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Review

An Update on South African Indigenous Sheep Breeds' Extinction Status and Difficulties during Conservation Attempts: A Review

Jabulani Nkululeko Ngcobo [1,2,*], Tshimangadzo Lucky Nedambale [1,2], Khathutshelo Agree Nephawe [1], Takalani Judas Mpofu [1], Tlou Caswell Chokoe [3] and Fhulufhelo Vincent Ramukhithi [2]

[1] Department of Animal Sciences, Tshwane University of Technology, Staatsartillerie Rd., Pretoria West, Pretoria 0183, South Africa; nedambaletl@tut.ac.za (T.L.N.); nephaweka@tut.ac.za (K.A.N.); mpofutj@tut.ac.za (T.J.M.)
[2] Agricultural Research Council Irene Campus, Old, Olifantsfontein Rd., Irene 0062, South Africa; ramukhithif@arc.agric.za
[3] Department of Agriculture, Land Reform and Rural Development, Directorate: Farm Animal Genetic Resource, Private Bag X 250, Pretoria 0001, South Africa; tlouc@dalrrd.gov.za
* Correspondence: jabulaninkululeko@gmail.com; Tel.: +27-67-2824-956

Abstract: South African indigenous breeds' population is decreasing at a time when their genetic material is mandatory due to the rising climate change and global warming. South African indigenous sheep breeds include Namaqua Afrikaner, Zulu, BaPedi, and Damara sheep. These breeds are the most preferred breeds by rural farmers in South Africa due to their adaptability, low feed, and veterinary requirements. However, since they are characterized by small body sizes, farmers tend to crossbreed them with exotic breeds. An early survey conducted in Kwa-Zulu Natal revealed a 7.5% decline in Zulu sheep between 2008–2011. It has recently been observed that the population left is genotypically mixed with exotic genetic material due to uncontrolled breeding techniques that rural farmers apply. Therefore, the aim of this review is to address the present status, difficulties, and conservation approaches applied to save these breeds. However, this review will be limited to the current extinction status as it appears in the Food and Agriculture Organization (FAO) system, data from recent studies, difficulties limiting the conservation success of these breeds, and the current conservation approaches in use to conserve these breeds.

Keywords: Namaqua Afrikaner; BaPedi; Zulu sheep; conservation

Citation: Ngcobo, J.N.; Nedambale, T.L.; Nephawe, K.A.; Mpofu, T.J.; Chokoe, T.C.; Ramukhithi, F.V. An Update on South African Indigenous Sheep Breeds' Extinction Status and Difficulties during Conservation Attempts: A Review. *Diversity* **2022**, *14*, 516. https://doi.org/10.3390/d14070516

Academic Editor: Luc Legal

Received: 30 March 2022
Accepted: 21 June 2022
Published: 25 June 2022

1. Introduction

Small ruminants (sheep and goats) play an essential role in the global food and wool production in developing countries affected by harsh climate change [1]. Indigenous sheep require less veterinary service and feed and are tolerant to harsh environmental conditions [2–4]. South Africa is home to several indigenous sheep breeds such as Namaqua Afrikaner, Zulu, BaPedi, and Damara sheep [5]. However, more than 67% of livestock farmers operate under village production with a lack of resources, veterinary services, and infrastructure [6]. Farmers in this production system prefer indigenous sheep to address food insecurity and poverty; hence, these South African indigenous breeds remain vital [4].

The South African smallholder farmers practice communal grazing during the day and confined their animals in the kraals at night [3]. In this way of farming, inbreeding and crossbreeding with exotic breeds cannot be controlled [3]. Selepe et al. [7] found a genetic mixture with Dorper in Zulu sheep diversity. This alone cause a huge genetic loss of Zulu sheep genetic material. On the other hand, Nxumalo et al. [8] revealed a compromised genetic material in the Namaqua Afrikaner flock.

The South African indigenous sheep breeds are not attractive to commercial farmers because of their poor growth rate and small body size [9]. Furthermore, indigenous breeds yield low carcass weights in comparison to locally developed and exotic breeds [10]. These factors led to their substitution with exotic breeds; hence, the South African indigenous breeds population is declining at a higher rate [11,12]. This decline occurs, whereas it is well known that small ruminants have the potential to address the imbalance between meat demand and the supply [13]. Furthermore, there is a noticeable role of the South African indigenous breeds in developing composite breeds [14], such as Afrino, Dorper, and Van Rooy [15–17]. Therefore, South African indigenous breeds are critical in the South African small ruminants industry, necessitating radical intervention for conservation. Conserving South African indigenous breeds will require an increase in their productivity and genetic material through advanced reproductive biotechnologies (ART).

Advanced reproductive biotechnologies such as in vitro embryo production using superior males and females accelerate genetic improvement in small ruminants. Nevertheless, according to the Data Retrieval Committee of the International Embryo Transfer [18], South Africa has no or less information reported on in vitro ovine embryo production. This might be attributed to the lack of reporting in developing countries, such as South Africa [19]. Therefore, this review is aimed to address the present status, encounters, and the conservation approaches applied to save these breeds. However, this review will be limited to the current extinction status as it appears in the Food and Agriculture Organization (FAO) system, data from recent studies, difficulties limiting the conservation success of these breeds, and the current conservation approaches in use to conserve South African indigenous breeds.

2. History, Characteristics, and the Importance of South African Indigenous Breeds

The South African indigenous breeds (Zulu, BaPedi, and Namaqua Afrikaner) are found in the different provinces of South Africa and are illustrated in Figure 1. Molotsi et al. [20] subdivided the South African landscape into wet, humid conditions on the eastern coast and a drier northern region. Zulu and BaPedi sheep are found in the wet, humid eastern coastal region, whereas Namaqua Afrikaner and the Damara are found in the drier northern region. The South African indigenous sheep play numerous roles in different ways ranging from the employment of rural farmers to food security and good investment [2,21,22]. Moreover, adapting to adverse environmental conditions made these breeds a significant contributor to the livelihood of farmers in Southern Africa [23]. For these reasons, South African indigenous sheep have been used to build composite breeds to supplement adaptive traits (Table 1).

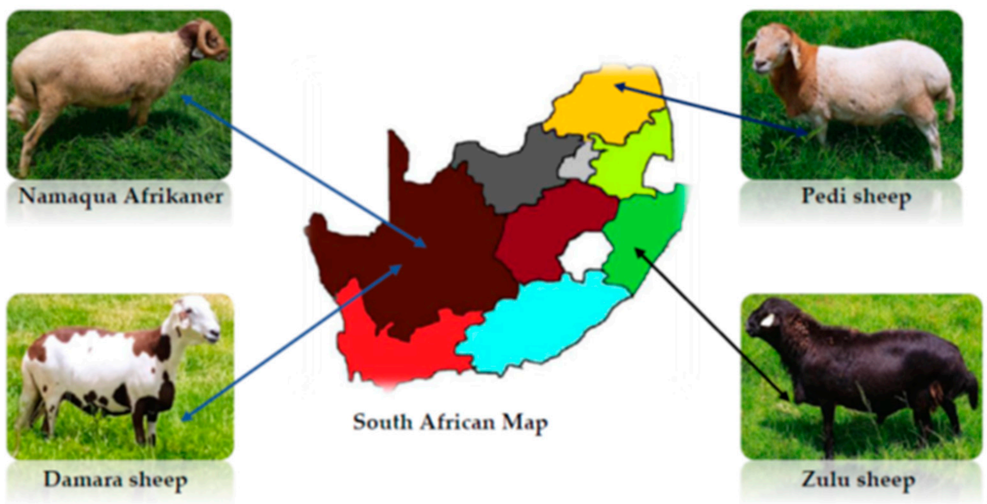

Figure 1. South African indigenous sheep and their geographical location.

Table 1. Role of South African indigenous breeds in developing composite breeds.

Locally Developed Breed (Composite Breed)	Use of the Breed Developed	Indigenous/Composite Breed Used	Exotic Breed Used	Breed Developer	Reference
Afrino	Meat and wool	Ronderib Afrikaner	Merino, SA mutton Merion	Carnavon Research Station	[16]
Van Rooy	Meat production and terminal sire crossing	Ronderib Africander rams	Rambouillet ewe	JC van Rooy	[16]
Meatmaster	Meat production	Damara	Ile de France	-	[24]
Dorper	Meat production	Black Persian	Dosert horn	South African Department of Agriculture	[17]
Vandor	Wool	Van Rooy	Dorset horn and German Merino	CJ van Vuuren	[15]
Bosvelder	Meat production	BaPedi, Van Rooy, white Dorper	-	-	[25,26]

2.1. Zulu Sheep

Zulu sheep is the oldest indigenous Nguni sheep breed of South Africa [6], predominantly found among subsistence rural farmers of Kwa-Zulu Natal in the areas such as Mutubatuba, Nkandla, and Msinga [2]. They have a small body frame (range between 35–38 kg matured rams) which simplifies the management challenges facing smallholder farmers [21].

According to Soma et al. [14], Zulu sheep have elongated fat tails for pilling surplus fat and thus belong to the fat-tailed Nguni sheep along with BaPedi and Swazi sheep. In color, Zulu sheep is dark brown but also come in black with white spots covered by a coat of wool or coarse hair [11]. To our knowledge, the Zulu sheep's role in developing locally developed breed is still lacking.

2.2. BaPedi Sheep

BaPedi is indigenous to South Africa and was first introduced between 200–400 AD [27] and originated from the semi-arid regions of Limpopo [23]. It was named as BaPedi breed mainly because it was first raised by the BaPedi people [14,28]. Not much information is available on BaPedi sheep in terms of their population size and reproductive performance. However, the breed is genetically distant from other indigenous breeds such as Zulu, Namaqua Afrikaner, and Damara breeds [29]. The reason behind such differences is not well understood but might be due to the discriminable crossbred that South African indigenous breeds suffered long ago before proper characterization. Noteworthy, this breed is reported at risk of extinction [4,16]. As a result, many institutions, such as the Agricultural Research Council Irene and Johannesburg Zoo, are conserving BaPedi sheep with the principal aim to increase its population in a controlled environment and make sure that their gene does not disappear.

2.3. Namaqua Afrikaner

It is believed that Namaqua Afrikaner ancestors were brought by Khoikhoi people down from the Middle East [14,22]. There are two varieties of Namaqua Afrikaner sheep: Namaqua and Ronderib Afrikaner, and they are the oldest indigenous sheep breeds of South Africa. They have a long fat tail that has been described as energy pilling storage to survive long dry seasons [30]. Likewise, Namaqua Afrikaner is a hardy, slender, and lanky sheep that always comes in red or blackhead with a white body [22]. Moreover, Namaqua Afrikaner has been associated with multi births [30]. Namaqua Afrikaner has been utilized mostly to develop hardy breeds. Afrino is among locally developed breeds containing Namaqua Afrikaner blood [16,28].

2.4. Damara Sheep

Damara sheep is found in the Northern Cape province, which is the driest part of South Africa [4]. This breed is characterized by its long horns, fat tail, and rump [4].

Damara sheep are well adapted to gastro-intestinal parasites [15] and tolerant to seasonal weight loss [26]. However, old Damara ewes fail to conceive due to fat accumulation in their tails, making it difficult for rams to mate successfully, necessitating tail docking [15]. Damara has a clear role in developing composite breeds such as Van Rooy and Meat master [14,24].

3. South African Indigenous Breeds Current Status and Extinction Risks

Despite superior South African indigenous breeds' genetic materials, numerous indigenous breeds in South Africa are threatened [16,20,22]. The effective population size of some is known, and some are not known (Table 2) [16]. This emphasizes the lack of reporting to DAD-IS or FAO in developing countries, hindering conservation programs of these breeds [4].

Table 2. Risk status of general South African indigenous sheep at a country level [16].

Population Data	Zulu Sheep	BaPedi Sheep	Namaqua Afrikaner Sheep	Damara Sheep
Reporting year	2022	2022	2022	2022
Population trend	Decreasing	Decreasing	Decreasing	Increasing
Population size	298	48	88	1003
Breeding ewes	258	23	74	655
Breeding rams	40	25	14	348
Ewes bred pure	95	23	Unknown	655
AI performed	0	-	-	-
Rams in AI	0	-	-	-

Kunene et al. [31] reported a serious extinction threat of Zulu sheep. On the other hand, Qwabe et al. [22] reported a high population size decline of Namaqua Afrikaner sheep. Indiscriminate crossbreeding subsidizes the loss of distinctive local genetic resources and the extinction of indigenous livestock species [32]. Furthermore, pose a threat to the sustainability of this unique gene pool and adaptive traits such as tolerance to native diseases and parasites. Therefore, sooner or later, these breeds will be extinct if no urgent intervention is made.

4. Phenotype and Genetic Characterization

Conserving endangered species requires phenotypic (Table 3) and genetic characterization for more understanding of the breed for successful ART applications [33].

Table 3. Phenotypic characteristics of South African indigenous sheep [16].

Phenotype Characteristics	BaPedi Sheep	Zulu Sheep	Namaqua Afrikaner Sheep	Damara Sheep
Head	Hornless	Hornless	Horned	Long and strong nose, horned, small dewlap, strong teeth
Average body size: Ram	-	39.1 kg	58.7 kg	61 kg
Average body size: Ewe	40 kg	33.4 kg	50 kg	45 kg
Birth weight	3.1 kg	2.8 kg	3.1 kg	3.9 kg
Weaning weight	13.4 kg	11.6 kg	10.5 kg	14.1 kg
Coat colour	White with brown head, variety of colours occur	Black, brown or reddish-brown coat sometimes pied	White usually with black or brown head, course hair	Brownish in colour
Tail type	Fat-tailed and rump	Long fat-tailed and rump	Fat-tail	Long Fat-tail

Phenotypic characterization could be defined as the physical trait/observable trait [34]. According to Ramukhithi et al. [35], phenotype characterization is sub-divided into: quantitative and qualitative. Quantitative phenotype is measured using a flexible measuring tape. Qualitative is assessed using visual judgment. Namaqua Afrikaner was phenotypically in early 2012 [22]. Namaqua Afrikaner semen has been characterized and cryopreserved [36].

Zulu sheep, on the other hand, have been characterized phenotypically [12]. In our best information, there are numerous studies on Zulu sheep, such as morphological structure [12], morphological differentiation [3], semen quality in different ages [34], and seasons [37].

Phenotypically, BaPedi sheep are white with brown head [16]; however, no specific studies characterize their phenotype appearances.

Damara sheep, on the other hand, is the most secure breed because of its commercialization in other countries such as Namibia [14]. Phenotypically, the Damara sheep is a large body frame and long-legged breed [15]. It can come as white, brown, black and white roan, doberman, or black [17]. Despite its internationalization, at a country level in South Africa, the Damara breed is at risk of extinction [16].

Genetic characterization could be described as the detection of variation as a result of differences in either DNA sequences or the genetic buildup of the individual [38]. Genetic characterization has been conducted in South African indigenous breeds [8]. Brief results of genetic characterization studies performed in South African indigenous breeds following the use of Ovine 50 k Chip and Microsatellites markers are summarized in Table 4. Buduram [29] revealed three different clusters where Persian, Dorper, Van Rooy, Damara, and Namaqua Afrikaner showed a close cluster. Zulu sheep in the same study clustered with Swazi, Karakul and Blinkhaar Randerib. These close clusters between South African indigenous breeds and composite breeds are due to the role of South African indigenous breeds in developing composite breeds [28]. BaPedi breed was not associated with any of these breeds analyzed by Buduram [29], suggesting less use in developing composite breeds.

Table 4. Genetic diversity of South African indigenous sheep breeds characterized using Ovine 50 k Chip and Microsatellites markers.

Markers	Type of Breed	Sampling Area	Ho	He	MAF	Fis	*p*-Value	Reference
Ovine 50 k Chip	BaPedi	Gauteng province	0.28 ± 0.22	0.28 ± 0.18	0.18 ± 0.16	−0.104	0.988	[8]
	Zulu	KwaZulu Natal province	0.32 ± 1.77	0.32 ± 1.60	0.24 ± 0.15	0.028	0.237	[8]
	Damara	Limpopo province	0.42 ± 0.18	0.40 ± 0.14	0.35 ± 0.16	0.017	0.343	[8]
	Namaqua Afrikaner	Northern Cape	0.26 ± 0.21	0.25 ± 0.19	0.18 ± 0.16	−0.017	0.591	[8]
		Western Cape	0.295 ± 0.22	0.280 ± 0.18	0.218	0.237 ± 0.05	-	[39]
Microsatellites	Zulu	KwaZulu Natal province	0.58 ± 0.02	0.57 ± 0.03	3.73 ± 1.34	−0.01	-	[7]
	Zulu	KwaZulu-Natal province	0.57 ± 0.2	0.61 ± 0.03	5.02 ± 1.98	0.0662	-	[38]
	BaPedi	Limpopo province	0.60 ± 0.05	0.76 ± 0.03	7.2 ± 0.4	0.19	-	[22]

Note: Ho—observed heterozygosity, He—expected heterozygosity, MAF—Minor Allele Frequencies Fis—inbreeding coefficient and SD—Standard Deviation.

A study by Kunene et al. [38] characterized Zulu sheep using microsatellites markers. In this study, Zulu sheep presented unique genetic characteristics, necessitating an exchange of rams for breeding among smallholder farmers. However, Selepe et al. [7], on the other hand, presented a mixture of Zulu sheep genetic material with composite breeds such as Dorper. Uncontrolled breeding strategies might be a primary cause of this mixture.

5. Conservation Approaches and Progress

Farm animal genetic resources (FAnGR) can be conserved in two different ways (Figure 2), either in situ or ex situ [40]. In situ can be defined as a type of conservation that occurs in the natural habitat of the animal, whereas ex situ involves the in vivo and in vitro [41]. In vivo could be defined as a type of conservation that occurs in a controlled environment. In vitro involves the preservation of gametes and the use of advanced reproductive biotechnologies.

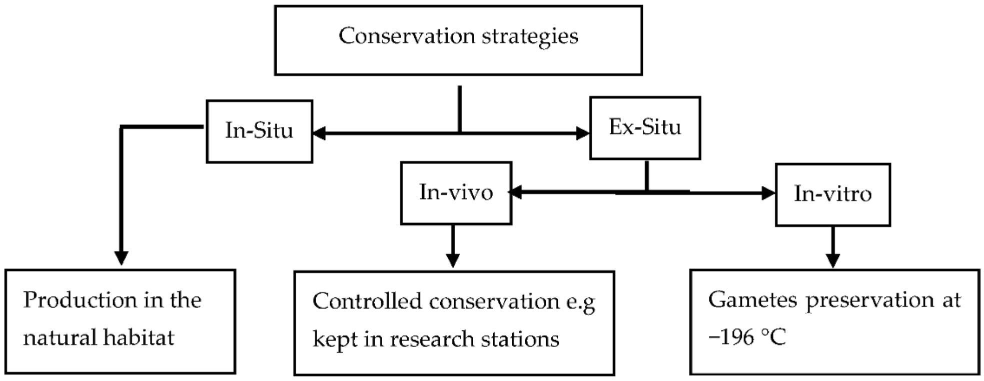

Figure 2. Different methods of livestock conservation [40].

In our view, in situ conservation of South African indigenous breeds is a challenge due to the lack of understanding of the importance of conservation in the rural farmers that was reported by Mavule et al. [2]. Therefore, ex situ conservation (in vivo and in vitro) has been a vital method to conserve these breeds (Tables 5 and 6). For instance, Zulu and BaPedi sheep are kept at the Agricultural Research Council (controlled environment) for in vivo conservation. Mara research station also kept some population of BaPedi sheep [21]. Makhathini Research Station also kept some population of the Zulu sheep population [9]. Namaqua Afrikaners are kept at the Carnarvon and Karakul experimental station near Upington in the Northern Cape Province [42]. However, Selepe et al. [7] reported that at the Makhathini Research Station, there is a mixture of Zulu sheep genetic material with locally developed breeds, especially Dorper sheep. This raises concern about whether the in vivo conservation is useful, especially when a research station has more than one type of breed.

Table 5. In vivo conservation of South African indigenous breeds [16].

Population Data	Zulu Sheep	BaPedi Sheep	Namaqua Afrikaner	Damara Sheep
Reporting year	2019	2019	2019	2019
Number of herds in the program	2	1	-	-
Number of males in the program	172	17	-	-
Number of females in the program	304	42	-	-
Conservation site	Dundee and Makhathini research station	Mara research station	-	-

Table 6. In vitro conservation of South African indigenous sheep breeds [16].

Breed	Zulu Sheep	BaPedi Sheep	Namaqua Afrikaner	Damara Sheep
Reporting year	2021	2021	2021	2021
Semen samples frozen	526 straws	31 straws	-	-
Semen donors	5	-	-	-
Embryos sample collected	0	413	-	-
Oocytes samples collected	0	-	-	-
DNA samples	-	461	-	-
DNA male donors	-	29	-	-
DNA female donors	-	431	-	-
Total DNA donors	-	461		-
Sample collectors	Agricultural Research Council	Agricultural Research Council	Agricultural Research Council	-
Breed extinction status	At risk	At risk	At risk	At risk

Oestrous synchronization and response: Advanced reproductive biotechnologies such as the oestrus synchronization have been used in South African indigenous sheep (Table 7) [43]. Moreover, semen from these breeds has also been cryopreserved [44,45]. However, fewer data are available for artificial insemination using post-thawed semen. This might be due to the poor post-thawed sperm quality [46].

Table 7. Oestrous response and fertility of South African indigenous breeds [43].

Parameters	BaPedi Sheep	Zulu Sheep	Namaqua Afrikaner Sheep	Damara Sheep
Oestrous response	88%	83%	100%	70%
Conception rate	84%	86%	44%	70%
Lambing rate	88%	89%	44%	60%

Ngcobo et al. [43] observed low birth weight in South African indigenous breeds not exceeding 5 kg (Table 8), with no birth difficulties. Zulu sheep are smaller than BaPedi, Namaqua, and Damara. The birth weight of Zulu sheep is also smaller than that of other South African indigenous breeds (Table 8). However, no significant differences between Zulu, BaPedi, and Damara for lamb weaning weights. Ngcobo et al. [43] concluded that Zulu sheep are more fertile than other South African indigenous breeds following synchronization due to the higher twinning rate (53%) and quadruplets (3%) (Table 9) [43].

Table 8. The birth, weaning weight and mortality rate of South African indigenous sheep breeds [43].

Breed	Lamb Birth Weight (kg) (Mean ± SE)	Lamb Weanig Weight (kg) (Mean ± SE)	Mortality Rate (%)
Zulu sheep	2.8 ± 0.1^{b}	11.6 ± 0.5^{ab}	$31\ (17/55)^{c}$
BaPedi sheep	3.1 ± 0.1^{b}	13.4 ± 0.7^{ab}	$29\ (9/31)^{c}$
Namaqua Afrikaner sheep	3.1 ± 0.2^{b}	10.5 ± 0.8^{b}	$44\ (4/9)^{b}$
Damara sheep	3.9 ± 0.2^{a}	14.1 ± 1.2^{a}	$67\ (6/9)^{a}$

NB; Values with different superscripts within a column differ significantly ($p < 0.05$).

Table 9. Litter size of South African indigenous sheep [43].

Breed	Single (%)	Twins (%)	Triplets (%)	Quadurpulets (%)
Zulu sheep	$28\ (10/36)^{d}$	$53\ (19/36)^{a}$	$3\ (1/36)^{a}$	$3\ (1/36)^{a}$
BaPedi sheep	$68\ (17/25)^{a}$	$28\ (7/25)^{b}$	0 (0/25)	0 (0/25)
Namaqua Afrikaner sheep	$33\ (3/9)^{c}$	$11\ (1/9)^{c}$	$11\ (1/9)^{a}$	0 (0/9)
Damara sheep	$50\ (5/10)^{b}$	$20\ (2/10)^{b}$	0 (0/10)	0 (0/10)

NB; Values with different superscripts within a column differ significantly ($p < 0.05$).

Semen characteristic: Semen has been characterized in South African indigenous rams (Table 10). There are numerous studies conducted to evaluate semen characteristics of South African indigenous rams [36,37,45,47].

Table 10. Semen characteristics of South African indigenous sheep breeds.

Sheep Breed	Semen Volume	Semen pH	Sperm Concentration	Progressive Motility	Total Motility	Reference
Zulu	1.1 ± 0.1	6.4 ± 0.1	4.0 ± 0.2	82.8 ± 2.6	84.0 ± 2.6	[36]
Zulu	0.97 ± 0.25	6.54 ± 0.98	5.29 ± 0.36	22.19 ± 0.82	91.30 ± 0.70	[37]
BaPedi	1.1 ± 0.4	7.8 ± 0.5	2.1 ± 0.2	34.5 ± 13.6	94.2 ± 13.2	[47]
Namaqua Afrikaner	0.9 ± 0.2	7.3 ± 0.3	1.2 ± 30.5	17.4 ± 14.7	37.1 ± 19.9	[45]
Damara	0.4 ± 0.1	7.3 ± 0.3	1.3 ± 48.5	36.4 ± 15.1	69.6 ± 16.5	[45]

6. Difficulties during Farm Animal Genetic Resource Conservation

6.1. Inbreeding

The South African indigenous breeds have small body frames and slow growth rates; hence, they are not suitable for commercial rearing [11]. Therefore, smallholder farmers use composite breeds to improve the body size and growth rate of indigenous animals [42], leading to genetic erosion. Smallholder farmers keep a small sheep population size (<10 sheep per flock) [10], making it impossible for animals to mate randomly and avoid inbreeding [48]. Repeated inbreeding over generations can lead to inbreeding depression [49]. Inbreeding depression refers to the decrease in mean phenotypic value with the increased level of inbreeding [49].

Smallholder farmers practice uncontrolled breeding whereby rams walk around with ewes and are confined in the kraal at night [2]. In this farming system, lambs are born all year round due to uncontrolled breeding; hence, many lambs fail to survive due to undesirable climate conditions. On the other hand, young rams mate with their mothers and sisters, resulting in inbreeding depression. This management practice depicts a lack of inbreeding and unnecessary crossbreeding knowledge. Breeding related sheep sharing a common ancestor reduces allelic variations, suppresses desirable alleles, and accumulates deleterious recessive alleles [6]. This further decrease female reproductive fitness [50], decrease the hardiness of the breed and phenotypic value [49], and even body weight [51].

6.2. Globalization

Globalization could be defined as the process whereby businesses are influenced by international standards [52]. Globalization accelerates the extinction of animals because farmers crossbreed indigenous breeds that have to compete with the exotic breed. For instance, Namaqua Afrikaner stores fat reserves in its tail, resulting in poor fat distribution throughout the carcass [53]. Therefore, this breed cannot compete with exotic meat purpose breeds for carcass quality. Nevertheless, this breed displays satisfactory levels of production and reproduction rate, which are analogous to those of commercial breeds [54].

6.3. Urbanization

Urbanization could be defined as a movement of people from rural areas to urban areas [2]. People move to urban areas to look for better employment opportunities but collapsing traditional subsistence farming cause land abandonment leading to ghost houses and farms [55]. Mavule et al. [11] reported urbanization as another factor leading to the loss of indigenous breeds. In this case, young people move to urban areas to look for job opportunities leaving adult people who cannot look after sheep. As mentioned before, the adult population in South Africa is made up of illiterate people mostly, who cannot grasp new technologies such as advanced reproductive biotechnologies.

6.4. Climate Change

The shifting of climate temperature and weather are caused by human activities [56]. This latter comes to play an adverse effect on livestock production through drought and heat [57]. Smallholder farmers cannot contend with the effect of climate change due to the lack of capital and resources [58]. South Africa is one of those developing countries that are adversely affected by climate change [59].

In South Africa, smallholder farmers are mostly affected by climate change [60] hence selling their animals at a cheap price [61]. In two provinces (Limpopo and Mpumalanga) of South Africa, 90% of farmers confirmed a change in grass availability, in which 55.19% of farmers attested that this was a cause of livestock fatalities [62].

6.5. Lack of Resources

The lack of necessary resources such as buildings, machinery, and irrigation equipment has been identified as the main challenge [58]. Veterinary service, on the other hand, has been a major problem for smallholder farmers [2].

6.5.1. Water Scarcity/Lack of Irrigation Equipment and Drought

Water scarcity is a major problem associated with the decrease in sheep performance [63]. Prolonged drought as a result of climate change results in limited water availability for livestock [57]. According to Halimani et al. [61], water scarcity at the smallholder farming level has an adverse effect because rural farmers cannot provide alternative water sources (Figure 3), leading to the unplanned selling of their sheep at a low price [61].

Only 1% of smallholder farmers have access to tap water and only 6.2% afford to erect boreholes [12].

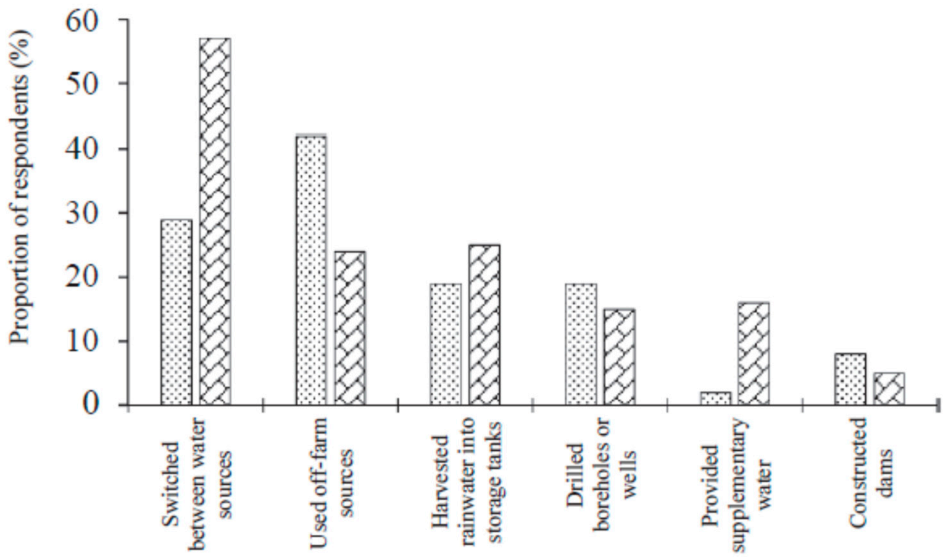

Figure 3. Water scarcity effect between smallholder farmers and commercial farmers [61]. The dotted bar represents commercial farming and the block bar represent smallholder farming level.

Drought, on the other hand, could be defined as an extended period of no rainfall. Studies by [12,64] identified droughts as the main cause of mortality (43.8%) of South African indigenous sheep [12]. In this study, farmers confirmed that sheep walk > 1 km in search of water, especially during winter. Most of the smallholder farmers (91.7%) drive their sheep to the nearby rivers to drink. Some farmers (18.8%) opt to fetch water from rivers and bring it to the kraals for sheep.

6.5.2. Lack of Veterinary Service

Diseases cause about 69.4% of lamb mortality in South African indigenous sheep [12]. Moreover, about 28.2% mortality of matured South African indigenous sheep was reported [12]. Extreme temperatures due to climate change may result in the outbreak of diseases such as brucellosis, foot and mouth, red-water, and tick-borne diseases [59]. With less veterinary service and knowledge that rural farmers have, these diseases wipe their animals off, leading to a decrease in the indigenous sheep population.

6.5.3. Lack of Knowledge/Education

Awareness of the global call for the conservation of farm animal genetic resources (AnGR) is still lacking among South African smallholder farmers [12]. There are smallholder farmers (10%) who find AnGR conservation not important [12]. Moreover, some (18.8%) keep indigenous sheep but find them insignificant [3]. Those who find indigenous breeds important are because of their adaptability.

In Africa, much of the old age group could not read and write due to the lack of access to education during apartheid [65]. For instance, Kunene and Fossey [31] reported that old people (40–50 years old) are the ones dominating sheep farming in KwaZulu Natal, South Africa. Forty percent of these farmers hold no academic qualifications [66], hindering conservation information dissemination. Illiterate can be a serious obstacle in retrieving newly developed technologies [67], such as artificial insemination and estrous synchronization. These are vital technologies used to improve the genetic material of livestock animals [68]. On the other hand, smallholder farmers (70.9%) do not know when to sell their animals (e.g., selling old ewes and unproductive rams), and some sell due to their needs [10]. Therefore, the government and stakeholders on the other hand need to encourage young people to raise indigenous sheep for effective training to conserve this superior genetic material.

7. Future Prospects or Solutions to Improve South African Indigenous Sheep Breeds

7.1. Gametes Cryo Conservation

Cryo conservation is one of the major strategies in conserving farm animal genetic resources and provides opportunities to improve animal genetic material at a cheaper cost [69]. This includes semen collection, oocytes retrieval, and cryopreservation.

7.1.1. Semen Cryopreservation

Semen can be collected either by electro-ejaculator or artificial vagina in small stock animals [70]. After collection, semen should be analyzed for motility, morphology, concentration, and pH [34,47]. These semen parameters are essential for concluding semen quality. Computers, expensive microscopes, and laboratory consumables are needed for these analyses. Not all smallholder farmers can afford research stations to do these analyses.

Even though semen cryopreservation is the only ART allowing the use of semen even after the death of the sire, in sheep, only ±60% remain viable and motile post-frozen–thawed [71]. Furthermore, among ±60% of spermatozoa retained post-thawed viability and motility, only ±30% remain biological functional [72].

7.1.2. Oocytes Cryopreservation

According to the Data Retrieval Committee of the International Embryo Transfer Society [18], millions of domestic animals are born because of assisted reproductive biotechnologies (ART). Furthermore, retrieving oocytes from the slaughtered donor of a good genetic material decreases the generation interval by almost 5–6 months [1]. However, despite these advantages of ARTs, there has been a noticeable decline regarding in-vitro-produced embryos globally, with no reported sheep embryo produced in Africa [18].

Follicular fluid retrieval methods: Oocytes can be retrieved either by slicing or aspiration [73]. According to Shiraz et al. [74], slicing yields better oocytes (grade A) considerable for in vitro maturation than the aspiration method. However, these methods (slicing and aspiration) are associated with vast disadvantages leading to cumulus damages. Disadvantages of slicing include: too much blood that leads to many oocytes washing before fertilization, whereas the size of the needle and the pressure applied during follicular fluid retrieval forms a major disadvantage of the aspiration method.

Oocyte donors: In the normal circumstance in South Africa, in vitro fertilization studies rely solely on the abattoir for ovary collection [74,75]. This alone hinders the success of the conservation program because the history of that donor is not known [76]. Moreover, nutrition, management, environment, and the climate have been proven to affect reproduction adversely [77]. Therefore, when ovaries are collected in the abattoir, it is very unlikely to be provided with such information. Thus, these hindrances associated with aspiration and slicing, as well as the ovaries collected from the abattoir, led to the development of the new method of collecting follicular fluid known as laparoscopic ovum-pic up (L-OP). Laparoscopic ovum-pic up (L-OP) is a non-invasive method but expensive and less used in ovine but with satisfying results when used in sheep [78]. This method was developed around 1984 by Pierre Dellenbach and colleagues in Strasbourg [79]. This method involves synchronization and the superovulation of the donor and can be a helpful method in the conservation of South African indigenous sheep because it can be performed on live animals. However, it is very expensive for smallholder farmers.

Oocyte cryopreservation: Gamete cryopreservation could be defined as the preservation of biological cells for many years at a lower temperature (−196 °C), reducing natural cellular biochemical processes [80]. Both semen [81] and oocytes [82] have been successfully frozen in cattle. However, it has not been the case in ovines [83]; hence, conserving indigenous sheep in South Africa has been a challenge [19]. Among challenges that have been reported to hinder the oocyte freezing in ovine, complicated retrieval methods and apoptosis has been reported as major problems [84]. Apoptosis is defined as programmed cell death [85]. This type of cell death in oocyte development generally occurs at a primordial germ cell stage and throughout oogenesis [84].

Oocyte quality before and after freezing determines the in vitro maturation and fertilization success [86]. The follicular fluid retrieval process is complex, especially in sheep [87]. Nevertheless, with this technology, animals can produce offspring even after their own life. However, involves the preservation of gametes at a low temperature of −196 °C. However, in vitro maturation and embryo transfer yield about 10–19.4% of lambs born after this technology [87]. There are numerous factors contributing to poor in-vitro-produced embryos, including the quality of oocytes used and sometimes mediums used [88,89]. Noteworthy, there are new promising techniques such addition of exogenous glutathione to improve survival rate [90].

7.2. Genetic Improvement Programs

There are genetic improvement programs at a South African national level managed by the South African Department of Agriculture, Land Reform, and Rural Development (DALRRD). For instance, Namaqua Afrikaner is conserved in the Northern Cape Department of Agriculture, Cannavon research station, and in Grootfontein Agricultural Development Institute [91], Karakul, and kept by a commercial farmer at Welgeluk in the Carnavon district [5]. All these Namaqua Afrikaner flocks are direct contributors to the GADI-biobank.

Zulu and BaPedi sheep flock, on the other hand, are maintained by the Agricultural Research Council, Animal Production Institute. Conservation projects of South African indigenous sheep breeds include maintaining a live herd, and surplus from these programs is sold or handed over to the farmers to improve genetic diversity [40]. Moreover, research stations such as Agricultural Research Council, Animal Production Institute, and Grootfontein maintain gene banks for embryos and semen, blood, and DNA for later use in case of extinction [91,92].

The Department of Agriculture, Land Reform, and Rural Development also developed an information system on animal genetic resources as the Integrated Registration and Genetic Information System (INTERGIS) [40]. In this system, information such as breed characteristics, population trends, and semen availability are stored.

8. Conclusions

Despite government intervention, South African indigenous sheep breeds (Zulu, BaPedi, Namaqua Afrikaner, and Damara) are still at risk of extinction. This review revealed various difficulties accelerating the population decline of these breeds. Among challenges, inbreeding and the lack of resources are the most factors catalyzing population decline and genetic erosion of these breeds. Fortunately, there are conservation measures (in situ and ex situ) in place to save these breeds. Nevertheless, the application of advanced reproductive biotechnologies (estrous synchronization and gametes preservations) is lacking at the farm level due to the distances between smallholder farmers and research stations. The lack of community-based conservation programs is still problematic, given that these breeds are mostly found in rural communities. Moreover, South African indigenous sheep keepers are adult people, hampering proper information dissemination and awareness about farm animals' genetic conservation and the value of indigenous breeds.

Author Contributions: Writing—original draft preparation, J.N.N.; writing—review and editing, J.N.N., F.V.R., T.J.M., K.A.N. and T.C.C.; supervision, T.L.N. and F.V.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Department of Agriculture, Land Reform and Rural Development (DALRRD)-Farm Animal Genetic Resource (FAnGR) project number 21.1.1/18/GR-02/API and Agricultural Research Council project number P02000172.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Authors would like to acknowledge the following institution for funding: Agriculture Sector Education Training Authority (AgriSETA) and the National Research Foundation (NRF)—DAAD (Deutscher Akademischer Austauschdienst) Scholarship (DAAD-NRF scholarship) and the Tshwane University of Technology (TUT).

Conflicts of Interest: The authors declare no conflict of interest.

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