportunities, strengthen food security and social stability, and preserve the environment and natural resources. In this context, FAO works to enhance the contribution of livestock to Sustainable Development Goals (SDGs) by supporting the transformation of animal production systems – small and large – in ways that are economically, socially, and environmentally sustainable.

A well-managed livestock sector offers substantial opportunities for agricultural development, livelihood improvement, food security, and improved human nutrition. The sector can also empower rural women and youth, reduce large-scale migration to urban centres, improve natural resource-use efficiency, and increase household resilience.

Of the nine components in the SRAD project, component 6 refers to 'strengthening the capacity of small-scale livestock holders'. This component has high complexity in terms of real possibilities of change, as the targeted geography and groups cover a vast area, a large number of animals, a large number of producers and stakeholders, cultural diversity, a large market, and a myriad of variables affecting husbandry, management, and production systems. The fact that poorly managed livestock systems constitute a threat for animal and human health may also have a crucial negative impact on climate change and desertification.

Overall, this makes the mapping, characterization, and assessment of small-scale livestock systems as much a challenge as an urgent need for the KSA.

OBJECTIVES

The aim of this report is to map, characterize, and assess small-scale small ruminant production, husbandry and management systems, technologies, and practices currently used in Jazan, Aseer, Makkah, Northern Borders and Eastern Region of the KSA. Understanding current practices in the targeted regions is key to support SRAD project component 6, which is on strengthening the capacity of small-scale livestock holders.

This report covers a key aspect of SRAD component 6, namely, livestock production and trade. The objective is to develop the sector, as a whole, by improving production and processing technologies, developing better farmer access to resources, improving research and extension services, developing the value chain, markets, contract farming, and rural agro-enterprises, delivering large-scale need-based capacity building, and improving the use of information and knowledge.

This report directly supports outcome 1 of SRAD component 6, namely, ‘technologies and innovative practices identified and adopted to sustainably increase rural agriculture productivity’. It also indirectly supports other outcomes of SRAD crosscutting component 6. These include: innovative practices and technologies pilot-tested and adopted to restore and conserve natural vegetation cover and sustainably manage vital natural resources (outcome 2); capacity of the MoEWA and rural agriculture institutions and small producers enhanced for better access to resources, services, and markets (outcome 3); capacity of public and private sector actors strengthened to develop rural agro-enterprises and create productive and decent rural employment, particularly among youth and women (outcome 5); and information and knowledge products developed and disseminated for evidence-based sustainable rural agriculture development (outcome 6).

This report relates mainly to deliverables under project Activity 1.2.1 (Component 6 reference LIV 1.3), namely, ‘Identify and assess current animal husbandry systems and practices adopted by smallholders in the target regions’, which lays the basis for the other SRAD component 6 deliverables. Finally, the report objective also considers how the FAO project links to MoEWA’s National Livestock Sector Improvement Plan (NLIP) and the corresponding initiatives.

This document is a work tool aimed at improving the situation analysis of livestock in KSA targeted regions in order to identify areas for improvement.

METHODS

Site and participant selection

Information obtained from the MoEWA and from FAO Saudi Arabia (FAOSA) experts was used to decide which areas and municipalities would be visited in the targeted regions of Jazan, Aseer, Makkah, Northern Borders and Eastern Region. Sixteen farmers and some 30 MoEWA staff were interviewed. The farmer interviewees were selected, as far as possible, to ensure a representative sample, considering number of animals, location, technologies used, access to resources, age, education status, and gender. Criteria considered for selection were preferences of MoEWA (purposive sampling) based on accessibility, personal relationship, and proactivity with farmers.

Information collection

Information in MoEWA and FAO reports on health, husbandry, and nutrition was used to inform this document. Additionally, MoEWA and FAOSA key staff information and knowledge retrieved by direct meetings was paramount to finding out as much as possible on the peculiarities of the livestock sector in KSA.

In field missions, data was collected using a specially designed guide-questionnaire adapted to the different stakeholders, mainly MoEWA experts, farmers, and the staff of cooperatives. The questionnaire focused on training needs and stakeholder perceptions of the livestock situation in the targeted regions, description of livestock production systems, feed resource availability, production and reproduction systems, health analysis, and available technologies. Semi-structured interviews focused on the global situation regarding small ruminant production threats and possibilities. Questionnaires and semi-structured interviews were complemented by observation of practices, animals, technologies, feed and feeding, labour, and facilities in visits to farms. Post-visit discussions were held with FAOSA experts and MoEWA staff.

Retrieved information was compared to international standards and best practices and to current research in the specified areas.

OVERVIEW OF LIVESTOCK PRODUCTION SYSTEMS

Describing livestock productions systems is a complex matter. The Seré and Steinfeld (FAO, 1996) system classifies livestock systems into four main types: (1) landless systems (LL, monogastric or ruminant); (2) grassland-based systems (LG, where crop-based agriculture is minimal); (3) mixed rain-fed systems (MR, mostly rain-fed cropping combined with livestock); and (4) mixed irrigated systems (MI, consisting of a significant proportion of irrigated cropping interspersed with livestock).

The classification system of Seré and Steinfeld includes 11 system subtypes: livestock only; LG sub-classified as arid/semi-arid (LGA), humid/sub-humid (LGH), or tropical highland/temperate (LGT); LL monogastric-based (LLM) and LL ruminant-based (LLR) systems; and MR and MI systems for three distinct agro-ecological zones. Only ruminant and arid/semi-arid systems are relevant for this analysis.

Following FAO recommendations (FAO, 2011) it could be argued that an ideal practical livestock production system classification scheme should be as follows:

- *Flexible*. The scheme should not predefine sets of production systems; rather it should set up a framework for users to define the systems they are interested in, in a coherent and comparable manner.
- *Consistent*. The criteria for defining the systems should be quantitative and measurable, and therefore, objective.
- *Mappable*. In order for the classification system to be effective, it should be possible to demarcate the defined production systems spatially.
- *Hierarchical*. Systems would ideally be hierarchical, to enable different levels of detail to be captured while maintaining consistency.

If we consider the FAO stepwise methodology for classifying and mapping livestock production systems, this classification should:

- Be dynamic in order to allow investigation of likely future developments of farming systems and of how they might evolve in response to global drivers such as population pressures, changes in demand for livestock and crop products, and climate change.
- Account adequately for livestock systems and deal with issues of convergence versus independence of livestock-cropping systems – in other words, support situations where a particular cropping system may be associated with a number of livestock systems, or a particular livestock system may be associated with a number of different cropping systems.
- Be poor-centred in terms of being able to identify relatively small populations of poor agriculturalists, but also ultimately have global coverage, enabling an understanding of the dynamics among developed and developing regions of the world, and analysis of the evolution of production systems.

Furthermore, the use of mapping and characterization approaches to livestock systems is a key consideration. Some of the main uses of livestock mapping and characterization are as follows: (1) livestock production evolution over time; (2) livestock's impact on the environment; (3) determination of animal health and the economics of disease interventions; and (4) livestock and livelihoods.

Livestock systems mapping and characterization in this report aims to address practices and technology use in specifically targeted areas so that improvement proposals can be developed. A description and assessment of KSA small ruminant livestock production/husbandry and management systems responds to the need to introduce pragmatic changes that can sustainably improve productivity and livelihoods. This requires a methodology that builds on specific variables so that the characterization and mapping of the KSA livestock becomes a useful decision-making tool to aid the best possible development of the sector.

PRODUCTION SYSTEM VARIABLES

A number of variables that directly influence and contextualize production systems are used to characterize and assess animal husbandry, management, and handling systems. Studied parameters linked to productions systems include: agro-climate, welfare, nutrition, health, technologies, housing, reproduction, handling, intensification, environmental impacts, holding size, market, and government and social aspects.

General description of the small ruminant production systems

KSA context

In the oil-based KSA economy, where the petroleum sector accounts for about 42% of gross domestic product (GDP), the share of the agriculture sector (agriculture, forestry, animal, and fishery sub-sectors) is a mere 4.2% of overall non-oil GDP. The livestock sector represents 52% of the total value of agricultural output, and plays an important social and cultural role in contributing towards economic diversification and in social and regional development. Developing the livestock sector promotes food security (currently the KSA only produces 30% of its food needs), which currently supports the livelihoods of several hundred thousand rural households and provides direct employment to 250,000 people (MoEWA 2021). Furthermore, the sector supports balanced rural and regional development, as livestock production is widely practised and distributed. For example, 76% of livestock holdings are small-to-medium in size and owned by farmers living in rural areas. In addition, the sector contributes to preserving sociocultural heritage. For example, Saudis prefer indigenous sheep and goat meat, and every year many animals are slaughtered for religious purposes.

In this socioeconomic context, the small ruminant sector in the KSA subsists mainly in a very traditional way in unfavourable agro-climate conditions. The climate of the KSA is semi-arid in the highlands and coastal areas while arid in inland parts of the country. Most of the KSA is covered with sparse vegetation and receives little annual rainfall. Therefore, water scarcity is an important constraint for agricultural activities. Agro-climate features and the corresponding constraints thus characterize livestock production systems in the targeted KSA regions.

Geographical distribution of small-scale livestock holders

Small ruminants account for over 90% of the KSA total livestock population. Estimates are approximately 17.5 million sheep and 6.1 million goats (MoEWA 2021), although only 10 million sheep and 3 million goats were reported in a 2015 statistical census of the General Authority for Statistics. The spatial distribution of livestock in the KSA (including camels and cows) is shown in Figure 1.

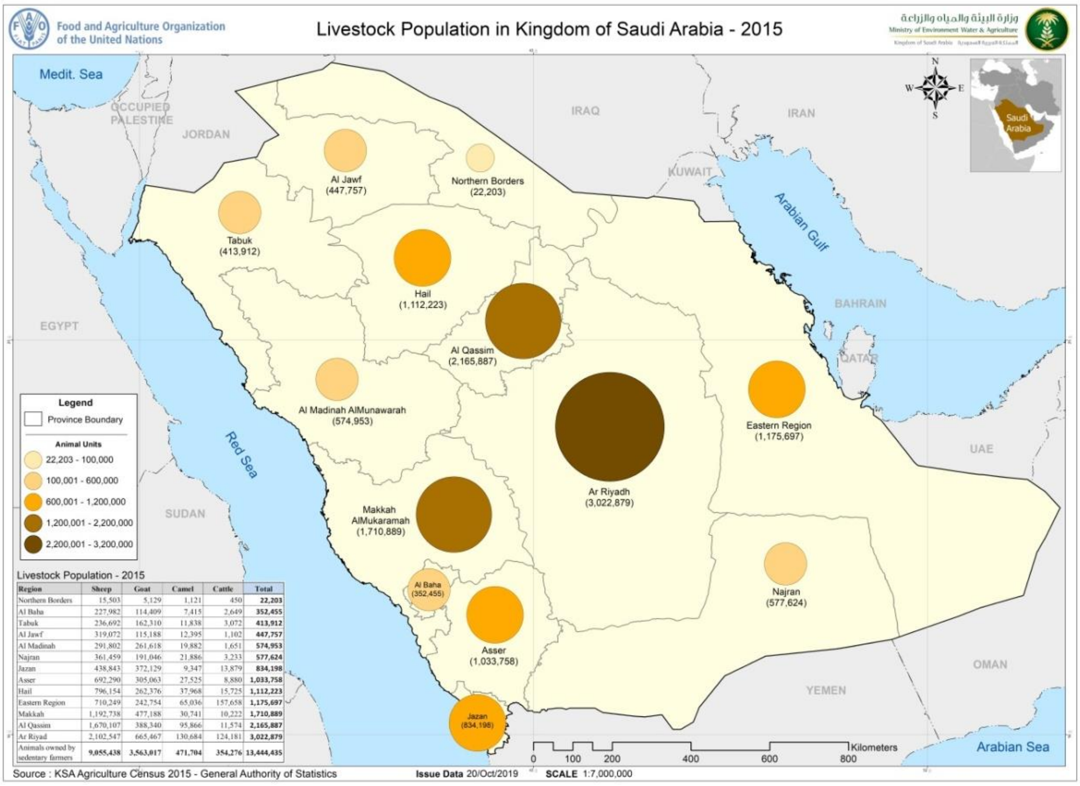


Figure 1. Geographical distribution of livestock in the KSA. Source: FAOSA

Small ruminants are distributed all over the KSA regions (Table 1). However, densities vary between and within regions and are greater near towns/villages, near feed/water resources, and in climate-favourable areas.

Region	Sheep	Goats
Ar Riyad	2,102,547	665,467
Makkah	1,192,738	477,188
Al Madinah	291,802	261,618
Al Qassim	1,670,107	388,340
Eastern Region	710,249	242,754
Asser	692,290	305,063
Tabuk	236,692	162,310
Hail	796,154	262,376
Northern Borders	15,503	5,129
Jazan	438,843	372,129
Najran	361,459	191,046
Al Baha	227,982	114,409
Al Jawf	319,072	115,188
Ownership by management system		
• Animals owned by sedentary farmers	9,055,438	3,563,017
• Animals owned by nomadic and semi-nomadic keepers	8,500,000	2,600,000
Total	17,555,438	6,163,017

Table 1. Distribution of small ruminant populations in the KSA.
Source: MoEWA 2021.

Yearly livestock data trends show a sudden increase in the number of small ruminants in 2014 (Figure 2) for unknown reasons and may be related to administrative factors rather than to any sudden increase in real numbers. The accurate number of small ruminants in KSA is unknown as there is no animal identification system in place to identify sheep and goats.

Figure 2. Yearly evolution of livestock numbers in the KSA.
Source: MOEWA.

Size and ownership of livestock holdings

The average size of small ruminant holdings in the KSA is 299 animals, with 72% of holdings having fewer that that figure, account for around 30-40% of the small ruminant population (Figure 3). Smallholdings are also predominant in other livestock sectors (cows and camels). Private citizens own 99% of livestock holdings; the remaining 1% are institutional holdings (corporations, companies, and government).

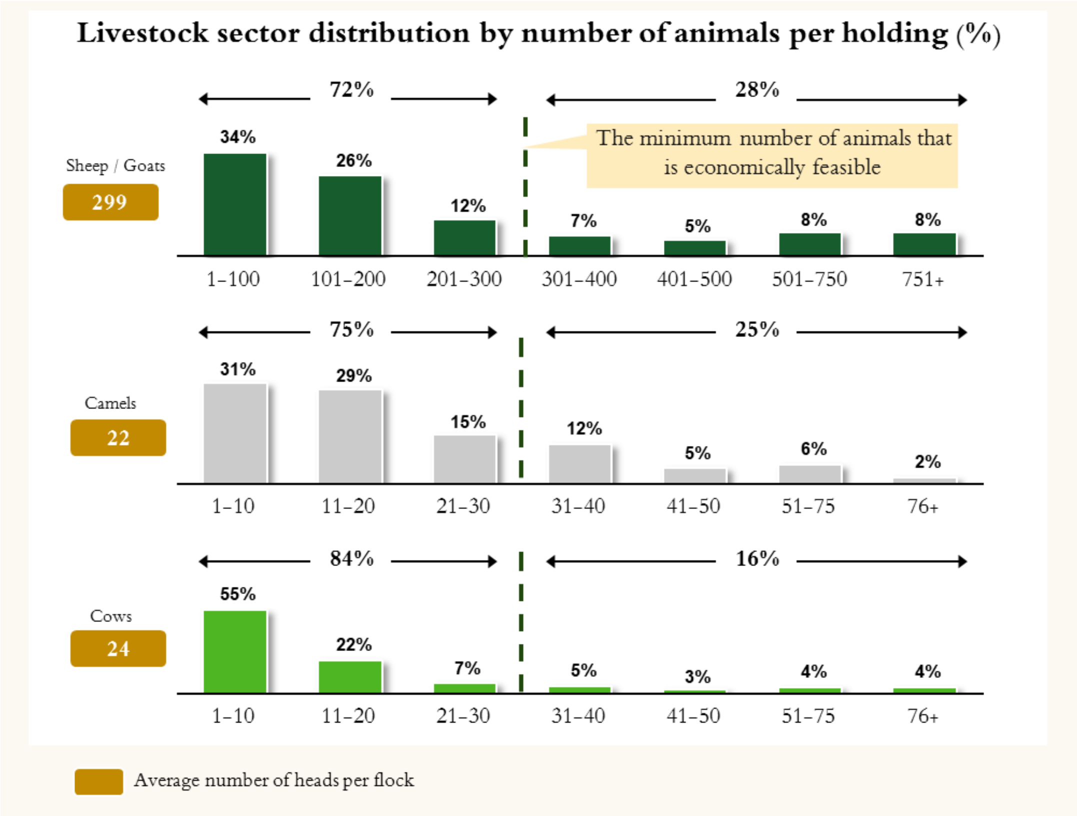


Figure 3. Distribution of livestock holdings by size in the KSA.
Source: MOEWA

Livestock numbers and land ownership

The entire livestock sector consists of about 155,318 holdings accounting for 38% of all agricultural holdings in KSA (General Authority for Statistics, 2015) (Table 2). Some are mixed holdings (more than a single species), and the largest proportion can be considered small-to-medium size holdings (fewer than 299 small ruminants per holding).

Size of holding	Number of holdings by livestock species			
	Cattle	Camels	Goats	Sheep
1-3	1,076	905	195	344
3-4	1,495	1,202	401	519
5-9	2,346	2,487	1,504	1,589
10-19	1,501	3,317	4,491	4,394
20-49	669	3,495	17,532	17,005
50-99	149	1,573	15,422	18,298
100-199	40	599	7,028	12,303
200-499	22	147	2,042	7,259
500 and over	40	35	266	2,685
Total	7,338	13,760	48,881	64,396

Table 2. Livestock holding size distribution in the KSA.
Source: MoEWA 2020.

Most livestock holders do not own land (69%). No data is available that links livestock holding size and land ownership. However, it seems likely that smaller holdings tend less to own land than larger holdings. Since the data available regarding land ownership is partial, it does not include 153,000 livestock holdings (Figure 4).

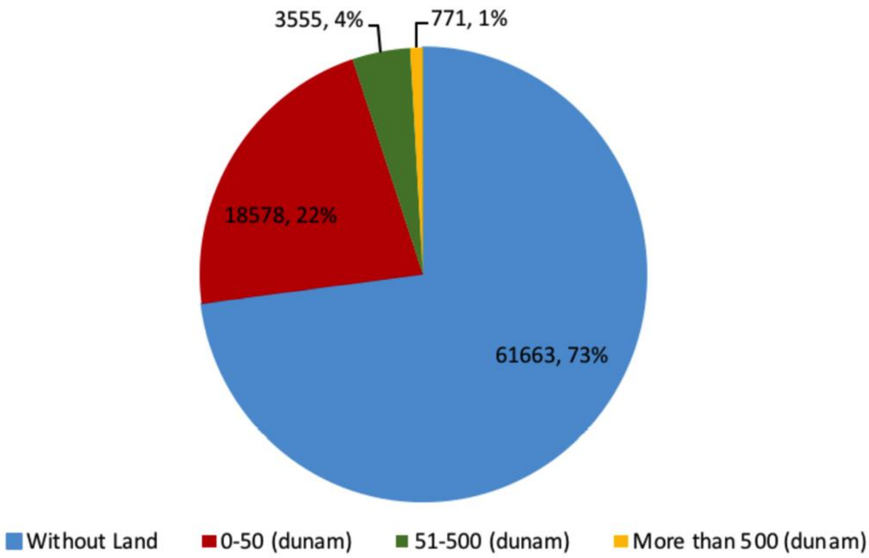


Figure 4. Livestock holding groups according to land ownership in the KSA.
Source: MOEWA

Agro-climatic zone

The KSA has average rainfall of less than 100 mm/year and high temperatures that can reach 50°C in summer. The KSA climate is classified as semi-arid in the highlands and coastal areas and arid in the inland parts of the country, which is mostly covered with sparse vegetation and receives little rain in winter and spring. Water scarcity is the most important constraint to agricultural activities in the KSA. Despite the overall weather conditions, however, approximately 10% of the small ruminant livestock corresponds to microclimates and vegetation cover favoured by a moderate climate. Figure 5 depicts an example of land cover for one of the targeted SRAD project regions. Land cover is directly linked to grazing possibilities, a key factor in determining production systems.

Figure 5. Land cover for the southwest regions of the KSA.
Source: FAOSA

Small ruminants imports

The KSA is the largest importer of small ruminants in the world, due to requirements for live animals in observance of religious rituals. The KSA also imports large quantities of carcasses, mainly from Australia and New Zealand. In 2021, Australia restarted live sheep exports to the KSA, following a decade-long hiatus. The KSA imports around 8 million live sheep and goats (Table 3), a figure expected to increase to 10-15 million by 2030. KSA total annual imports of live sheep and goats destined for slaughter represent about 80% of the 10 million country-produced lambs, according to fecundity data (MoEWA, 2020). However, imports could double locally produced lamb meat, estimated at 75,000 tonnes according to MoEWA data. The main sources of imports for live animals are Sudan, Djibouti, Somalia, Jordan, and the United Arab Emirates. Imported live animals are 2 to 6 times cheaper than local animals, depending on the animal and the time of the year.

Animal imports	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Goats	1375,8	1929,7	2036,5	1670,1	1740,2	2252,4	1781,3	1362,2	1086,9
Sheep	3780,6	4715,0	5874,4	5977,2	6309,7	7761,6	6326,4	5788,7	5625,0

Table 3. Number of imported live animals (in thousands) per year.
Source: MOEWA

Livestock welfare

Introduction

Welfare and productivity are closely linked. Welfare problems leading to severe stress have important effects on reproduction (Ehnert & Moberg, 1991), growth rate (Elsasser et al., 2000), meat quality (Apple et al., 1995; Ruiz-de-la-Torre et al., 2001), milk production, resistance to parasites (MacKay 1974), and resistance to disease (review by Blecha, 2000). Animal welfare is also an ethical issue of public interest and considered an important value to be preserved (Lagerkvist, 2011).

Many different definitions and approaches have been taken regarding animal welfare. Some broadly accepted general concepts on animal welfare are as follows: (a) animal welfare is a property of the animal (rather than of the environment, or something given to the animal); (b) animal welfare concerns are quality-of-life concerns; and (c) welfare exists on a continuum from very poor to very good.

From the many definitions and methods used to determine animal welfare, this report uses the classical 5-freedoms definition (FAWC, 1965) that splits welfare into different areas that can be compared and linked to specific problems:

- Freedom from thirst, hunger, and malnutrition: ready access to fresh water and a diet that maintains full health and vigour.
- Freedom from thermal or physical distress: an appropriate environment including shelter and a comfortable resting area.
- Freedom from pain, injury, and disease: prevention or rapid diagnosis and treatment.
- Freedom to display normal patterns of behaviour: sufficient space, proper facilities, and company of the animals' own kind.
- Freedom from fear and distress: conditions and treatment that avoid mental suffering.

Extensive systems in the KSA may imply high physical distress mainly due to climate, and there may also be welfare problems linked to nutrition, water, and medical attention (Silanikove, 1998). Although local breeds in the KSA are highly adapted to the local climate, unsuitable temperature, scarce water, or feed can rapidly decrease productivity.

Adopting enclosure production systems (that may not be intensive) can especially jeopardize behavioural needs related to foraging, engagement in social behaviour, etc. (Fraser, 1983). Small ruminants living in extreme high-density or competition situations can develop stereotypical behaviours such as pulling at their skin, repetitive movement, etc.

Despite each system featured by specific welfare problems, often we find similar welfare issues in extensive and intensive systems, related to the five freedoms.

Welfare in hot weather

Sheep have rectal temperatures of 38.3-39.9 ℃ (average 39.1 ℃). A rise in ambient temperature increases heart rate and respiratory rate, panting to increase evaporation from the respiratory tract (Silanikove, 2000), and sweating, and leads to reduced feed intake and greater water loss in faeces and urine.

Plasma cortisol increases following acute heat exposure, while thyroid hormone activity decreases with chronic exposure to high temperatures, resulting in a decreased metabolic rate. Provision of shelter and shade are crucial for protection from solar radiation: with shade, sheep are able to maintain their body temperature in ambient temperatures of up to 50 ℃ (Johnson, 1987). Exposure to high temperatures reduces ram mating activity in breeds adapted to cold climates, while in most breeds sperm production is affected (Lindsay, 1969).

Welfare and social/spacing conditions

Any changes potentially lead to stress and to reduced feed intake. The importance of familiarity with the physical environment and with the social group suggests that changes in either will have at least a short-term negative impact on animal welfare.

To avoid competition, stress, and undernourishment in livestock under intensive management, for sheep, a maximum of three adult ewes per feeding-trough metre is usually recommended to ensure equal access to feed. Space allowance recommendations, depending on size and physiological status, are 1-1.4 m^2 per head for ewes, 0.25-0.90 m^2 for lambs, and 0.5-2 m^2 for rams. Note that ideal spacing between individuals varies considerably across breeds. Mountain breeds usually require greater spacing than lowland breeds: a distance between nearest neighbours of 6.9 m has been observed for Welsh Mountain and 7.5 m for Blackface sheep, compared to 3.4 m for Suffolk and usually less than 1.5 m for Merino sheep (Lynch et al., 1992).

The comfort and tolerated distances for KSA local breeds of sheep and goats are unknown. Observations in the targeted regions indicate that pen space availability is normally high, although in some farms, feeding and drinking space is reduced, with some animals displaying competition behaviour, and some waiting their turn to drink and feed. Shaded areas are also an issue, as shade is not always provided or is insufficient for all small ruminants in the holding. Seasonal wool shearing of sheep is greatly underused, leaving problems to dissipate heat in summer and increasing heat stress.

Main welfare issues

The main issues affecting small ruminant productivity in the KSA are high disease prevalence, seasonal heat stress, and feed management issues. According to the welfare freedoms:

- Freedom from pain, injury, and disease: In extensive (enclosure) and intensive systems, this issue seriously affects welfare and productivity. Lack of biosecurity measures and inadequate vaccination plans are mainly to blame.
- Freedom from thermal or physical distress: In either intensive or extensive systems, and especially in high temperatures areas, shaded facilities are inadequate. The fact that sheep are often not sheared annually is a main cause of overheating.
- Freedom to display normal patterns of behaviour: This is occasionally seen mainly in intensive and in some backyard systems, where sheep and goats are not allowed to graze. Eating and drinking space is also a concern in some cases.
- Freedom from thirst, hunger, and malnutrition: Extensive systems relying more on grazing have periods of low pasture availability/quality, so pasture must always be supplemented with external provision of feed. Pasture availability is dependent on altitude, the season, rainfall, and animal density. Diets in both extensive and enclosure systems are often not well balanced according to sheep needs. In some cases, eating space is limited leading to feeding competition and waiting times.

Small ruminant husbandry and handling practices

Ewe management

Ensuring that the physiological condition of ewes is on target for the specific production system leads to improved fertility, lambing performance, and reduced metabolic disease. The target body condition varies depending on the farm type, breed, time of year, and ewe prolificacy. Flock productivity can be increased by regular body condition scoring (BCS) of ewes and acting on the results. The scoring scale is 1 (thin) to 5 (very fat), and half or quarter scores can be used (e.g., 2.25, 3.5). Figure 6 depicts the BCS evaluation method.

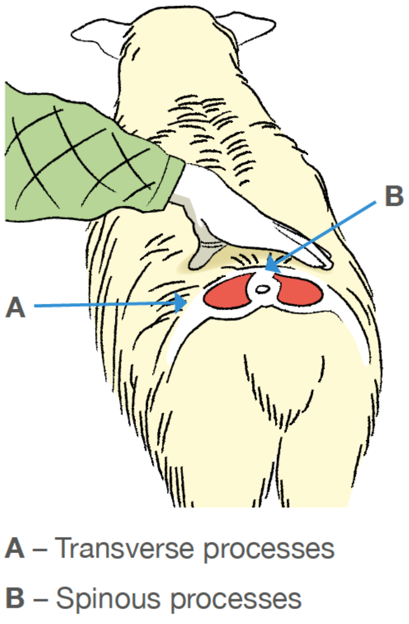


Figure 6. BCS evaluation method
Source: Tisserand 1989

Mating and flushing

Flushing is the provision of a diet high in protein and energy 2-3 weeks before mating (tupping). While research suggests that flushed ewes will achieve higher pregnancy rates, flushing ewes above BCS 4 or below BCS 2 does not improve conception rates or fertility. In other words, flushing has the biggest impact on ewes in reasonably good condition, i.e., between BCS 2 and BCS 4. At least 90% of a sheep flock should be at target BCS for tupping to optimize productivity. Embryos are particularly vulnerable to stress in early pregnancy (i.e., until the embryo is attached to the uterine wall around 3 weeks after mating), so it is vital to avoid any stress (vaccination, movement, regrouping, etc.) and abrupt changes in animal diet (body condition) in this period, to reduce the risk of embryo loss.

In the KSA, it is observed that flushing is not practised in the targeted holdings, mainly because farmers are unaware of the technique.

Pregnancy scanning

Scanning using ultrasound is a way to determine the lambing season and efficiently manage holdings. There is a positive relationship between ewe BCS at lambing and lamb weaning weights, so managing and maintaining ewe BCS through appropriate feeding practices in the last 6 weeks of pregnancy is critical. Each additional ewe BCS unit at lambing is associated with a 5.4 kg increase in lamb weaning weight. Scanning could allow matching feed with litter size (number of embryos) by arranging different feeding lots through preferential feeding of leaner ewes. Therefore, ewes should be monitored regularly for body condition to adjust feeding levels.

In the KSA, pregnancy scanning is not practised in the targeted regions.

Primiparous animals

Primiparous small ruminants should not be mated before reaching two thirds of the adult live weight. The goal should be to mate them at 7-8 months if they have been correctly fed. Females should be fully vaccinated before mating for first time.

Lambing

Vigilance and assistance should be available in the hours around lambing. Births should be in a place not previously used or fully disinfected. Sheep should give birth alone in boxes of at least 1 x 2 m but not visually isolated from the flock or other ewes. Ideally, if lambing cradles can be moved, lambing should take place where no previous birth occurred. If cradles cannot be moved, they should be fully disinfected with dry disinfectant or quick lime before re-bedding between ewes.

Characteristics of the birth site per se appear to be less important than the ewe remaining undisturbed with her lambs for at least 6 hours after giving birth. Therefore, even without knowing KSA sheep breeding behaviours, we should expect that ensuring this undisturbed time will increase lamb survival. Postnatal mortality can be as high as 15-25%, with most lamb deaths attributed to the starvation-mismothering-exposure complex, often linked to infectious diarrhoeas. Note that stressed and undernourished ewes take longer to interact with their lambs and are more likely to abandon or reject them.

In the KSA targeted regions, holdings do not apply the BCS system. While farmers are generally aware whether an animal is fat or thin, they do not respond according to the needs of each animal and its reproductive status.

According to the MoEWA (2020), the KSA annual lambs weaned per ewe is as low as 0.52. Low weaned lamb numbers can be attributed to low fertility and low fecundity (high abortion rate), but also to a high rate of pre-weaned lamb mortality.

A minimum equipment list for lambing season is as follows:

- Suitable antiseptic solution
- Obstetric lubricant
- Arm-length disposable gloves
- Lambing ropes, snares or other aids
- Clean needles and syringes
- Antibiotics for treatment of mastitis or metritis
- Injectable anti-inflammatory drugs
- Plastic retainers or harnesses, local anaesthetic, clean obstetric tape and needles for the management of vaginal prolapse
- Calcium borogluconate injection for the treatment of hypocalcaemia
- Propylene glycol or other concentrated energy supplements for the treatment of pregnancy toxaemia
- Strong iodine tincture for navels and a dip cup or spray to apply
- Stomach tubes, colostrum, a warming box, glucose injection, syringes and needles for the treatment of starvation and hypothermia
- Rehydration drench or formula for lambs
- Elastrator rubber rings for lambs if needed
- Marker paint
- Spare hurdles for making addition to pens
- Disinfectant for pens and floors
- Sufficient clean buckets for feed and water
- Artificial colostrum and milk replacers (or be ready to milk another ewe)
- Standard animal ID ear tags with ID applicators

Rotate ewes in groups of up to 10-15 ewes with their lambs after separating them from the rest of the flock.

In the KSA targeted regions, there appears to be a great deal of improvisation if any problem arises during lambing. Individual boxes are rarely used and cleaned or disinfected. Farmers quite often separate lambing sheep from the flock, allocating them to lambing groups, but only for the first four or so days. Some farmers thereafter create lots according to lamb age, but ewes and lambs are more frequently turned out with the main flock.

Lamb care

Newborn lambs should receive 50 mL/kg of ewe colostrum or a colostrum substitute within the first 4 hours of life and the equivalent of 10-20% of their body weight in colostrum within 24 hours. Colostrum has three vital functions: (a) it supplies concentrated energy and other nutrients, such as vitamin E, in the first vital hours, (b) it acts as a laxative and helps the digestive system get started, and (c) it transfers passive immunity and protects the lamb against disease. Hygiene standards should be high: navels should be treated, gloves used, hands washed, lambs with diarrhoea should be isolated, and biosecurity measures implemented, etc.

In the KSA targeted regions, many or all hygiene and biosecurity measures regarding lamb care are lacking.

Restocking

While selection for production traits is possible, it only improves economic productivity when the animals' environment and management are appropriate. Good record-keeping is important to identify animals with desirable traits and the performance of relatives. Desirable traits include good motherly aptitudes, twins, weight at slaughter, conformation, etc. Selecting for several traits at once results in slower progress than selecting for a single trait. In contrast, the more heavily a trait is selected, the more quickly a population shift is observed. In efficiently managed holdings, annual culling is approximately 25%, so 40-50% of females (1-1.2 fecundity rate) should be kept for restocking; thus, slaughtered lambs are typically 65% male and 35% female.

In the KSA targeted regions, high abortion and mortality rates makes selection for restocking very difficult, as most females stay in the flock. Until 2 years ago, the KSA forbade the killing of females to guarantee future productivity. However, direct observation in regional slaughterhouses indicates that males account for 95-99% of slaughtered animals. This is compatible with very low lamb production, requiring all females produced to be used for restocking.

Effective restocking management of females is inexistent, as they are included in the main flock and mate without any supervision of weight or age.

Males

Rams and bucks should be checked at least 4-8 weeks before the mating season. If issues are found, this allows enough time for treatments or replacement animals to be sourced and quarantined. Males may benefit from high-quality protein and high-energy rations 6-8 weeks pre-tupping to help improve fertility and strength. BCS and testicle tone should be monitored. Mature rams and ram lambs should have a scrotal circumference of at least 36 cm and 34 cm, respectively.

To achieve a compact lambing period, males should be removed after 2 cycles (34 days for rams, 42 days for bucks). It is important to prevent inbreeding by using males from outside the holding, with special attention to quarantine and biosecurity measures. Home-bred rams and bucks should be selected, based on recorded data, for vigour as newborns, growth rates, health, and dam and relative prolificacy and performance. Where the dam's breeding history is known, rams whose mothers have good traits (e.g., good mothering ability) should be preferentially selected. Holdings using continuous mating strategies should have approximately 3% of males; this figure rises to 6% or more when programmed reproduction strategies are used.

In the KSA targeted regions, there is little or no male management. Males are continuously mixed with females, normally at a higher proportion than necessary (average 12%). Males are often from the same farm, so inbreeding problems are likely. When they are obtained from elsewhere, they rarely undergo any health check, and no biosecurity measures or quarantine is adopted. Reproduction lots, either natural or artificial using hormones, are largely unused, and likewise for advanced reproduction techniques, such embryo transfer and artificial insemination.

Mating strategies

Current practice is to run a teaser (vasectomized) ram at a ratio of 1:100 animals, 17 days before the tupping date to synchronize ewes and make the lambing period more compact. Note that that a minimum of 8-10 weeks must have elapsed since the vasectomy of a teaser. After 15-16 days, teasers are removed and replaced with breeding rams. An alternative is to place ewes, olfactorily and visually separated for at least the previous 2 months, close to rams so that the pheromones stimulate the ewes to cycle early. Housing or grazing of ewes near to rams, separated by very secure fences will ensure a success in this ram effect. More rams may be needed to serve all the ewes if lots are ovulating at the same time.

In the KSA targeted regions, no controlled mating strategies are used. However, some non-targeted holdings visited do implement controlled mating strategies and use other advanced breeding systems.

Culling

Farmers should replace 20-25% of ewes on average every year, depending on the culling policy and ewe mortality. Ewe mortality should ideally be below 5% annually.

The main reasons for culling ewes are severe chronic lameness, reproductive failure, severe mastitis, and other debilitating diseases. Strict culling of poorer and older ewes before tupping will improve flock performance and reduce replacement costs. General principles of culling rely on: (a) removing unhealthy animals that are not productive, (b) removing animals with defects or poor production traits that may be passed on to their lambs, and (c) removing animals whose management necessitates inputs that are out of proportion to their contribution to production. Strict culling before tupping will improve flock performance and reduce replacement costs.

Accurate records and animal identification are the key to successful culling. Ewes and lambs should be permanently marked or tagged, or identified as such via electronic identification (EID) tags. Ear tags colour-coded by year are useful for culling efficiently by age. Pregnancy scanning and weaning periods are opportunities to examine animals and select them for culling.

In the KSA targeted regions, voluntary restocking rates are very low, while many animals die of disease instead of being culled. Holdings could profit from voluntary culling, as prices for non-fertile culled sheep are around 200-400 riyals.

Dead animal disposal

Dead animals are a source of contamination. Governments typically legislate dead animal disposal methods and many countries have systems in place to remove dead animals from collection points.

A major risk factor is dogs, including stray and guard dogs as they feed on uncooked offal. Stray dogs are common in peri-urban areas and spread diseases to other animals and to humans. SEPCO is a Saudi biohazardous waste-management corporation that works with human hospitals and research and veterinary facilities, collecting contaminated material and carcasses; however, it does not collect dead animals.

In the KSA targeted regions, dead animals are typically abandoned in remote areas or by the roadside, and so become a source of contamination. Prevalence of Echinococcus cysts in Nadji sheep in the Riyadh area has been reported to be as high as 6.5% in winter and 1.4% in summer, with ewes having the highest prevalence (Abdel-Baki, Almalki et al., 2018), placing humans at high risk (data contrasted with observations in various visits to regional slaughterhouses).

Farm data retrieval

Collecting, examining, and acting on animal performance records can help improve output by highlighting strengths and weaknesses of a holding. As a recommendation, specific areas of concern should be recorded first and the focus should continue on collecting other useful data. An example of standard data to be collected (Table 4) and standard data to be analysed (Table 5) are given.

Period	Data recorded
Mating	Number of ewes
	Number of rams
	Average weight/average body condition
Scanning	Number of singles
	Number of doubles and triplets
	Number of barren ewes
	Total number of lambs
	Number of ewes culled
Pregnancy	Number of abortions
Lambing	Number of lambs born
	Number of lamb deaths at 2 days
	Number of lamb deaths at 30 days
	Number of ewe deaths
Weaning	Average age (days) when sold
	Number of lambs sold
	Number of ewes culled

Table 4. Example standard data to collect

Calculated ratio	Target
Ewe to ram ratio	1-5% (depending on mating system)
Fertility % f = no. ♀ pregnant / no. ♀ at reproductive age	More than 95% (ideally more than 98%)
Prolificacy % p = no. born or aborted / ♀ aborted or giving birth	Depends on breed and environment (1 to 2)
Fecundity at lambing % F = no. animals born/ no. ♀ at reproductive age	Depends on abortion rates More than 95% (ideally more than 98%)
Abortion %	Difference between prolificacy and fecundity. Less than 5%
Lamb mortality at day 2	Less than 5% (10-15% is acceptable)
Lamb mortality at day 30	Less than 5%
Total lamb mortality	Less than 15%
Total lamb production Lambs finalized / no. ♀ at reproductive age	Above 1 (above it depends on breed potential)
Ewe mortality %	Less than 5%
Culling ewe restocking %	20-25%
Lamb daily growth rate until sold	Depends on breed and age of lamb

Table 5. Standard data analyses

Reproduction systems

Productive groups

Irrespective of how intensive a system is, there should be at least three groups of animals, with different requirements and therefore requiring different handling:

- Animals mounted by males, pregnant females, and males. This group includes animals from weaning until few weeks before giving birth (including those that have reached puberty). Genetics and reproduction techniques are important for this group.
- Females 6 weeks before giving birth and lactating females. This group has high energy and protein needs and special care needs.
- Animals for fattening (up to desired weight for sale) and for replacement (until puberty).

Successful introduction of reproductive systems (see below) requires:

- Good organization of human labour
- Suitable facilities

- Quality tailored nutrition
- Long-term reproductive planning
- Excellent handling
- BCS or weighing system
- Good animal health care system.

5-births-in-3-years system

The 5-births-in-3-years system (also known as the STAR system) assumes a reproductive rhythm for each ewe of 5 births in 3 years (1.67 births a year). An example will explain this reproduction model. The interval between deliveries is (3 x 365) days / 5 births = 219 days (7.2 months). Given that gestation lasts 146 days, the interval between birth and the next fertile cover is 219 - 146 = 73 days (slightly more than 2 months). The STAR system enables good productivity of around 1.5 lambs/sheep per year (theoretically 1.67). High prolificacy sheep in this system (>1.3 lambs/birth) can exceed 2 lambs/year. Note that this reproductive rhythm is never fully achieved, however, because not all sheep become or remain pregnant.

3-births-in-2 year system

This system is less stressful for sheep than the STAR system, but has similar requirements for success. It requires tupping 3 months after giving birth and can produce 1.3-1.4 lambs/sheep per year (theoretically 1.5). Figure 7 shows a proposed reproductive and management calendar for the KSA that can be adapted to market prices, feed availability, and agro-climate zone; this calendar can be moved by up to 2 months maximum to produce different settings.

	Year 1												Year 2											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Birth Tupping			B			T					B			T					B			T		
Flushing Culling Scanning					C			S C		F			C			S C		F			C			S C
High dietary requirements																								
Heat stress																								
Veterinary		V 1		V 2	V 3					V 1		V 2	V 3					V 1		V 2	V 3			
Stress avoidance																								

Figure 7. Yearly planning for 3-births-in-2-years system

1-birth-in-1-year system

This system is less productive than the previously described systems but may be better adapted to market needs, climate, and feed availability. It is also less demanding on farmers and requires less technology and labour. It requires tupping 7 months after birth. Figure 8 shows a proposed reproductive and management calendar for the KSA.

	Year 1												Year 2											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Birth Topping			B							T					B							T		
Flushing Culling Scanning						C			F			S C						C			F			S C
High diet requirements																								
Heat stress																								
Veterinary		V 1			V 2	V 3	V 4	V 5						V 1			V 2	V 3	V 4	V 5				
Stress avoidance																								

Figure 8. Yearly planning for the 1-birth-in-1-year system

Continuous breeding system

This approach means that males are always with females and that lambing happens at any time. It has the major drawbacks that diet cannot be tailored, scanning, culling, and flushing practices cannot be adopted, and no medical treatment plan is possible.

Breeding systems in the KSA

In a context with good health standards and highly professionalized farms, the 5-births-in-3-years system, or more realistically, the 3-births-in-2-years system would undoubtedly be the most productive approaches to animal management in the KSA, given the low seasonal influence on reproduction by local breeds and the high prices. However, the targeted KSA regions are not prepared or ready to introduce these systems on any significant scale. There are too many uncontrolled infectious diseases, as well as a lack of implanted technologies, high feed prices, and extreme weather conditions. MoEWA support capacities and labour technical skills are also a handicap to introducing these systems.

Consequently, the 1-birth-1-year system could be more feasibly introduced, as it can be better tailored to weather and to feed availability, and can be moved progressively according to the religious calendar and so maximize lamb sale profits.

Low lamb production

One of the main issues in KSA targeted regions is the very low number of offspring produced per reproductive female. Causes can be multiple (Figure 9); the main problems are preventable infectious diseases, causing infertility and abortions, infertility due to age, and newborn lamb mortality, largely in response to mismothering due to poor husbandry practices. A deficit in planned culling does not affect the total number of lambs produced per year, but does affect the ratio of lambs produced per reproductive female. Inbreeding-related problems are difficult to assess but could be significant in certain holdings.

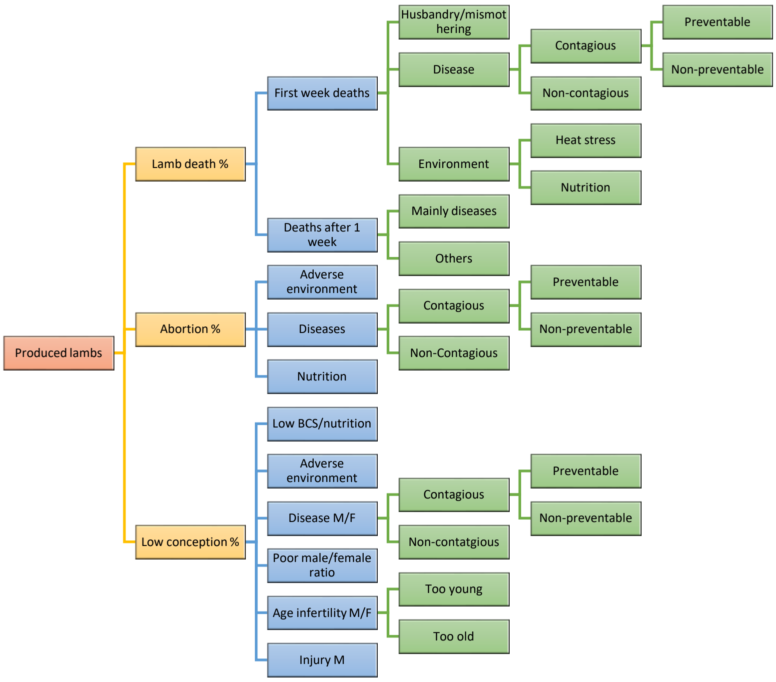


Figure 9. Causes of KSA low lamb production

Social, cultural, and market influences

Religious events and meat prices

Demand for meat is highly linked to religious events. Some 10 days before Ramadan, which lasts for 30 days, the population may buy and freeze meat. A common practice is to buy half a young lamb for soup and half of an older lamb to mix 50% with beef to make samosas and other typical foods. Lamb meat is also highly consumed immediately after Ramadan, in a celebration called Eid al Fitr lasting for 4 days.

During these religious events, people show a preference for their main local breeds (Nahimi or Awassi in the north, Harri in the west, and Nahdji in the centre). When slaughtered, lambs typically still have their milk teeth, are aged 5-8 months, and have a carcass weight (CW) of 14-20 kg.

Local breeds normally cost 1700-2100 riyals (approx. 35-40 kg live weight), i.e., up to 100 riyals/kg CW. Farmers may receive 700-1500 riyals, depending on weight, aspect, location and season.

The Barbari breed from the Horn of Africa and the Sawakni breed from Sudan cost less than half the local breeds (500-800 riyals each, approximately 40-50 riyals/kg CW). If bought before the religious period, these imported breeds can cost as little as 20 riyal/kg CW. Imported live animals from Sudan, the Horn of Africa, and (more recently) Australia have to be older than 6 months and without physical defects to comply with religious requirements. Ritual slaughter for international pilgrims in Makah can account for 2-3 million of imported live animals.

Two months after Eid al Fitr is the 4-day Hajj, for which animals can be slaughtered until midday of the third day of this religious event. It is part of the KSA culture that each family buys live animals (about 80% of families) for themselves, a family member/neighbour, or a local slaughterhouse to slaughter. There are also online businesses and supermarkets specializing in slaughtering animals previously chosen by clients from photographs.

During Hajj, KSA families tend to slaughter a sheep for themselves and another one as a present for relatives. Sheep dealers buy local sheep 2 months before Hajj and 1 month before Ramadan at 700-1200 riyals and sell them for 1400-2000 riyals. Many imported sheep (200-300 heads on average) are purchased at auctions (in Makah among other places) 3 weeks before Hajj for 300 riyals per sheep on average and are kept for 2 weeks and sold for about 500-700 during Hajj.

After religious events, sheep demand goes down and so do prices, especially for local breeds. Supermarket prices for Australian (imported), Sawakni (imported), and Harri (local) breeds are approximately 45-50, 42, and 60 riyals, respectively.

Overall, local sheep prices, especially during religious events, are among the highest in the world. Outside religious events, farmers may only receive 700-800 riyals per 3 to 4-month-old lamb, but during high-demand periods, are paid up to 1500 riyals for the better lambs.

Owners and labour

In Europe in 20 years, the number of sheep per unit of human labour (1 person) has increased from 400 to 600 while maintaining productivity, resulting in increased profits. In the KSA, while it is estimated that one person can manage 300 sheep, flocks are typically smaller and human work capacities are underused.

Some farm owners depend on livestock for a living; other farm owners are hobby farmers with other businesses or jobs, but still may have large numbers of sheep. Out of the 153,000 KSA livestock breeders, 23,000 have a government job, 18,000 have other jobs, 9,000 are investors and the remaining 100,000 have no other job (MoEWA 2020).

The owner and labourer are frequently not the same person, and the owner is often absent. Owners tend to be quite old, with a low to a very low educational level. When they die, their offspring (normally sons) take control of the flock and sometimes sell it off.

Labour tends to be underpaid, overworked, uneducated and unmotivated foreign males living in poor facilities. Wages are 1000-1500 riyals per month and days off are rare. This foreign labour is responsible for all aspects of the job (including vaccinations and treatment) and typically lack hygiene, biosecurity, and advanced handling knowledge.

Effects of subsides

The current KSA small ruminant subsidy is granted to 90,000 sheep owners at the rate of 5 riyals/sheep/month. Only holdings of 50-500 sheep and only the first 300 sheep are entitled to this subsidy. Beneficiaries are evaluated for other incomes.

This subsidy system is generally positive for the sustainability of the small-scale livestock holders that it aims to support. However, it was noted that the system is misappropriated by putting the flock in the name of another family member, or moving sheep from place to place so sheep are double counted. It seems that people sometimes abuse the system pretending to be farmers so they profit from subsides and are allowed to contract foreign labour, which they use for other purposes than keeping animals.

The proper control of subsidy sometimes may become difficult due to the lack of an animal ID system in the country. Subsides are also granted without considering variables such as zone, breed, age, productivity, vaccination, etc.

Farm incomes and costs in the international context

International lamb prices, 2-5 times cheaper than the KSA, are 4-8 USD/kg CW, depending on lambing seasons and demand. Sheep and goat feed costs are generally higher in the KSA because it relies mainly on purchased feed rather than on pasture, although some high-income countries with lower meat prices than KSA also have zero-grazing systems. While extreme weather conditions may affect production, deficient husbandry practices and deficient animal health management are mainly to blame for the poor cost effectiveness of local holdings.

Nutrition as part of the production system

Nutrition for small ruminants

Modern small ruminant nutrition based on information and planning considers requirements for water, energy, protein, mineral, and vitamins. Factors affecting nutritional requirements in small ruminants are related to species, genetics, animal size, physiological stage, production, activity, environment, and diseases. Nutritional status within a flock and availability/price of feed alternatives complement the development of rational nutrition systems.

In the KSA targeted regions, there is a general lack of knowledge dissemination and access to experts able to advise small ruminant farmers. This limits the implementation of good nutrition practices. Feed availability, affordability, and diversity are other handicaps that need to be addressed.

By-products as small ruminants feed

Alternative feed sources for small ruminants have been identified, including dates, date pits and date by-products (e.g., palm leaves), urea, chicken litter, natural, irrigated or sea-irrigated halophytes, other pasture forages, algae, different species of cactus, etc. (FAOSA, 2020). However, formulation and production issues limit the real feasibility of using those alternatives. For example, chicken litter and urea (which culturally may be difficult to accept) are only useful if low protein and medium-high energy or highly fibrous feed is also readily available. Date production is estimated at 1.2 million tonnes per year (FAOSA, 2021). KSA government often buys dates mainly with pits and of very poor quality and donates to African countries. While palm fronds can be produced in significant quantities, the production of other crop by-products can be very difficult to scale up to significant country-level quantities in countries where labour is costly.

In the KSA targeted regions, while the use of dates and cactus is observed at the local scale and close to origin, making the most of by-products in an efficient way would require a national feed and feeding strategy.

Small ruminant nutrition practices

Small ruminant nutrition in the KSA is based on 52% fodder (90% of which is alfalfa, mainly locally produced), 35% barley, and 13% compound feed (MoEWA, 2020). Depending on the region, productive rangeland availability, and husbandry system (more or less extensive), grazing is an important seasonal component of small ruminant nutrition. In relatively cool and rainy high-altitude areas (Taif, the Abha Mountains), grazing often occurs all year around, meeting an average of 40-60% of daily needs in winter-spring and 10-20% in summer. In these areas, summer grazing takes place between approximately 6.30 and 10.30 in the morning to avoid heat. Hotter areas have zero grazing or just seasonal grazing for 1-3 months per year. Around 60% of sheep belonging to large holdings in Ar Ar are transported up to 1000 km by truck to pasture; the sheep population in the region therefore oscillates 2.5-6 million depending on the season. Figure 10 shows an altitude map of the KSA. Grazing may happen all year around above 1800-2000 metres; below that and above 1000 metres (but also depending on other factors) grazing may be available (for more months at higher altitudes).

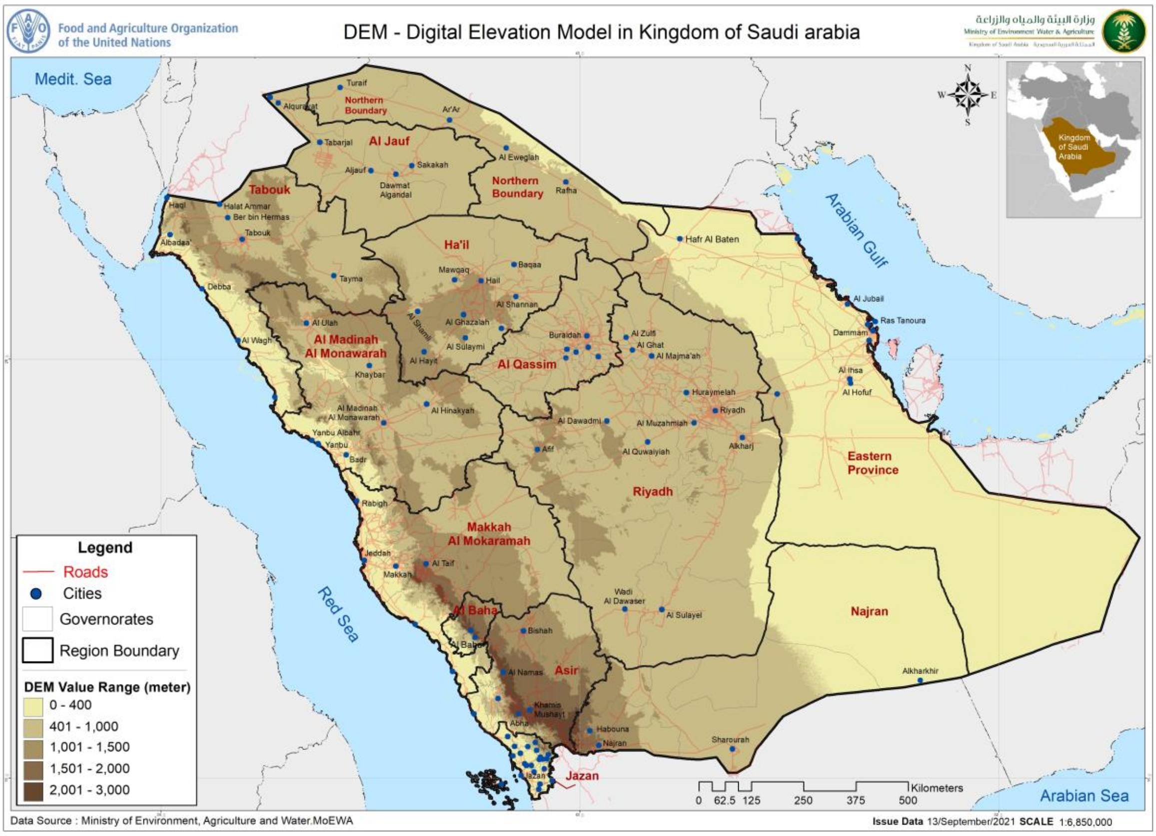


Figure 10. Altitudes and grazing availability. Source: FAOSA

Locally and regionally available crops and by-products ca- complement a basic alfalfa and barley diet. Sorghum is available in feed markets and in many farms, a possible side effect of irrigation limitations on alfalfa. While sorghum leaves/stalks, straw stalks, discarded olives, dates, date by-products, and human food by-products are occasionally used. However, availability/accessibility is low. Therefore, they do not have a significant impact on current small ruminant nutrition, nor are likely to do so in the future.

Animal feed intake and production

The 23.6 million sheep and goats in the KSA consume an estimated 12.9 million tonnes of animal feed (52% of total animal feed): 52% fodder, 35% barley, and 13% compound feed. Locally produced fodder (alfalfa and other plants such as Rhodes grass and berseem) is estimated to be about two thirds of the total (6.6-6.8 million tonnes). Therefore, small ruminants feed about 4.4 million tonnes of locally produced fodder (186 kg/sheep/year). Feed is complemented by imported alfalfa, some locally available wheat straw (0.75 million tonnes), and an estimated 2-2.5 million tonnes of pasture (of the 3 million tonnes estimated to be utilized by KSA livestock). The total quantity of agro-industrial by-products consumed is unknown, but is likely to be very low. Sorghum production seems to be rising but the amount produced is unknown.

The green fodder production area is estimated at 501,183 hectares (data for 2015) - nearly half of the cultivated area in the KSA – and is estimated to consume 16.7 billion m^2 of water (MoEWA 2020), i.e., 82% of water is used to produce mainly alfalfa (86% of the fodder produced in the KSA).

Water demand for feed production

Fodder production in the KSA is 6.8 million tonnes, irrigated with 9.5 billion m^2 of water annually, (MoEWA, 2020). Each hectare consumes approximately 35,000-45,000 m^2 of water per year and yields 16,000-22,000 kg of dry alfalfa. According to water consumption per cultivated hectare, fodder surface is 237,500 hectares, and according to estimated fodder yield per hectare, the surface cultivated is 340,000 hectares. Dividing total water used by total fodder produced shows that each kg of dry alfalfa produced requires 1,397 litres of water.

Each KSA sheep is estimated to consume an average of 0.5 kg/day of alfalfa (185 kg/year). Each small ruminant accounts for 258.4 m^2 per year of water consumption from the local fodder intake. As shown below, each sheep yields 7.32-3.18 kg CW per year; thus each kg CW requires 35.3-81.3 m^2 of water for local alfalfa production. This calculation does not include water used in other feed production systems, farming, transport, and slaughter, which may be an additional 5-10 m^2 per kg. The fact that water used in fodder irrigation in the KSA is mainly from underground non-renewable sources make fodder irrigation highly unsustainable.

Overall, the KSA water requirement for meat production is 3-9 times greater than in the rest of the world, at 10-20 m^2 per kg including all water used in feed production, farming, transport, slaughter, and processing (Water Footprint Network, 2021).

Fuel consumption and CO_2 emissions in animal feed production

As mentioned, fodder production overall (6.8 million tonnes) in the KSA requires 9.5 billion m^2 of water and 2.3 billion litres of fuel per year (MoEWA, 2020). The small ruminant sector alone accounts for about two thirds of all fuel and water needed to produce fodder (1.53 billion litres of fuel and 6.3 billion m^2 of water). Since each litre of fuel accounts for 2.2 kg of CO_2-equivalent (CO_2-e) emissions (Carbon Trust, 2021), fodder production is responsible for 3.36 billion kg CO_2-e, or 142 kg CO_2/small ruminant/year. Fuel used to produce fodder (2.3 million m^2) divided by total fodder produced (6.8 million tonnes) means that 0.338 litres of fuel is used per kg of fodder; hence, each kg of fodder produced in the KSA accounts for 0.744 CO_2-e from the fuel used for its production (excluding transport).

Feed costs

MoEWA estimates small ruminant feed costs to be 13.1 billion riyals/year (555.1 riyals/sheep/year). Current fecundity rates are 0.52 lambs/ewe. Since females represent 88% of flocks, this equals 0.458 lambs/ewe/year. Cost in nutrition alone per produced lamb is 1211.9 riyals. Since feed accounts for 80% of total costs in KSA farms, once the average price of sold lambs is known, the overall profitability of farms can be estimated.

Another way to calculate feeding costs is to use internationally standardized sheep diets and KSA feed prices. An average KSA sheep is assumed to annually consume 185 kg of alfalfa, 190 kg of barley, 71 kg of compound feed, and around 127 kg of pasture and by-products (MoEWA, 2021). At current KSA prices for barley of 1.36 riyals/kg, alfalfa of 0.8 riyals/kg, and compound feed of 1.3 riyals/kg, consumption is 258 riyals in barley, 148 riyals in alfalfa, and 92.3 riyals in compound feed, summing (and excluding by-products costs) 498.3 riyals/sheep/year. This value is close to the 555.1 riyals/sheep/year cost calculated for total KSA small livestock, nor is it far from real farm feeding cost analysed during visits, set below 1.3 riyals per day (474 per year) in high-standard farms.

The cost of feeding small ruminants in the targeted KSA regions is high, comparable to costs in fully intensive production systems in high-income countries, while productivity is very low, comparable to productivity in extensive production systems in low-income countries. This contradiction determines the poor cost-effectiveness of KSA farms.

Nutrition adequacy

KSA sheep, as mentioned, consume 185 kg of alfalfa per year (this figure only includes local alfalfa and so may be higher), 190 kg of barley, 71 kg of compound feed, and approximately 127 kg of pasture and by-products. Total feed utilized is therefore 573 kg per sheep/year (1.57 kg per sheep/day). Expressed in dry matter (85%), this amounts to 1.3345 kg per sheep/day (2.22% of the body weight of a 60-kg sheep). Ewe requirements in dry matter intake (Table 6) and in energy and protein vary significantly during the year, depending on body weight, physiological state, and litter size, while energy/protein demand can rise fourfold from maintenance to peak lactation.

As an example, the maintenance requirement for a ewe weighing 60 kg is 7 MJ per day (60 g of metabolic protein), but this requirement increases significantly in late pregnancy and lactation to 10-11 MJ (80-100 g of metabolic protein). According to Tisserand & Alibes (1989), in the last 3-4 weeks of pregnancy, ewes carrying multiple lambs require an additional source of high-quality protein for lamb growth and colostrum production. By the third week of lactation, however, energy requirements can reach 30 MJ, i.e., 300 g of metabolic protein.

Production stage	Feed intake requirements (% body weight)
Dry	1.5
Late pregnancy	2
Lactation	3+

Table 6. Approximate feed intake requirements of ewes at different production stages

In the KSA, compound feed is generally given to lambs, so an average standard diet is likely to be 60% alfalfa complemented by 40% grazing and by-products, depending on the production system, by-products available, area, and season.

The mixed physiological states of sheep in flocks in the KSA do not allow diets to be tailored according to needs, leading to overfed unproductive or maintenance sheep and undernourished lactating sheep (mainly in ruminal non-degradable protein). Mineral and vitamin needs should also be balanced according to physiological state.

Feeding times and variations (daily and yearly) add even more variability to possible diet inadequacies. It is also likely that in a diet based almost exclusively on alfalfa, the amount of protein (especially non-protein nitrogen) may affect fertility and health, and make coping with heat stress difficult. This is particularly important if alfalfa hay has been cut very young or if it is complemented with other high-protein pasture (as may happen in spring) or other high-protein supplements. A diet based almost exclusively on alfalfa also exceeds calcium recommendations and may lead to metabolic problems, especially around birth. As for reducing heat stress, summer feeding strategies and products available in areas with high temperatures should be taken into account in formulating rations.

Expertise and rationing software are available in the KSA, but it is necessary to build MoEWA capacity to reach as many farmers as possible. Since feed is the main cost of sheep production (80% of total costs in the KSA) and is directly linked to health and productivity. Farmers would benefit from learning about nutrition requirements, principles of feed rations, and nutritious qualities of feed.

Environment and climate

Climate change context

Climate change, the most severe threat ever experienced by humankind, is being caused by rapidly increasing anthropogenic emission of greenhouse gases (GHGs), namely, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which, in 2019, reached annual averages of 410 ppm for CO_2, 1,866 ppb for CH_4, and 332 ppb for N_2O (IPCC, 2021). The temperature of the earth's surface, which is rising at an alarming rate, is estimated to rise by 1.4-3°C by 2050 (IPCC, 2021), and this will necessarily affect sea and land food productivity in many regions of the world. In this context, in agriculture and livestock production systems, controlling/reducing harmful GHGs has become crucial for environmental protection.

Climate change affects food security because of disturbances to agricultural production systems. Anthropogenic-driven climate change alterations to temperature, rainfall, and water availability have critical repercussions on agriculture and animal production.

Small ruminants are widely distributed, with around 56% located in more arid regions and 27% and 21% in temperate and humid regions, respectively (Marino et al., 2016). Small ruminant production supports the livelihoods of many, especially in developing countries relying on adapted breeds to different locations/climates. Small ruminant breeds are adapted to a wide range of climates, so changes may lead to breed displacement. However, some conditions are too extreme for small ruminants, so major changes can be expected in the production capacities of already harsh climate areas. Small ruminants also play a key socioeconomic role in the management of landscapes and conservation of biodiversity. Small ruminants also make high-quality protein food bioavailable.

Climate change impact on small ruminant production systems

Climate change affects small ruminant production through changes in: a) pasture availability and sustainability; b) quantity and quality of produced fodder; c) distributions of diseases and pests; and d) extreme weather events on health and production (Sejian et al., 2013).

Despite regulations already in place regarding grazing lands, 70% of rangelands are degraded in KSA. The regulations are so far ineffective given the very large areas of land to survey, the growing demand for animal products, and the increasingly complex feed sourcing for animals. Pasture availability and sustainability, for instance, is already affected by climate change.

Due to local forage production relying mainly on non-renewable subterranean water supplies, current regulations limit the amount of irrigated cropland to 50 hectares/household, while the KSA is considering completely banning cropland irrigation using underground non-renewable water in the future.

Many infectious notifiable diseases are already present in the KSA. These include brucellosis, Q fever, small ruminant morbillivirus (formerly peste des petits ruminants), bluetongue, contagious caprine pleuropneumonia, Rift Valley fever, sheep and goat pox, foot and mouth disease, and paratuberculosis. It is difficult to predict how climate change might affect the prevalence of these and other diseases, but additional heat stress is likely to have a negative effect on animal resistance to diseases. A warmer winter is also likely to lead to greater viability of arthropod vectors capable of transmitting existing or as-yet unidentified infectious diseases.

There is incontrovertible scientific evidence that heat stress leads to lower productivity in small ruminants worldwide, affecting human livelihoods: fertility and fecundity are affected, abortion and stillbirth rates are increased, growth rates are reduced, and immune systems are weakened (Sejian, Veerasamy et al., 2017). Adaptation measures are adequate shade, evening/night grazing patterns (if possible), and grazing into the wind (Scott & Sutherland, 1981).

Small ruminant production impact on GHGs

Small ruminant production is endangered by anthropogenic-caused climate change, to which, paradoxically, small ruminant production contributes. Worldwide, livestock accounts for nearly 18% of total anthropogenic greenhouse gases (GHG) (Thornton, 2010), while production systems are also associated with heavy water use, contamination, deforestation, desertification, biodiversity loss, antibiotic resistance, and zoonotic diseases outbreaks.

GHG emissions from livestock production systems are a concern in this climate change era. Small ruminant production is to blame for an important share of CH_4 and N_2O production. Several methods are available to quantify real CH_4 emissions, including mechanistic models such as the widely accepted Intergovernmental Panel on Climate Change (IPCC) model. No scientific studies have as yet determined GHG emissions by KSA livestock taking into account local specificities of agro-climate zone, husbandry, and feeding systems. For the purposes of this report, therefore, KSA livestock emissions are estimated based on global data.

Of total world's livestock GHG emissions, the approximately 2.2 billion small ruminants contribute nearly 474 million tonnes of CO_2-e (6.5%), mainly in CH_4 and N_2O (FAO, 2013), corresponding to 215 kg CO_2-e per live small ruminant/year.

According to MoEWA data, KSA has 23.6 million sheep (88% females) producing an average of 0.52 lambs/ewe/year, corresponding to 0.458 lambs/sheep/year. For a world average CW of 16 kg (FAO, 2013) multiplied by 0.458 lamb/sheep/year, the average CW/sheep/year is 7.32 kg CW/sheep/year. Dividing the world average yearly CO_2-e emissions per sheep by the yearly average CW produced in the KSA results in 29.3 kg CO_2-e/kg CW. Therefore, the production of 1 kg of lamb CW in the current KSA production system results in 29.3 kg CO_2-e/kg CW, slightly higher than the world average of 23.8 kg CO_2-e/kg CW. This estimation draws mainly on MoEWA data on sheep fecundity and excludes mortality.

Another way to estimate CO_2-e/CW is to divide the total small ruminant number (23.6 million) by the 75,000 tonnes of meat produced yearly (MoEWA, 2020), resulting in 3.18 kg CW per small ruminant, equal to 67.61

CO_2-e /kg CW (well above double the world average). Note that this estimate relies on MoEWA data and possibly excludes non-market meat consumption.

Local green fodder (mainly alfalfa) irrigation is calculated to require 2.3 billion litres of fuel per year, of which two thirds (1.53 billion litres) is used to grow fodder for small ruminants, thereby producing approximately 3.36

billion kg CO_2-e (Carbon Trust 2021), i.e., 142 kg CO_2-e annually for each of the 23.6 million small ruminants in the KSA. Using this figure, fuel used for irrigation accounts for 19.39-44.65 CO_2-e /kg CW, depending on whether the lamb production or meat production estimate is used.

Another way to calculate emissions attributed to local fodder intake is to multiply 185 kg/sheep/year (i.e., average annual sheep consumption of fodder) by 0.338 litres of fuel required per kg of fodder produced and by 2.2 CO_2-e/litre of fuel. The result is 137.56 CO_2-e /sheep/year, which is very close to the above estimate.

Adding direct small ruminant GHG emissions (mainly CH_4) and fuel emissions associated with small ruminant fodder production results in 48.69-112.26 CO_2-e/kg CW (depending on the production estimate, used, i.e., lamb or meat). The calculations exclude other emissions from land use, transport, other farm activities, etc. Taking the EU vehicle target of 95 g CO_2/km, this indicates that 1 kg of lamb equals fuel emissions for a car driven a distance of 512-1181 km (depending on the production estimate, used, i.e., lamb or meat).

This preliminary analysis of CO_2-e in the KSA shows that sheep production is highly unsustainable mainly because of poor animal productivity and fuel and water demand for fodder production. Specific scientific studies are urgently required that consider land use and real KSA small ruminant CH_4 and N_2O production, as well as other variables not taken into account in this analysis.

Health and production systems

Disease and health management

Several notifiable diseases (listed above) affect small ruminants in KSA. As for non-notifiable diseases, such as chlamydia, toxoplasma, colibacillosis, and enterotoxaemia, prevalence rates are unknown. Prevalence of these diseases could be high given the poor biosecurity practices. Data are scarce but, almost anecdotally, in a study published in 2019 for Medina, of 665 sheep, 228 goats, and 107 camels with no history of vaccination, 7.7%, 8.8%, and 6.5%, respectively, were positive for brucellosis (Shabana & Krimly, 2020). It is also significant that, in 2015-2016, 7,295 human cases of brucellosis were reported in the KSA (Sabirovic, 2018). Despite high abortion rates for the KSA, no data is available on enzootic abortion often caused by *Chlamydia abortus*. Regional MoEWA laboratory experts (personal communication), provided first-hand anecdotal information (no data were provided) that anaplasmosis, Q fever, and chlamydiosis are highly prevalent. *Chlamydia abortus* and Q fever prevalence should be analysed to start vaccination programmes as may be needed (these vaccines are currently not available in country).

The KSA imports very large numbers of live animals, mainly from African countries. Among diseases introduced into KSA through live animal imports are the Rift Valley fever (especially prevalent in the southwest and may have been introduced around 1997-1998 during an epidemic in East Africa), and the lumpy skin disease that affects cattle, which first occurred in February 2015.

There is clearly a need to screen further and better for both notifiable and non-notifiable diseases. Animal health care is limited and not managed on any meaningful scale. Traditional producers to any meaningful extent have not adopted the concept of biosecurity. As one example of an easily implemented measure to prevent health risk, aborted ewes are not quarantined or culled. Vaccination coverage is not systematic, and is often conducted late and in response to perceived disease outbreaks. Animal treatment is largely improvised, via purchases of medicines at veterinary pharmacies as needed, or when/if livestock owners bring representative cases to government clinics. Minimal on-farm services are available largely due to the high cost of private

veterinarians visiting farms and rural areas, leaving many farmers with poor access to affordable veterinary services (Mariner-FAO, 2020).

A frequent source of spreading infectious and parasitic diseases is grazing on rangelands and pastures. Although grazing has advantages in terms of diversifying diet, it creates special challenges by increasing contact risk with animals from other holdings, wildlife, and feral animals (including stray dogs). Furthermore, most farms do not isolate new introductions, and the education level of many owners, managers and workers is a challenge to the adoption of biosecurity plans (Mariner, 2020).

Currently available in the KSA, free of cost, are vaccines for small ruminant morbillivirus, brucellosis, contagious caprine pleuropneumonia, foot-and-mouth disease, pasteurellosis, enterotoxaemia, sheep and goat pox, and, in certain regions, Rift Valley fever, while vaccines for chlamydia and Q fever are not available. Evidence from private conversations and the Annam website's farm records is, however, that farmers use even the free vaccines inconsistently.

Introducing nationwide vaccination programmes and biosecurity measures is a matter of urgency and would have an immediate impact on productivity, especially if combined with improvements to husbandry practices. The absence of a compulsory animal health certificate system means that market trade or direct dealing is a common source of disease transmission in the KSA.

Overall, main animal health issues affecting KSA livestock and national strategies proposed are described in the KSA Animal Health Strategy report and it is urgent to implement specific actions leading to deploy this strategy.

Health and husbandry practices

The KSA rate of lambs sold/sheep is particularly low (0.52 lambs/ewe/year). This is the consequence of low fecundity and low fertility, a high abortion rate, and high mortality of newborns, due, in turn, to deficient health and husbandry practices. While a situation analysis by the MoEWA points to the large number of old/unproductive females and to traditional breeding systems to explain low fecundity, this does not in itself explain the extremely low numbers of weaned lambs/ewe per year. Animal health care (through biosecurity, hygiene, and preventive medicine) needs to be improved. There is a need for comprehensive small ruminant husbandry strategy, including suitable genetic improvement programmes and reproductive techniques.

Live animal imports and health risks

Annually, KSA imports approximately 8 million live ruminants, most of which are small ruminants, imported shortly before Ramadan and Hajj and imported from Sudan and other East African countries, where many infectious animal diseases are enzootic. More recently, after a decade-long ban, Australia has reopened exports to the KSA, with consequent welfare concerns for the animals during the long-distance travel.

Importing large number of live animals from diverse sources endemic for transboundary animal diseases could raise the risks and threats to local farm animals and many welfare issues. While KSA culture and religion rely on live animals for ritual slaughter, particularly at Ramadan and Eid and during Hajj, it is clear that a compromise between both situations needs to be found. KSA may wish to strengthen veterinary quarantine systems and ensure that animal identification and traceability systems are in place as well as sanitary guidelines for safe animal trade.

Technology use in small ruminant husbandry

Energy and water supplies

Reliable supplies of energy and water are essential for intensive breeding and production systems, whereas extensive systems can use generators or batteries as needed. Some of the targeted KSA farms, however, even intensive or semi-intensive ones, lack both utilities. Water is often brought to farms by trucks, and energy, when not available, is obtained from small-scale solar panels or generators.

Electronic ID

Animal identification (ID) is essential for introducing further technologies, proper data registers and advanced husbandry methods.

ID methods, which include visual tags or RFID ear tags, subcutaneous microchips, or ruminal bolus, are widely used in the world, with visual tags, replaced by RFID and ruminal bolus. Subcutaneous microchips (which remain in the meat) and ruminal bolus cannot be viewed but also cannot be easily manipulated easily. Ear tags are viewable but can be illicitly manipulated or lost. Notice that goat’s tags should be very small otherwise, they are lost very easily.

ID technology has hardly been implemented in KSA small ruminant sector. While some larger holdings not targeted by the SRAD programme have visual ID systems. However, their data is not systematically recorded and analysed.

Weighing and drafting

Electronic weighing and drafting systems allows sorting of animals and automatically recording data according to sex, weight, weight gain/loss, using electronic ID, visual ID and remote control. These systems can operate at the rate of 400-600 sheep/hour. Current well known brands are MS Schippers, Maréchalle, Prattley and Gallagher. For example, a Prattley system is fitted in the King Faisal University research centre in AlHasa. More affordable for small KSA holdings are dynamometers or manual scales.

In the KSA targeted regions, farmers rarely or only rudimentarily weigh live animals, usually only at birth or before market or slaughter. No weighing or drafting system was observed anywhere except at a Pratlley Unit in King Faisal Veterinary University in Alhasa.

MS Schippers

Maréchalle

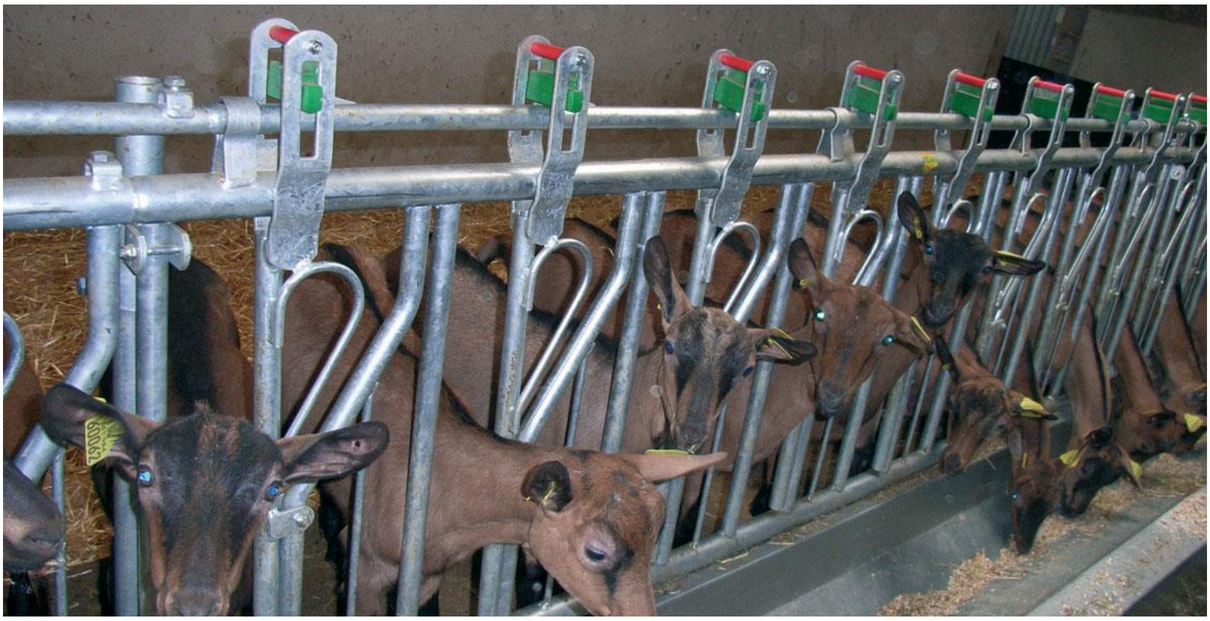
Prattley

Gallagher

Head lockers

Head lockers are universally used in modern ruminant farms. They facilitate the handling, restraining, drafting, scanning, medical treatment, blood sampling, etc., of large numbers of ruminants. Several designs are available in the market, fitting approximately 9 small ruminants every 3 m.

Head lockers in use have not been observed in the KSA targeted regions. A single technology such as head lockers can have a profound cascade impact as they facilitate many other necessary animal husbandry and animal health procedures.



Handling units

As a contention method, handling units complement head lockers, facilitating footbaths, whole body baths, vaccination, scanning, etc. They can be combined with revolving units that, with minimum effort, immobilize/turn animals belly-up for hoof trimming, for artificial insemination, etc.

In the KSA targeted regions, no such systems have been observed in small farms; animals are typically captured one by one by hand when they have to be manipulated. They have been observed in some more advanced large farms, and one is fitted in the King Faisal University research centre in AlHasa.

Feeding technologies

Belt feeding systems, automatic feeding systems, and total mixed ration (TMR) systems are increasingly important in significantly reducing labour requirements.

These systems are not used in the KSA, where feeding is done manually because labour costs are low. Consequently, such systems are only economically viable for large operations. However, small-scale operations can be improved using manual trolleys and well-designed feed storage facilities.

Troughs and watering

Feed and water must be provided to small ruminants of all ages in a way that ensures that all animals can satisfy their needs, waiting and competition is avoided, feed and water quality is preserved, bacteria and vectors (especially mosquitos in the water) are avoided, and waste is minimized.

Feeding and drinking systems in the KSA targeted regions are rudimentary. Water accumulation and stagnation in troughs favour mosquito proliferation, feed is often wasted, and adults frequently have access to feed earmarked for young animals.

Premises and fences

Well-structured spaces that consider space allowances should be designed according to the reproductive lots predicted for the farm. Fencing should be secure, easy to handle, affordable, modular, easy to clean, durable, and suitable for the animal. Built farms in countries with high rainfall or low temperatures tend to be masonry based, although some small ruminants live permanently outdoors. In KSA, we find both, light-modular fencing and masonry-based farms. Masonry based farms are not necessary in KSA context.

KSA farms use all sort of materials that are typically difficult to move and clean; often these pose a risk of injury to animals. Mobile fencing would allow farms to be easily reorganized and adapted, e.g., to variable reproductive needs, to avoid contaminated soils, etc. Since shade availability is crucial in hot climates, mobile canopies in conjunction with mobile/modular fencing are recommended for the KSA.

Surveillance

Farms in high-income countries frequently use cameras (which work with WiFi or 5G technologies) to monitor animals when humans are absent. Cameras can be programmed to alert owners in case of abnormal movement, and enable rapid responses to predators, births, illnesses, etc. GPS systems and drones are used to track movements and events for larger holdings managed in extensive systems. Cameras are an affordable option, suitable for the KSA targeted farms though often not a priority.

Reproduction technologies

In countries with changing photoperiods, hormonal oestrous synchronization is frequently used, especially in seasonal sheep breeds. In the KSA, the utility of these methods is linked to the use of artificial insemination or embryo transfer techniques.

Reproductive technologies are not used in the KSA. However, before considering the introduction of advanced reproductive techniques, other basic technologies, animal healthcare plans and biosecurity measures would need to be introduced.

Cooling technologies

Cooling technologies are shade and sprinkler, ventilation, and cooling devices. Sprinklers and automatic ventilators have been successfully used to create microclimates in the dairy cattle subsector. Shade, however, is potentially the simplest approach to cooling.

The KSA rarely uses cooling technologies for small ruminants, although experience using these technologies for dairy cows could be adapted to small ruminants. One of the farms visited in AlHasa uses a water-cooling system though with no real effects as this farm suffers other much more important problems.

Information technologies

Information technologies, including animal and nutrition management softwares, are essential to livestock systems worldwide. They allow integration of various farm technologies (cameras, cooling systems, feeders, scales, etc.) and combination of this information with production parameters.

While KSA farmers and labour widely use smart phones, few take advantage of this to use animal husbandry technologies. However, animal ID is the first essential step to computerize data recording and analysis, although systems that take advantage of this data are also necessary, as data is useless if not analysed, while analysis is useless if no decision is taken afterwards.

3D imaging

3D imaging offers rapid and non-invasive estimation of sheep weight, body condition, and conformation. This innovative technology has good potential for use in zoometric studies for breed standardization purposes.

Automated farm cleaning systems

As done with cattle, intensive small ruminant farms can use automated cleaning systems to reduce use of labour and enhance hygiene. These systems are more suitable for large operations that use premises with flat concrete surfaces. It has a very limited utility in the KSA.

Technology implementation

The implementation of available technologies in the KSA should follow a logical order. An initial first step should consider head lockers and handling units, modular buildings and shade, animal ID, and water and electricity supplies as crucial in laying the basis for and enabling other technologies. Many of the advanced reproduction technologies, for instance, can only be properly and successfully introduced once animal health and farm biosecurity is assured.

Head lockers are low cost, low maintenance; sturdy and can facilitate many health and husbandry practices bringing a cascade of many necessary changes in targeted farms.

Introduction

Livestock systems operate along a continuum between intensive (all nutrition is provided in-farm by humans) and extensive (all nutrition is obtained outdoors by the animal). Intensive systems require greater technological input to maximize production and offset higher costs. Farmland availability and irrigation possibilities also shape production systems, according to the classification by Seré and Steinfeld (FAO, 1996).

KSA production systems

Grassland-based arid/semi-arid production (LGA)

The LGA system is defined as a land-based system in arid and semi-arid regions, featured by growing periods of less than 180 days, with grazing by ruminants as the predominant form of land use. This kind of enterprise generates around 90% of the total value of production, while the remaining 10% of dry matter consumed by animals is provided by crop production (stubbles, crop by-products, and annual forage crops). This was the traditional system in Saudi Arabia, and it continues so in many African countries.

Even the most extensive systems in KSA practising transhumance (a number of Ar Ar operations) or allocated land in rangeland areas or in high mountains around Taif or Abha require external feed provision. The vast majority of KSA holdings obtain 70% or more of their dry matter requirements from crop production. We can conclude that in the KSA, the LGA system de facto no longer exists. Figure 11 shows agro-climate zones, rainfall data, and rangelands allocated to seasonal grazing and transhumance.

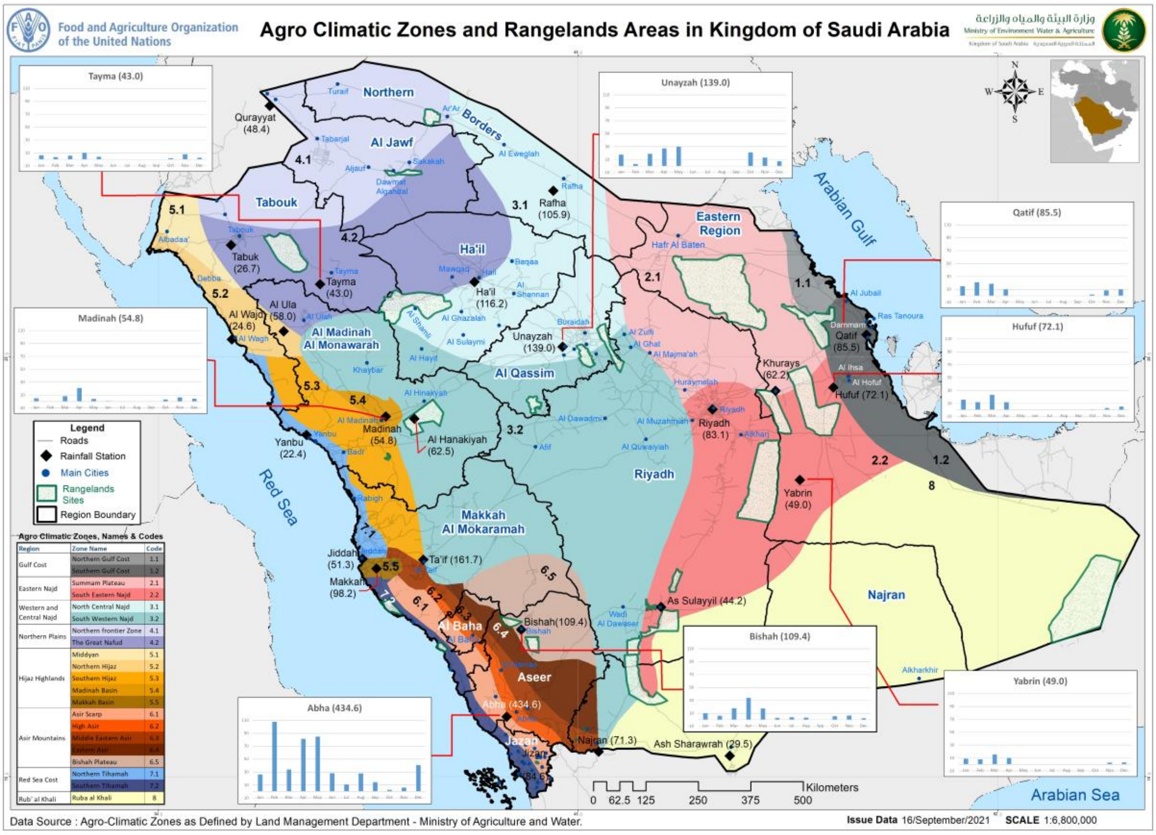


Figure 11. KSA agro-climate zones, rainfall data, and rangelands allocated to seasonal grazing and transhumance. Source: FAOSA

Land-less ruminant production (LLR)

Ruminant feed is mainly introduced from outside the farm system, thus separating feed decisions from feed production decisions, and particularly manure utilization on fields to produce feed and/or cash crops. An LLR system can be based on zero grazing or opportunistic grazing, depending on season and location. This system is very open in terms of nutrient flow, a feature it shares with the landless monogastric system. The main difference between those systems is that ruminants need more fibrous rations, so the conversion rate of feed concentrates to live weight gain is substantially lower. The LLR system is expanding because of desertification, the lack of pastures, and growing ruminant numbers. Animal numbers, location, technology use, and improved husbandry determine the difference between what are locally called backyard, pen, and specialized systems in the KSA.

Mixed rain-fed arid/semi-arid production (MR)

Grazing land not suitable for crop production is the main feed resource in the MR system, supported by strategic use of crop stubbles and straw. This system is rarely used in in the targeted KSA farms, as land destined to crop production is very low. However, there are some examples of farms in south-western regions feeding farm by-products to their small ruminants, especially sorghum and other crop by-products.

Mixed irrigated arid/semi-arid production (MI)

In the MI system, irrigation makes year-round intensive crop production feasible. This system is rarely used in the KSA targeted farms, as little irrigated land is destined for crop production for local animals. Small ruminant farmers cultivating irrigated sorghum or irrigated fodder (more than 10% of the production) would potentially belong in this category.

Future trends

Lack of grazing (reduced surface area and restricted seasons) and limited interaction between crop production and small ruminant production systems are shifting traditional LGA systems to intensive LLR systems, with some few exceptions. Seasonal and opportunistic grazing, in some cases in the same region, and in other cases (mainly in Ar Ar) via transhumance (nomadism has not been confirmed), is a feature of a significant number of holdings. However 40-60% of animals never graze, with farmers in all regions providing most of the feed needed.

Sustainable intensification of livestock farming is widely advocated to meet the growing demand for livestock products, reduce the carbon footprint, and contribute to improving livelihoods. This approach produces more outputs through more efficient use of resources, while reducing the negative impact on the environment (this approach would, for instance, reduce pressures on Latin American forests). In the KSA context, extensive overgrazing systems are known to cause desertification. Because pasture is unavailable during many months of the year, LLR, semi-intensive, and mixed systems in the KSA have to be supported with environmentally costly locally produced feed. KSA livestock enclosure systems use large amounts of non-renewable water and energy to grow local feed in a non-sustainable manner, resulting in a very high carbon footprint, yet not increasing productivity. Enclosure systems in the KSA need to be transformed into intensive systems based on excellent husbandry and animal health approaches that guarantee high productivity in order to offset high costs. Well-managed opportunistic systems integrated in advanced husbandry systems could be an important approach for small ruminant production systems in the KSA.

Production system analysis

Husbandry in KSA targeted regions can be broadly classified as traditional, with little or no reproductive management, little or very little technology use, poor facilities, poor animal health care, and very high environmental impact. Other common characteristics are heat-stress welfare problems and production subject to seasonal demand with high prices. Variations between farms are found (Table 7) with respect to:

- Use of advanced practices (husbandry, technology, nutrition, health)
- Agro-climatic zones (linked to opportunistic grazing and transhumance, possibly with some degree of nomadism)
- Availability of own farm feed resources
- Holding size
- Farming model (livelihood, business, hobby).

The main issue with KSA targeted regions is that the LLR system (with or without opportunistic grazing) does not lead to improved husbandry, health, and technology practices. Low productivity is only economically feasible when costs are very low (extensive systems with cost-free pasture). Lamb prices from local breeds in the KSA, particularly during religious events, are among the highest in the world, while feed prices are comparable to international prices, and wages fall between low-income and high-income country labour costs. Improved husbandry, health, nutrition, and technologies should be aimed at increasing productivity, by increasing the number of lambs produced per ewe.

The environmental sustainability of KSA small ruminant systems is affected by dependence on locally produced crops, land degradation, and low productivity. It is recommended to limit or optimize local fodder production, implement strict grazing regulations, and develop a national land-use plan that considers by-products or alternative feed sources.

Land/crop relationship	**Traditional or improved practices** Husbandry Technology Nutrition Health				**Agro-climatic zone**	**Pasture as % of yearly dry matter provision**				**Transhumance**		**No. of animals**	**Models** Business Hobby Livelihood
	H	T	N	H		0%	1%-10%	11%-30%	>30%	Y	N		
LGA													
LLR													
MR													
MI													

Table 7. Proposal for a KSA production system classification.

CONCLUSIONS

Animal health

C.1 Poor health status, deficits in biosecurity and hygiene in targeted livestock sectors is one of the most important problems affecting productivity of farms and jeopardising the successful implementation of productivity improvement strategies.

C.2 Transition from traditional to modern animal production systems is a great opportunity for the KSA as the country has comparative advantages with other countries thanks to its prepared professionals, to the Kingdom's high income and to a local market greatly valuing local breeds especially for the very important religious events.

There is paucity of information on adapted or local small ruminant genetic resources (not characterized) for designing sustainable breeding programmes in the KSA. The KSA has not reported to FAO (as per the call of the Global Plan of Action for Animal Genetic Resources 2007, Interlaken, Switzerland) on the status of its livestock breeds, level of genetic diversity, risks and threats in order to design conservation and sustainable use.

Nutrition

C.3 KSA animal feed price is comparable to other international settings. However, small ruminant farms low productivity and agro climatic context makes nutrition very expensive and local production of fodder highly unsustainable.

Production systems analysis

C.4 Particular conditions of KSA livestock production systems require a country-specific analytical framework to assess and monitor country livestock situation and its future development.

RECOMMENDATIONS

R.1 Animal health

R.1.1 MOEWA should implement compulsory vaccination especially for notifiable animal diseases, including zoonotic diseases. Farm vaccination proof could be used as a requirement for access to markets, trade, slaughterhouses and to farming licencing.

R.1.2 MOEWA should consider introducing a compulsory country-level dead animal carcass disposal system with the following features:

a. Animals should preferably be collected weekly from specific communal collection points by contracted service and then incinerated
b. A less preferable option is that animals are disposed securely in the same farm

R.1.3 MOEWA should maximise the usefulness of central and regional veterinary laboratories that are already endowed with highly prepared professionals and modern equipment by:

a. Increase the number of samples analysed to laboratories through MOEWA veterinarians proactively working with farmers.
b. Capacitate and capitalize on the data-results at farm, regional, country and at preventive or therapeutic and research levels updating the information sharing current system.

R.1.4 MOEWA must strengthen livestock health status and husbandry practices in farms to guarantee that future possible genetic improvement programmes are feasible and sustainable.

R.2 Husbandry, management and technology

R.2.1 MOEWA should promote the introduction of low cost/high impact technologies prioritising animal ID, head lockers, modular farms and shades by:

a. Restricting subsides to specific technology attested to enable farm improvements that have a demonstrated impact on productivity and income.
b. Alternatively, increasing subsides to +-10 riyals/month/sheep, linking subside eligibility to farming good practices such animal ID, farm registers, vaccinations compliance, periodic veterinary visits, and culling of unproductive animals.
c. Adapted small ruminant genetic resources should be characterized and sustainable breeding programmes designed
d. KSA need to report to FAO (as per the call of the Global Plan of Action for Animal Genetic Resources 2007, Interlaken, Switzerland) on the status of its livestock (including small ruminant) breeds with details on genetic diversity, risk status and threats as well as the conservation and sustainable use activities conducted so far and future plans.

R.2.2 MOEWA should set up an extension strategy that will include:

a. Periodic compulsory farm visits with focus in nutrition, husbandry and health.
b. Building the capacity of veterinarians on animal production competencies.
e. Continue current subsector modernising strategy to help farmers adopt best husbandry practices and technologies: Improved reproduction systems, best animal management standards, targeted nutrition, head lockers, animal identification, modular farms and shadow availability.

R.3 Nutrition

R.3.1 KSA policy makers to consider developing a country livestock feeds and nutrition strategy:

a. Undertaking an inventory of national feed resources as a prerequisite for developing a strategy for improving management of animal feeds and feeding systems in the Kingdom.
b. Develop an integrated by-products country plan by Identifying, collecting, transforming, mixing, and using/distributing locally available sub-products in a controlled manner through local feed mills as part of a TMR (Total Mixed Ration).
c. Optimize or limit the non-sustainable production of local fodder

R.4 Production systems analysis

R.4.1 MOEWA should introduce a relevant production systems analysis using country determining variables also developing key performance indicators for each section, to evaluate progress of the KSA small ruminant subsector and help to guide further decisions.

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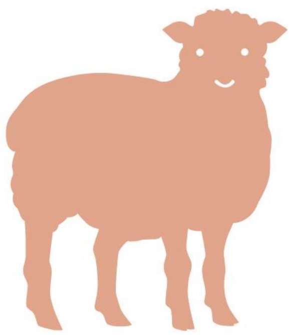

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