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From expectations to performance: a mixed-method approach evaluating newly-introduced cattle breeds in Himba pastoral systems

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Title: From expectations to performance: a mixed-method approach evaluating newly-introduced cattle breeds in Himba pastoral systems

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Abstract

In Namibia, livestock improvement programmes promoted genetic "upgrading" in communal areas through breeding-bull distribution to improve productivity and carcass quality, reflecting perceptions that indigenous Nguni cattle's small body size and low growth rate, generate lower returns when sold. Himba pastoralists have also independently introduced new cattle breeds and crosses, expecting higher milk and meat production. However, whether these productive advantages translate into better reproductive and economic performance under highly-variable pastoral conditions remains poorly understood. Data were collected using mixed-methods. In 44 semi-structured interviews, three group discussions, and extended participatory observation, Himba pastoralists' motivations and expectations for keeping introduced breeds and maintaining breed diversity were examined. We compared age at first calving (AFC), inter-calving interval (ICI), factors affecting reproduction, and sale prices among indigenous, acquired, and crossbred cattle based on 27 progeny-history interviews covering 125 cows

and longitudinal cattle-sale records from 36 herds in three study locations in Kunene North. Pastoralists valued acquired and crossbred cattle for their higher milk-production potential, meat yield, and social status, whereas Nguni cattle were valued for reproductive performance, maintaining good body condition during dry-season and demanding less labour. Nguni cows had a mean AFC of 43.7 months, similar to crossbreds (43.7 months) but earlier than acquired breeds (52.9 months). Their mean ICI was also shorter (15.0 months) than acquired (18.6 months) and crossbred (18.4 months). While droughts mainly affected Nguni reproduction, acquired and crossbred cattle could not fully meet their higher nutritional requirements during regular dry-seasons, partly because they were kept for their milk-production potential. Breed group was not significantly associated with sale price after accounting for age–sex class, season, and sale-location ($p = 0.465$). These findings show that higher production potential alone does not determine cattle performance in pastoral systems. Under dry, highly-variable conditions, features enabling use of scarce, dispersed forage resources, and maintaining reproductive performance become important. Livestock improvement strategies should recognize pastoralists' detailed knowledge of breeds' performance under environmental and husbandry conditions of their production systems, to reduce failure risk in interventions aimed at enhancing milk and meat output.

Key words: Nguni; breed diversification; rangeland adaptation; reproductive performance; cattle prices, Namibia

Introduction

Pastoral livestock keepers across Africa rely on keeping locally adapted cattle breeds, but are also increasingly introducing foreign breeds and their crosses into their herds. Specifically, larger-framed breeds with higher milk production and growth rates, as well as their crosses, are increasingly incorporated into pastoral herds (Kamuanga et al. 1999 in a review in three west African countries; Jabbar and Diedhiou 2003 in a review in Nigeria; Ilatsia et al. 2012; Traoré et al. 2018 in Mali; Houessou et al. 2022 in Benin; Bereda et al. 2024 in Ethiopia).

However, the highly variable conditions of arid rangelands, characterised by spatially and temporally uneven resource distribution (African Union Commision 2010) limit the performance and survival of these introduced breeds (Bester et al. 2003; Köhler-Rollefson et al. 2009), particularly during dry seasons and droughts. As pastoralists use strategic mobility to access variable rangeland resources throughout the year (Kratli and Schareika 2010; Scoones 2023), the indigenous breeds possess physiological and behavioural adaptations that enable them to sustain production and reproduction under these conditions (Poland et al. 2003; Köhler-Rollefson and Mathias 2010), whereas introduced breeds often lack the adaptive traits required to thrive in such mobile production systems (Bester et al. 2003; Köhler-Rollefson et al. 2009).

For the Himba pastoralists, in northern Kunene, cattle fulfil nutritional, economic, cultural and spiritual functions. Besides providing milk and meat, cattle are central to ancestral commemorations, healing rituals and wedding ceremonies, while also serving as an important store of wealth and medium of exchange (Crandall 2002; Bollig 2006; Hangara et al. 2020), and thereby also contribute to social status. Within Himba communities, during dry periods when fodder becomes scarce near their permanent settlements, herders move their animals to distant and, in some areas, elevated mountain pastures, and return to the valleys surrounding their permanent homesteads once rainfall has resulted in new growth of forage (Behnke 1999; Crandall 2002; Bollig 2006). Given the rugged terrain and long distance dry-season grazing areas, cattle must be capable of reaching these pastures for their nutritional requirements (Nuule et al. in preparation).

The Nguni cattle breed, originally kept by Himba pastoralists, is a hardy, small-framed breed that is well adapted to the conditions of Kunene region (Bollig 2006; Hangara 2020). Similar to pastoralists elsewhere in Africa, Himba herders maintain indigenous Nguni cattle while

also incorporating introduced breeds to combine adaptive and productive traits (Ilatsia et al. 2012; Traoré et al. 2017; Houessou et al. 2022; Bereda et al. 2024). They therefore intentionally maintain breed diversity within their herds.

This strategy is consistent with findings from Kenya, where pastoralists valued indigenous breeds for drought tolerance, disease resistance and adaptation, while introduced Sahiwal cattle were preferred for productivity and fertility despite their lower environmental adaptation (Ilatsia et al. 2012).

Likewise, studies across East and West Africa have shown that introduced high-producing breeds are primarily adopted to increase household income and food security through milk production (Green et al. 2017; Balirwa and Emmanuel 2018; Marshall et al. 2020; Bereda et al. 2024). However, these productivity gains generally depend on substantial changes in animal husbandry practices to accommodate their specific requirements (Green et al. 2017).

In Namibia, livestock improvement programmes implemented by the Ministry of Agriculture, Water and Land Reform, Meatco Foundation, Meat Board of Namibia and other organisations promoted genetic upgrading in communal areas through the distribution of breeding bulls. One prominent example is the Bull Scheme, which introduced breeds such as Brahman and Simmental to improve reproductive performance and carcass quality. The programme was motivated by the perception that indigenous Nguni cattle, owing to their relatively small body size, did not meet the commercial slaughter standards (Meatco Foundation 2016), resulting in livestock keepers receiving low prices in livestock and meat markets. According to the Meatco report (2016), the bulls were part of the Meatco Foundation's 'Sustainable Cattle Production in Namibia' initiative. The objective of bull allocation was to 'help farmers whose livelihood depends mainly on farming, to improve the genetics of their herd in respect of reproductive capacity and suitability for slaughter'.

While these initiatives were implemented with the objective of enhancing reproductive performance and carcass quality in communal areas such as northern Kunene (The Namibian 2014; Meatco Foundation 2016), the performance of these introduced breeds under pastoral production conditions has not been evaluated.

Although the last Bull Scheme projected was implemented in 2015, herders in northern Kunene have independently continued to acquire new breeds such as Brahman, Herero, Afrikaner and Simmental aiming for breed diversity in their herds (as discussed in Nuule et al. in preparation). However, the productive and reproductive performance of these newly introduced breeds in the area has not been quantitatively evaluated to determine whether they meet the objectives the pastoral livestock keepers were hoping to achieve when they purchased them. One study that assessed the bull scheme project (Marius et al. 2022) focused on comparing herd sizes before and after the bull scheme and examining changes in the weight of animals sold and income earned by the beneficiaries. Although Marius et al. (2022) reported increases in the weight of animals sold and beneficiaries' income following implementation of the scheme, the study did not provide sufficient details to establish whether the animals sold were offspring of the introduced breeds. Moreover, given that the bulls had been present in the herds for only five years upon scheme evaluation, it remains unclear whether the reported improvements can be attributed to the scheme. This uncertainty is reinforced by their finding that, by the fifth year, only 46% of the bulls introduced through the scheme remained alive and available for breeding; the remainder had died, been sold, castrated, gone missing, or been returned to the scheme (Marius et al. 2022).

Further comparative evidence from Southern African systems remains limited. Research conducted in Eastern and Western Africa has shown that introduced breeds exhibit better production, higher reproductive performance, and higher market value than local breeds. However, achieving these outcomes required considerable interventions and inputs, such as

124 artificial insemination, supplementation, close veterinary services, and vaccination training of
125 farmers (Masama et al. 2003; Maichomo et al. 2009; Ilatsia et al. 2012; Houessou et al. 2022;
126 Bereda et al. 2024; Ssekibaala et al. 2025). Such interventions are absent in Kunene North.

127 In Namibia, studies on breed comparison have been confined to research stations (a review
128 by Schoeman 1989; Lepen 1996a; Lepen 1996b; Samkange et al. 2019), but comparison
129 under pastoral production conditions could not be located in literature. Therefore, the aim of
130 this study was to compare the reproductive performance and the market value (in this case,
131 the sales prices achieved) of the introduced breeds and their crosses with those of the
132 indigenous Nguni breed under the pastoral production conditions in northern Kunene. The
133 purpose of this assessment was to determine whether the pastoralists' perspectives regarding
134 the performance of various (cross-) breeds are reflected in the performance data from their
135 herds. The study used a mixed method approach that combines qualitative information on
136 herders' perspectives with quantitative data collection on performance parameters and cattle
137 sale prices. The specific objectives of this study were:

138 1. To identify the cattle traits that motivate livestock keepers to introduce new cattle
139 breeds into their herds, and strive for breed diversity
140 2. To compare the reproductive performance of Nguni, cross breed (CB), and acquired
141 breed (AB) groups kept under pastoral management in northern Kunene
142 3. To investigate the factors influencing reproductive performance among the breed
143 groups as perceived by Himba pastoralists
144 4. To compare the sale prices of cattle across different breed groups and the factors
145 affecting cattle prices in the local markets of northern Kunene

Materials and methods

Description of the study area

The study was conducted in Epupa constituency, located at coordinates -17°00’13.97"S 13°14’53.70" E), in the northern part of the Kunene region, in north-western Namibia (Fig. 1). In this study, this area is referred to as Kunene North, covering approximately 23,617 km² with an estimated population of 26,491 (Namibia Statistics Agency 2024).

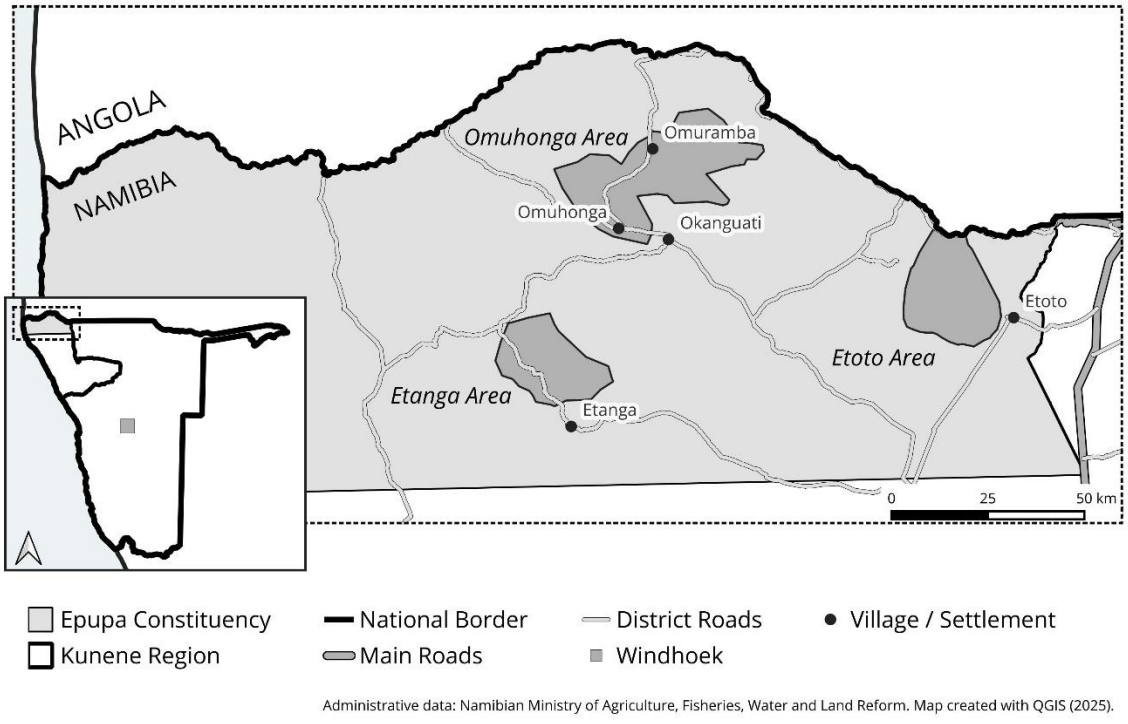


Fig. 1 A map showing the location of the study area. The map was adapted from QGIS software

Kunene North is predominantly occupied by Himba pastoralists, who speak OtjiHimba, a dialect of OtjiHerero. Their livelihood mainly involves the rearing of cattle, sheep, and goats, and is supplemented by the rain-fed crop cultivation in small gardens along riverbeds. The Himba's diet is largely composed of sour milk from cattle and goats, along with maize porridge. Livestock provide the primary source of milk and meat and are bartered for maize, clothing, blankets, and other products. Goats are frequently sold to meet household

expenditures, whereas cattle are sold less often but play a vital role in cultural ceremonies and rituals (Bollig 2006; Hangara et al. 2020). Moreover, livestock are exchanged for livestock species or breeds.

The temperatures in Kunene North usually fluctuate between 5°C at night and 26°C during day in winter, while summer temperatures range from 14°C to 35°C (Namibia Planning Commission 2015). Like the rest of Namibia, Kunene North is characterized by an arid climate with low and erratic rainfall. Annual rainfall increases from the west to the east and ranges from 50 mm and 400 mm. November typically marks the onset of the rainy season, however, most rainfall occurs between February and April, while the remaining months constitute the dry season. Himba pastoralists divide the year into four distinct seasons, each comprising three months: *oruteni*, the onset of rains – starting from November to January; *okuroro,* the rainy season – occurs from February to April; *okupepera,* the cold-dry season – extending from May to July and *okuni*, the hot-dry season – occurring between August to October (Behnke 1999; Crandall 1998). Years of exceptionally poor rainfall, resulting in fodder shortages and livestock mortality, are referred to as *ourumbu* (drought). Bollig (1997) reported that Kunene North has experienced a prolonged dry spell since the mid-1970s.

The elevation in the Kunene region ranges from -2 to 2,398 m above sea level, with an average elevation of 772 m (Topographic-map.com, 2026). Kunene North is characterised by extensive plains and interspersed with mountain ranges. The study was conducted in three locations: Etanga, Etoto and Omuhonga, which differ in topographic relief. Omuhonga is characterized by rocky, rugged terrain with steep slopes and a mountainous topography. Etoto is moderately rocky with a gradual incline that forms a plateau at the top. Etanga exhibits gentle slopes and, according to herders, is characterised by rolling hills rather than steep mountains.

185 The main town of Kunene region is Opuwo, located approximately 115 km from Omuhonga,
186 130 km from Etoto and 100 km from Etanga. The people of Etoto also travel to Ruacana, a
187 town in the Omusati region of Ovamboland, which is located about 60 km away.

188 ***Sampling strategy***

189 Participants were selected from a list of 50 contacts, which was developed through the first
190 author's relationship building with the communities. This relationship-building process
191 involved over 16 months of interaction with the pastoralists prior to data collection, allowing
192 the first author to gain insights into their daily activities such as milking practices, calving
193 management, livestock marketing procedures, as well as their perceptions of cattle breed-
194 rangeland interactions under local conditions. The selection process employed purposive
195 sampling, targeting individuals with extensive knowledge of their cattle production system,
196 such as knowledge of different cattle breeds, their productive and adaptive traits, grazing
197 behaviours, and human-animal-environmental interactions.

198 ***Data collection***

199 Data collection followed a mixed method approach, combining qualitative and quantitative
200 data. Data collection was carried out by the first author, with additional contributions from
201 the third author.

202 *Herd breed composition*

203 Between March 2023 and June 2024, a total of 44 semi-structured interviews and three group
204 discussions were conducted with Himba herders and herd owners. Participants were asked to
205 provide detailed information regarding the characteristics of different cattle families within
206 their herds comprising different breed groups, and to explain the reasons for keeping these

breeds. Additionally, they were asked to explain the benefits and challenges associated with maintaining multiple cattle breeds.

Reproductive performance

A total of 27 herders were selected for progeny history interviews between January 2025 and April 2025, based on their detailed knowledge of individual cows and their reproductive histories. Each herder was asked to identify the oldest three to five cows (depending on the herd size) in their herd, which resulted in the collection of progeny data for 125 cows. Of these, 76 were Nguni, 19 were CB, and 30 were AB.

For each cow, information was collected on breed, age, total number of calves born, the number of offspring still present in the herd, and age of first parturition. Follow-up questions were used to obtain qualitative information on factors influencing reproductive performance, including reasons for differences in offspring numbers among cows of the same age and variation in the age at first parturition. Additionally, three focus group discussions were conducted to understand the herders' views on the reproductive performance of cows of different breeds. The discussions explored whether herders had observed differences in the calving patterns among breeds groups and reasons underlying these differences .

The Himba estimate the age of their livestock by associating births to locally remembered events. For example, they reference years marked by severe droughts, the most recent drought, the passing of a prominent community elder, or the occurrence of a particular disease outbreak.

Cattle prices

Data concerning cattle prices and marketing were gathered from February 2023 to April 2024 by the third author, who conducted the interviews in Otjiherero, with the aim to document

cattle sales within Himba herds over a one-year period. In each study location, 12 herders were selected, and commenced with a semi-structured questionnaire in February 2023. Thereafter, these herders were revisited every 3 to 4 months to gather updated information on cattle sales using a fact sheet. During each follow-up visit, herders were asked whether they had sold cattle since the previous visit. For each cattle sale, the following information was recorded: breed, age and sex class, season of sale, type of buyer, location of sale, sale price in Namibian Dollars (NAD), and the herder's satisfaction with the price received.

All interviews conducted by the first author were facilitated by a research assistant who translated the questions from English into Otjiherero, and subsequently translated the participants' responses from Otjiherero into English for the interviewer. The interviews were recorded then translated and transcribed by a native speaker of the local Otjihimba language that is spoken by the herders, to ensure accuracy.

Data analysis

Statistical analysis

Quantitative analyses were conducted using Stata version 18. Differences in age at first calving and inter-calving interval among breed groups were assessed using one-way ANOVA, followed by Tukey's post hoc test for pairwise comparisons. Cattle sale prices were analysed using multiple linear regression with log-transformed sale price as the response variable and breed group, age-sex class, season, and sale location/distance as explanatory variables. For this analysis, acquired breeds (AB) and crossbreeds (CB) were combined into a single breed category because of the small number of sales within the individual groups. Robust standard errors were used. Buyer type was excluded from the final model because it was perfectly associated with sale location. Multicollinearity and influential observations were assessed using variance inflation factors and Cook's distance, respectively. Sensitivity

analysis was conducted by re-estimating the model after excluding influential observations (Cook's distance > 4/n). Statistical significance was set at $p < 0.05$.

Qualitative analysis

Qualitative data from semi-structured interviews and group discussions were analysed thematically. Interview transcripts and field notes were reviewed and coded according to recurring themes related to reasons for maintaining breed diversity, reproductive performance, cattle husbandry practices, and market value. Herders' explanations and perceptions were compared across breed groups and used to contextualise and interpret the quantitative findings.

Results

The results section begins with an overview of the breed composition of herds in the three study locations, and the reasons why pastoralists maintain different breeds groups. This is followed by results on reproductive performance among the breed groups. Finally, the market value of the breed groups and other factors influencing cattle prices in Kunene North are presented.

Herd-breed composition and reasons for keeping different breeds

The breed composition of herds in Kunene North varies across the three study locations (Table 1). In rocky, mountainous areas such as Omuhonga, herds predominantly consist of Nguni cattle (79%), compared with 40% in Etanga. While in flatter, sandy areas like Etanga, breeds less suited to rugged terrains account for 60% of the herd composition. Across all study sites, Nguni cattle represented the largest breed group (58%), followed by CB (27%), while AB accounted for 15% of the herd composition (Table 1).

277 **Table 1** Average percentage of cattle breeds by herd per study area

Area	Grazing Areas' Description	Nguni	Brahman	Herero	Afrikaner	Nguni x Brahman	Nguni x Herero	Nguni x Simmental
Omuhonga n=17	Rocky and rugged, steep mountains	79	1	5	0	7	7	2
Etoto n=12	Gradual slopes, moderately rocky with plateaus tops	56	9	5	6	4	17	3
Etanga n=15	Flat and hilly, easy to climb, rather sandy	40	3	16	0	22	15	4
		Nguni	AB			CB		
Total average %		58	15			27		

278 **Note:** The percentage of cattle breeds in the herd was calculated based on the breed distribution within cattle
279 families; n= number of herds.

280 Himba pastoralists associated acquired breeds primarily with higher milk production, larger
281 body size, faster growth and higher market value (Table 2). These large animals produce a lot
282 of meat, typically sufficient for the ceremonial events such as weddings, funerals and
283 ancestral commemorations. In contrast they stated that Nguni breed, which has a smaller
284 frame, necessitates the slaughter of multiple animals to produce sufficient meat, and is often
285 perceived as a low-value animal by buyers.

286 *'At events like funerals and ceremonies where we slaughter cattle, mostly when you slaughter*
287 *one of that kind [AB/CB], the entire village can eat and get satisfied by that Brahman. But*
288 *when you slaughter a Nguni, it will only be eaten by a few people. We can even eat it for just*
289 *two days and finish it, and by the third day, it would seem as if we never slaughtered*
290 *anything. Also, the Herero and Brahman have better prices when it comes to selling them;*
291 *they are very different from the Nguni when you are selling them. That is why we want them.'*
292 *Herder 5, Etoto, February 2024*

Moreover, Himba herders expressed that a household owing even a small number of AB/CB cattle is perceived as wealthier than one with a large Nguni herd. These breeds are considered highly valuable because they are expensive to acquire and are often referred to as '*white people's cattle'* a term linked to beliefs of white superiority. Consequently, ownership of these large-framed animals is associated with high social status.

'They [other herders] will be jealous of you and they would envy you because you have beautiful animals. Even if they have many Nguni cattle and you only have 20 Herero, they will still be jealous.' GD, Etanga, March 2025

Breed composition also influenced household relations, particularly the allocation of milking cows among wives: *'When you have two breeds and you have to give your wives milking cows [each wife is given her designated cows that she milks for her household], the one who gets the Nguni will feel unloved while the other one given the Herero will feel good. So, in most cases when you have to give a Nguni to a wife, they have to be two, which is equal to one Herero.' GD1, Omuhonga, January 2025*

On the other hand, herders reported that the Nguni cattle are well-adapted to the challenging conditions of Kunene North (Table 2). Nguni do not only make households resilient to recurrent droughts in the area, but also enables them to reproduce effectively, therefore herders continue to keep them. Herders indicated that the high reproduction rate of Nguni cattle promotes herd growth and allows for rapid recovery after droughts (Table 2). Furthermore, during drought periods, Nguni cattle require minimal effort from herders, as they can independently travel to water sources and climb mountains to access pasture. This contrasts with acquired breeds, which demand considerable effort.

'[During drought] The herder with the Nguni breed will not really stress because he knows that the cattle are able to survive. This is because the Nguni can climb the mountain that has

grass, while the other breeds cannot. The ones [herders] with the Brahman and Herero will struggle with them because they will not be able to come back to the water point for up to three days. That means you will need to take them to the mountain with grass and bring them back to water and sometimes you will notice that two of them are missing, but the Nguni cattle do not separate from each other. Even when we use the same water point, the herder with the Herero and Brahman will have to go and collect their cattle [from the mountain], while the one with the Nguni will go straight to the water point and wait for them [his cattle] there.' GD2, Omuhonga, January 2025

Furthermore, herders expressed that the heavy weight of the AB/CB cattle poses a challenge during the critical drought periods, when the animals become weakened by feed shortages thereby frequently requiring physical assistance to stand and reach water and pasture. Due to their heavy weight, more than one herder is needed to lift the animal, unlike the lighter Nguni breed, which can be assisted by a single herder. Herders further reported behavioural differences between breed groups, noting that Nguni attempts to cooperate by also trying to stand while being assisted, whereas the AB/CB breed tends to become annoyed and may even try to fight the herder who is trying to help. Additionally, when the AB/CB fails to stand, the herder must provide the animal with water and fodder. Given the animal's high feed requirements, this process demands considerable effort because animals usually need to be supported for up to a week to ensure their survival. In contrast, herders have reported that the Nguni, under similar conditions only requires feeding for about two days, after which it can stand and graze independently.

Moreover, herders emphasized their limited experience in keeping the recently introduced breeds, and thus felt they lack the knowledge required to care for them properly, unlike the Nguni cattle that they have been keeping throughout their lives.

341 **Table 2** Reasons for keeping different breed groups as perceived by Himba pastoralists

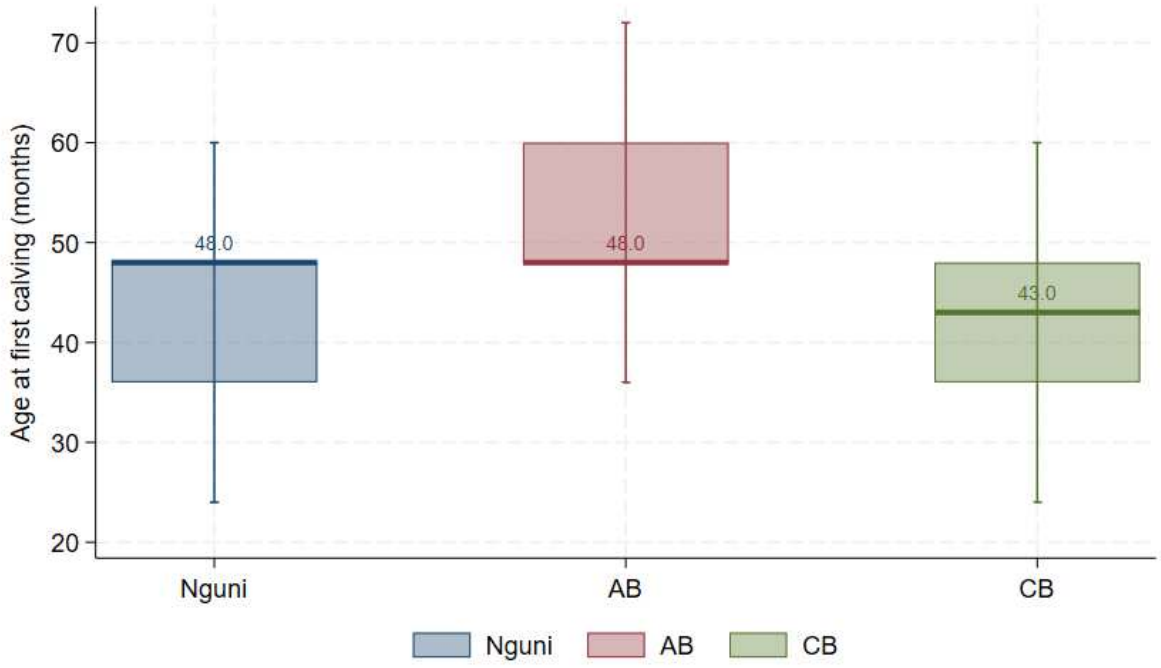
Breed	Reasons
Nguni	• Well-adapted to local conditions • Drought-resistant • High reproductive performance, promoting herd growth and post-drought recovery • Low labour requirements
Acquired Breeds (AB)	• High milk production • Large body size and high meat yield, high market value • Fast growth • High social status
Crossbreed animals (CB)	• Combination of parents' traits - Expression of traits from either parent breed - Better milk and meat yield than Nguni - Better adaptation than AB

342

343 ***Reproductive performance (RP) among the breed groups***

344 *Age at first calving (AFC)*

345 The herders' claims that the Nguni breed has better reproductive performance than acquired
346 breeds was supported by the analysis of age at first calving. Age at first calving differed
347 significantly among breed groups (one-way ANOVA: $F(2,116) = 8.12$, $p < 0.001$). AB cattle
348 calved on average at 52.9 months (Fig. 2), approximately nine months later than both Nguni
349 (43.7 months) and CB cattle (43.7 months). Tukey's post hoc comparisons confirmed that AB
350 cattle had a significantly higher age at first calving than both Nguni and CB cattle, whereas
351 no significant difference was observed between Nguni and CB cattle.



352

353 **Fig. 2** Age at first calving by breed group. Boxes represent the interquartile range, whiskers
354 extend to the most extreme values within 1.5 times the interquartile range, and horizontal
355 lines indicate medians. Diamonds (◆) and adjacent values indicate group means

Inter-calving Interval (ICI)

Inter-calving interval differed significantly among breed groups (one-way ANOVA: $F(2,116) = 8.15$, $p < 0.001$). Nguni cows had the shortest mean ICI (15.0 months), compared with 18.6 months for AB and 18.4 months for CB cows (Fig. 3). Tukey's post hoc comparisons showed that ICI was significantly longer in both AB (mean difference: 3.6 months, 95% CI: 0.7–6.5) and CB cows (mean difference: 3.4 months, 95% CI: 1.0–5.8) than in Nguni cows, whereas no significant difference was observed between AB and CB cows.

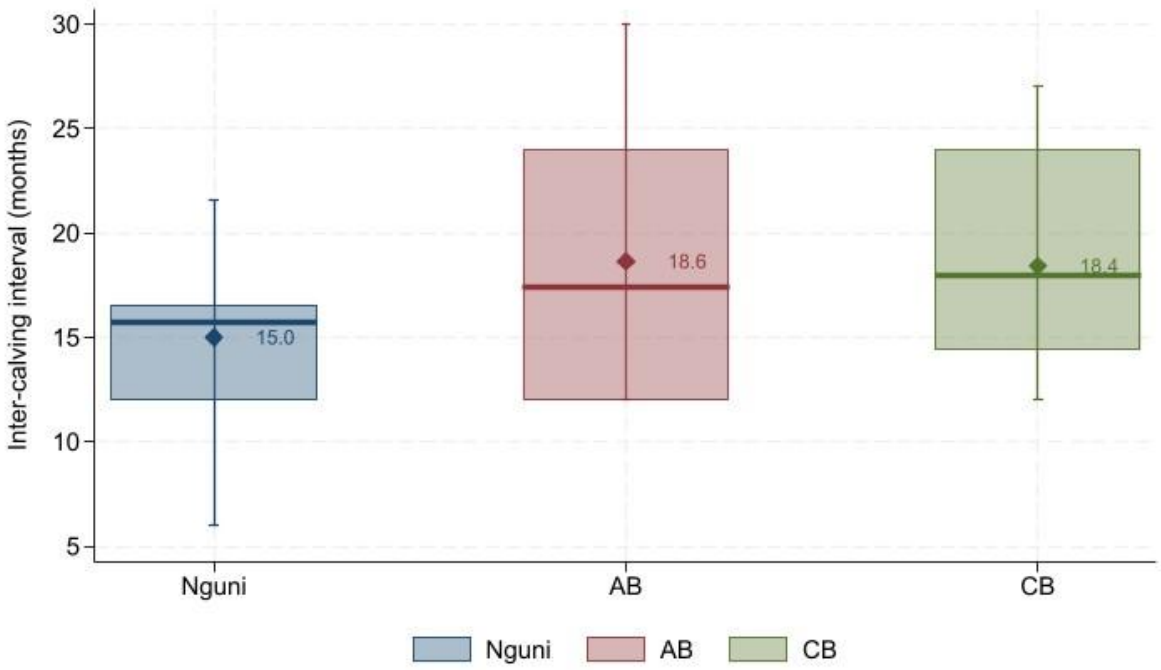


Fig. 3 Inter-calving interval by breed group. Boxes represent the interquartile range, whiskers extend to the most extreme values within 1.5 times the interquartile range, and horizontal lines indicate medians. Diamonds (◆) and adjacent values indicate group means

Factors affecting RP among the breed groups

The reproductive performance of cows in Kunene North is influenced by a range of environmental, management, nutritional, and socio-cultural factors, whose effects vary between the breed groups. Herders identified drought conditions as the primary factor

371 impacting the reproductive performance of Nguni cows. In contrast, the reproductive
372 performance of AB/CB breeds is not only strongly influenced by drought conditions but also
373 by the interplay between the breed characteristics and the husbandry system. This interplay
374 includes the breed's adaptation to local conditions, higher feed requirements, and the herders'
375 milking practices, which are further influenced by the individual cow's behaviour and
376 cultural status.

377 Drought: Although Nguni cattle typically exhibit an earlier AFC and a shorter ICI, these
378 intervals can be prolonged beyond their typical range during drought conditions, when fodder
379 and water shortages result in poor body conditions, thereby limiting their ability to attract a
380 bull.

381 *'Our cows'[Nguni]calving rate has fallen behind because of poor rainfall, which results in*
382 *them not getting a bull. So, this cow delayed with 2 more years from the expected time'*
383 *Herder 6, Omuhonga, February 2025*

384 *'It [a Nguni cow] started giving birth at 6 years old because we were facing drought, and the*
385 *movement was too much. Drought contributed to cows giving birth too late because they*
386 *were hungry and could not attract a bull' Herder 8, Omuhonga, February 2025*

387 Inability to meet nutritional needs: On the other hand, herders indicated that the longer
388 intervals are the norm for the AB group in Kunene North (Fig. 2 and 3). Herders explained
389 that the large-frame breeds struggle with the environmental challenges of the area, such as
390 mountain climbing, walking on rocky terrain, and long distances. Furthermore, their large
391 body size often prevent them from fulfilling their nutritional needs, resulting in poor body
392 condition and a limited capacity to attract a bull. During lactation, these cattle experience
393 further weight loss, prolonging the recovery period before they can attract a bull again.

'The Nguni cow gains weight quickly, it just eats little, the small grass that it finds is enough to make it full. While the other breeds do not get full, they graze from morning until night time that they will not come back home, at night they are still grazing. So, considering that this is the type of cow that is already hungry most of the times, and it does not really get full, suckling makes it even worse. It stays hungry [thin] for a longer period, which leads to it not attracting a bull faster' Herder 5, Etoto, February 2024

Herders' milking methods: according to herders, the weight loss of AB cows during lactation is further exacerbated by their milking practices. In Kunene North, milk is the primary dietary component, with sour milk and maize porridge serving as the staple food of the Himba pastoralists. Additionally, milk is churned to produce butter, which can be stored and used later in the dry season when milk availability is limited. Beyond its nutritional value, butter is also used as a cosmetic; it is mixed with red ochre powder and applied as a body lotion and hair cream by Himba women. Consequently, herders have indicated that high milk production ensures an adequate supply of butter for these purposes.

Given that the AB/CB breeds are primarily acquired for their high milk production, their presence in the herd redirects the focus of milking towards them, as the Nguni is recognized for its low milk production. Herders have observed that these animals, already struggling to meet their nutritional needs, experience further weight loss due to excessive milking. Moreover, their calves may not receive sufficient nutrition early in life, resulting in poor body condition and delayed attraction of a bull, thereby increasing AFC. Additionally, the mother takes longer to recover from weight loss, delaying her ability to attract a bull again and thus prolonging the ICI. These combined findings suggest that RP in Kunene North is influenced by factors beyond breed type alone.

'It [AB cow] lactates the calf for a full year because it has a lot of milk, and when it gives birth, women at home rejoice because it can give as much milk as this bucket [5 litres], which means it remains thin for a long time and is unable to attract a bull quickly.' Herder 3, Etanga, February 2025.

In contrast, a herder stated that *'You can only milk a Nguni when the calf starts to graze but before that, you will not attempt it, while the other one [AB/CB] you can milk it soonest [after giving birth]' GD1, Omuhonga, January 2025*

However, herders have observed instances where certain individuals within the AB group exhibit higher reproductive performance. For example, heifers may calve as early as 24 months of age, either because the mothers are not milked or because of exceptionally favourable rainfall conditions. In the latter scenario, herders reported that a heifer born in a year with abundant rainfall is likely to attract a bull sooner than usual, as the mother has access to sufficient feed to produce adequate milk, and the fodder is abundant and easily accessible when the young animal begins grazing. Consequently, the offspring develops good body condition.

Instances where cows are not milked at all may occur due to:

Cow's cultural status: herders indicated that if an animal from the AB/CB groups is converted into a sacred cow – with its milk reserved for a specific family member (e.g., the head of the extended family), it is typically not milked at all if the designated consumer does not reside in the household where the cow is kept. As a result, the offspring/and mother may maintain a good body condition, which favours their reproduction.

Cow's behaviour: according to herders, cattle with aggressive behaviours, such as fighting or kicking the herder, or fear-related behaviour , such as attempting to escape or jump over the

kraal (*otjindandi*) are not milked. Herders further explained that when an animal from the AB/CB groups exhibits such behaviours, it is difficult to handle due to its large size and considerable strength, posing a risk of injury to both the herder and the animal. As a result, these animals are often left unmilked.

'It [Herero heifer] was born in 2013, and in 2015, it gave birth to its first calf; it was a fat heifer because we could not milk the mother, as it [the mother] was very aggressive. In most cases, heifers get a bull sooner when the mother is not being milked. Probably in one year [after birth], and the next year it will get a bull.' Herder 3, Etanga, February 2025.

Cattle prices among the breed groups

Between February 2023 and April 2024, a total of 51 cattle were sold across 36 herds that were visited on four occasions during this period across the three study locations. Of these cattle, 32 were Nguni, and 19 were AB/CB.

Although herders reported that AB/CB cattle typically command higher prices than the indigenous breed due to their larger body size (Table 2), only such a trend was observed in the data. However, statistical analysis did not reveal a significant difference between the prices obtained for the Nguni and AB/CB groups ($p>0.05$), which may partly reflect the relatively small number of cases recorded. The average prices (NAD) were 5,072 and 6,211 for the Nguni and AB/CB groups, respectively (Table 3).

Table 3 Comparison of cattle prices by cattle characteristics and market categories in Kunene North (n=51)

	Category	n	Mean NAD	SD
Breed	Nguni	32	5,072	1,881
	AB/CB	19	6,211	2,084
Sex class	Heifer	5	3,200	1,304
	Cow	6	5,333	1,063
	Steer	23	4,783	1,623

	Ox	17	7,194	1,689
Season	1 Oruteni	10	4,130	1,637
	2 Okurooro	12	5,200	2,268
	3 Okupepera	15	5,773	1,908
	4 Okuni	14	6,429	1,722
Distance to market (km)	Homestead	31	5,400	2,171
	15	12	5,800	1,956
	≥ 60	8	5,513	1,618

Note: Prices are reported in Namibian dollars (NAD). At an approximate exchange rate of €1 = NAD 19, NAD 1 ≈ €0.053. AB = Aquired Breeds; CB = Cross Breeds.

Factors influencing cattle prices in Kunene North

For the regression analysis of cattle sale prices, acquired breeds (AB) and crossbreeds (CB) were combined into a single category because of the small number of observations in the individual groups. The resulting breed variable distinguished Nguni cattle (n = 32) from AB/CB cattle (n = 19), with Nguni used as the reference category.

The regression model explained 54.5% of the variation in log-transformed cattle sale prices ($R^2 = 0.545$, $p < 0.001$; Table 4). Breed group was not significantly associated with sale price after accounting for age-sex class, season, and sale location. AB/CB cattle had an estimated 5.9% higher sale price than Nguni cattle, but this difference was not statistically significant ($p = 0.465$). In contrast, sale prices differed significantly between age-sex classes and seasons. Compared with heifers, cows and oxen had approximately 55.8% and 88.7% higher sale prices, respectively, whereas the difference for steers was not statistically significant. Cattle sold during Okuni had approximately 64.4% higher sale prices than those sold during Oruteni ($p < 0.001$; Table 4). Cattle sold 15 km from the homestead were associated with approximately 20.4% lower sale prices than homestead sales ($p = 0.005$), whereas prices of cattle sold ≥60 km away did not differ significantly from homestead sales.

Table 4 Multiple linear regression of factors associated with log-transformed cattle sale prices in Kunene North (n = 51).

	Category	Coefficient (ß)	Robust SE	Approx. % difference	P>|t|	[95% conf. interval]
Breed	Nguni	Reference				
	AB/CB	0.057	0.077	+5.9%	0.465	-0.099 to 0.212
Age-sex class	Heifer	Reference				
	Cow	0.443	0.170	+55.8	0.013	0.099 to 0.787
	Steer	0.221	0.180	+24.7	0.227	-0.143 to 0.585
	Ox	0.635	0.167	+88.7	<0.001	0.298 to 0.971
Season	1 Oruteni	Reference				
	2 Okurooro	0.127	0.147	+13.5	0.396	-0.171 to 0.424
	3 Okupepera	0.199	0.110	+22.1	0.078	-0.023 to 0.422
	4 Okuni	0.497	0.099	+64.4	<0.001	0.295 to 0.699
Distance to market (km)	Homestead	Reference				
	15	-0.228	0.076	-20.4	0.005	-0.382 to -0.074
	≥60	0.078	0.156	+8.1	0.620	-0.238 to 0.394

Note: β = regression coefficient; SE = standard error; CI = confidence interval. Approximate percentage differences were calculated as 100 × [exp(β) − 1]. Robust standard errors were used. $R^2 = 0.545$. Reference categories were Nguni, heifer, Oruteni, and homestead. AB and CB were combined for the regression analysis because of the small number of observations in the individual groups.

Sensitivity analysis indicated that the estimated association between breed and sale price was sensitive to a small number of influential observations. Five observations exceeded the Cook's distance criterion (>4/n), comprising three Nguni and two AB/CB cattle. These included two relatively high-priced Nguni sales and two relatively low-priced AB/CB sales. After excluding these observations, AB/CB cattle were associated with approximately 17% higher sale prices than Nguni cattle (β = 0.156, p = 0.010). Several other coefficients also became stronger in the reduced model. Given the small sample size and the substantive influence of these observations, the full-sample model was retained as the primary analysis and the breed-price association was interpreted cautiously.

Herders' accounts provided additional insight into the local market dynamics underlying cattle sales. They distinguished between regular Kunene buyers, including market traders and

speculators; occasional buyers travelling from Ovamboland; and fellow herders. Herders reported that prices depended not only on animal characteristics but also on the buyer and circumstances of the transaction. Higher prices were received when selling to occasional Ovambo buyers or fellow herders, when a buyer had an urgent need for an animal, or under pay-before-collection arrangements.

'I sold it to a guy who needed it to pay bride price. He said he would give me 4,000NAD because he needed it urgently; other than that, he would have given me 2000 NAD because it was too small according to him' Herder 6, Etanga, February 2023

In contrast, herders reported that regular Kunene buyers, particularly those purchasing cattle directly from herders' localities, generally offered lower prices than at the Opuwo market. They attributed this partly to buyers accounting for the transportation costs of moving cattle to the market.

'He said that after buying the cows, he will sell them further. So, he may not get any profit as he also has to spend money on fuel to go there' Herder 11, Omuhonga, June 2023

Additionally, when herders were in urgent need of money, they reported being more likely to accept lower offers.

'I didn't have a choice because I had someone being hospitalised.' Herder 8, Omuhonga, 2023

Discussion

Reasons for keeping breed diversity

The strategies of Himba herders to mantain breed diversity within their herds reflect the unique role that each breed fulfils within the households. Rather than maximizing the performance of a single breed, herders appear to diversify functional traits across breeds to cope with the variable environmental and livelihood conditions characteristic of pastoral

systems. Similar to the practices of Himba herders, several studies from other parts of Africa have shown that pastoralist intentionally maintain breed diversity. Specifically, the AB/CB breeds are valued for their productive traits, while the indigenous breeds are valued for their adaptive characteristics (a review by Kamuanga et al. 1999 in three west African countries; a review by Jabbar and Diedhiou 2003 in Nigeria; Maichomo et al. 2009 in Kenya; Illatsia et al. 2012 in Kenya; Tamou et al. 2018 in Benin; Houessou et al. 2022 and Bereda et al. 2024 in Ethiopia). For instance, a study by Bereda et al. (2024) in Ethiopia on farmers' preferences for different breed traits showed that herders acquired exotic crossbred cows for their high milk yield, rapid growth, greater traction power, and good fertility while still maintaining indigenous cattle for their disease resistance, and adaptation to local conditions.

Reasons for high societal status perceptions associated with AB/CB breeds

The high societal status of the AB/CB breeds within Himba communities is linked to their productive capacity, particularly during periods of favourable rainfall. Given that milk is the primary dietary component for Himba pastoralists, the high milk production of the AB/CB has contributed to the high value attributed to them. Introduced cattle have value not only because of what they produce, but also because of what their ownership signifies. Within communities, households with AB/CB are perceived as wealthy because these breeds can provide adequate nutrition for household members and butter used as cosmetic by women. This elevates the herd owner's reputation as a capable provider, reinforcing the perception of him as ‘a real man’ who can sustain his household well. This is because, in Himba communities, an adequate supply of animal products is associated with a high standard of living, which equates to wealth Similarly, Traoré et al. (2018) demonstrated in their study on the impact of different cattle breeds on household food security in southern Mali that the food consumption score was positively correlated with the household wealth index, with the highest wealth index observed in households with breed-mixed herds.

In addition, while the daily household meat requirements are generally met by small stock, large ceremonies and important events such as ancestral commemorations, funerals, and weddings, are fulfilled by cattle slaughter (Bollig 2006). As a result, the AB/CB breeds, which can produce larger quantities of meat for these events, are highly appreciated, and their owners are highly respected. Furthermore, the strong promotion of the introduced breeds by development projects may contribute to the perception of these breeds as more valuable than indigenous ones (Ilatsia et al 2012).

In South Africa, European colonists arriving in the 16th and 17th centuries devalued indigenous cattle as inferior and poor producers, labelling them as 'scrub' animals. This perception was later adopted by local herders, who came to regard high-input, highly productive exotic breeds as superior to their indigenous cattle (Bester et al. 2003; Bayer et al. 2004). Although the value of the Nguni cattle was eventually recognized as that of a highly fertile, hardy, well-adapted, and low-maintenance breed suited to low-input systems (Lepen 1996a; Bester et al. 2003; Mapiye et al. 2007), herders in Kunene North continue to describe the Nguni cattle as having an 'ugly body' due to their small frame. Some herders even use the belittling term 'okaHimba [okaNguni],' which translates as ‘something small and of low value’. Nevertheless, the same Himba herders may also commend and appreciate the Nguni for its low-labour input and adaptability to the environment.

Labour requirements of different breed groups

The AB/CB breeds are highly valued by Himba pastoralists for their larger frames and higher milk production and fast growth. However, these productive advantages are associated with higher mantainance requirements. These observations demonstrate that the labour demands associated with introduced breeds extend beyond routine husbandry and become particularly pronounced during periods of environmental stress. Marshall et al. (2020) reported that herds composed entirely of exotic breeds not only had higher feed expenses, but also had higher

570 labour costs, costs for artificial insemination, and costs associated with animal housing, such
571 as shaded structures, compared to herds with indigenous breeds and those with crossbreeds.
572 Green et al. (2017) observed that certain dairy cows introduced to rural farmers are
573 physiologically unfit for long-distance trekking. Additionally, these cows face risks such as
574 ingesting toxic plants and debris, as well as increased exposure to disease-carrying ticks,
575 necessitating stall feeding and thereby increasing labour requirements. Similarly, in Kunene
576 North, during critical droughts, herders must supply water and feed for AB/CB unable to
577 graze independently for extended periods, leading to similar high labour costs. This task is
578 combined with the need to assist the same slow-moving breeds in trekking to mountain
579 pastures and returning to water sources, resulting in a time-consuming and labour-intensive
580 processes for herders. Green et al. (2017) further argued that the tasks of fetching and
581 carrying water place substantial demands on household labour, necessitating a reorganization
582 of time and resources within the homestead to accommodate the introduced breeds. This
583 suggests that the full benefits of introduced breeds can only be realized through increased
584 management and labour inputs (Lepen 1996a; Green et al. 2017; Marshall et al. 2020).

585 ***Variations in reproductive performance among breed groups***

586 In Kunene North, Nguni cows exhibited superior reproductive performance, characterised by
587 an earlier age at first calving and shorter inter-calving intervals. Together, the quantitative
588 and qualitative findings suggest that adaptation to local environmental and husbandry
589 conditions contributes to the observed differences. Additionally, studies conducted in
590 Namibia under extensive grazing conditions on a research farm, also revealed that the Nguni
591 breed exhibits significantly higher conception rates than other breeds such as Afrikaner and
592 Simmental (Lepen 1996a; Samkange et al. 2019).

Comparative studies evaluating reproductive performance between indigenous breeds and introduced or crossbreeds breeds in pastoral production systems are rare. Most studies have focused on smallholder production systems, where indigenous and introduced breeds are not reared under identical conditions.

For instance, Bereda et al. (2024) evaluated the performance of dairy cows kept by project beneficiary farmers in the Angolelana Tera district of central Ethiopia. While all dairy cattle utilised common feed resources, including crop residues, hay, and natural pasture, crossbred milking cows were additionally supplemented with wheat bran. Furthermore, crossbred cattle were also bred using artificial insemination, whereas indigenous cows were serviced exclusively by bulls. The study reported that indigenous cows had a significantly higher AFC (48.61 months) than Holstein–Friesian crossbred (32.91 months) and Jersey crossbred cows (30.56 months). Indigenous cows had significantly longer ICIs (797.44 days), whereas both crossbred groups had ICIs of less than 450 days. The authors acknowledged that the superior reproductive performance observed in crossbred cows was due to their preferential care, mainly feeding, watering, housing, healthcare and AI services.

Another study, conducted by Abera (2016), evaluated the performance of indigenous and crossbred dairy cattle in smallholder production systems in rural, peri-urban and urban areas in Oromia, Ethiopia. Results from the rural production system showed that the ICI for indigenous cattle (748.25 days) was longer than for the three crossbred categories (480.32 days, on average). Indigenous cattle were also older at first calving (54.22 months), than the crossbreds (37.82 months, on average). Similar to Bereda et al. (2024), Abera (2016) also linked the higher performance of crossbred cows; to long-term government and NGO interventions that enhanced farmers' access to improved practices and technologies, including AI services, supplementation, and zero-grazing systems.

Unlike the Ethiopian studies, all breed groups in Kunene North were kept under essentially identical extensive conditions, relying entirely on natural mating and natural pasture (except during critical periods), often trekking long distances and, in some areas, navigating challenging terrain to access forage resources. Consequently, differences in reproductive performance are more likely to represent genuine differences in adaptation to the production systems' environmental conditions. These findings demonstrate that reproductive performance cannot be interpreted independently of the production environment in which breeds are evaluated.

In addition, indigenous Nguni cattle in Kunene North demonstrated better reproductive performance than indigenous cattle reared under similarly extensive production systems in Ethiopia. Nguni cows had a shorter ICI of 15 months and a lower AFC of 44 months, compared with ICIs of 27 and 25 months and AFCs of 49 and 54 months reported by Bereda et al. (2024) and Abera (2016), respectively. Studies conducted on Namibian research farms (Schoeman 1989, Lepen 1996a; Samkange et al. 2019) similarly found that Nguni cattle outperformed the fellow indigenous Afrikaner breed under comparable conditions. Together with evidence from comparisons involving introduced breeds, these findings indicate that, when evaluated under similar management and environmental conditions, Nguni cattle consistently exhibit superior reproductive performance. This suggests that the Nguni breed combines reproductive performance with adaptation to the prevailing environmental and management conditions. .

Variations in factors affecting reproductive performance among the breed groups

In Kunene, the reproductive performance of Nguni cattle is impacted by drought conditions. Bollig (2006) noted that in Kunene North, cows face difficulties in becoming pregnant during dry years, and the yearly calving rates vary significantly based on the availability of fodder.

Similarly, Martinez-Boggio et al. (2021) examined the reproductive performance of various breeds and their crossbreeds within Uruguay's extensive grazing system. They reported fluctuations in average calving success and days to calving across different years, and attributed this to annual climatic variability affecting pasture growth, thereby affecting the nutritional intake of breeding cows. Ilatsia et al. (2012) also noted that Maasai pastoralists in Kenya believe that prolonged droughts negatively impact the growth and reproductive performance of their herds. During droughts, when pasture quality and quantity diminish, animals experience weight loss due to nutritional deficiencies, leading to extended postpartum anoestrus and reduced oestrus expression (Pradhan and Nakagoshi 2008).

Beyond drought effects, the reproductive performance of the AB/CB breeds is also influenced by a set of interconnected factors resulting from their inability to interact well with the rangeland conditions of Kunene North. During the lactation phase, cows must trek long distances daily between pasture areas and the homestead to suckle their calves. For AB/CB cows with a slow pace, this results in prolonged commuting times, thereby reducing feeding time and leading to inadequate feed intake. As these cows are also subjected to excessive milking, they lose considerable weight during lactation. This also means that calves do not receive adequate milk, as their milk needs may be neglected due to household milk demands. Pradhan and Nakagoshi (2008) stated that underfeeding lactating cows not only creates poor body condition, delaying ovulation and the return to oestrus post-calving, but it also reduces milk production, limiting the nutrition available to the calf and potentially lowering weaning weight and delaying puberty. Together, these effects can reduce the female calf's lifetime reproductive and productive potential.

The challenge faced by AB/CB cattle to meet their nutritional needs are a critical factor affecting their reproductive performance. Herders reported that under favourable rainfall

conditions their reproductive performance are comparable to that of Nguni cows. However, as the environmental conditions in Kunene North are not consistently favourable, AB/CB cattle often encounter difficulties in fulfilling their intended roles.

Overall, these findings highlight that breed performance cannot be evaluated independently of the production environment. Under the highly variable conditions of Kunene North, reproductive success depends less on the potential of a breed than on its ability to maintain energy balance while coping with the ecological and management constraints imposed by mobile pastoralism.

Variation of cattle prices among the breed groups

The statistical analysis revealed no significant difference; however, herders' narratives suggested that the AB/CB breed commands higher prices. Similarly, Sekibaala et al. (2025) who investigated pastoral communities' perceptions of cattle breed improvement in Uganda, found that 80% of herders believed crossbreeds (Sahiwal x Local) possess a higher market value than local cattle of the same age. Illatsia et al. (2012) also reported higher sale prices as one of the main reasons given by Maasai pastoralists for maintaining Sahiwal cattle in their herds.

Research comparing the market value of indigenous and introduced cattle breeds in Africa is limited, with most studies focusing on dairy farming, particularly milk yield and sales (Masama et al. 2003; Abera et al. 2016; Green et al. 2017; Marshall et al. 2020; Bereda et al. 2024). Other studies have compared the market value of large-framed Zebu cattle with local small-sized taurine breeds (Kamuanga et al. 1999; Jabbar and Diedhiou, 2003). Jabbar and Diedhiou (2003) noted that although buyers sometimes pay premium prices for prefered breeds, breed alone generally explains little variation in cattle prices. Most price differences are attributed to animal size and body condition. However, when other factors are held

689 constant, smaller breeds tend to recieve lower market prices than larger breeds (Jabbar and
690 Diedhiou 2003). Kamuanga et al. (1999) found that adult Zebu cattle in good body condition
691 sold for approximately 30% more than local taurine breeds (Baoulé and N'Dama) in similar
692 good condition. However, when the animals were in poor body condition, prices did not
693 differ significantly between breeds.

694 In Kunene North, the estimated price difference between AB/CB and Nguni cattle was 5.9%,
695 but this association was not statistically significant. This suggests that the larger body size of
696 AB/CB cattle does not necessarily translate into higher realised sale prices under the
697 prevailing pastoral conditions. Instead, other factors, including age–sex class, season, and
698 sale location, played a more important role in determining the prices received by herders.
699 This finding contrasts with herders' perceptions of higher market value for AB/CB cattle and
700 suggests that the expected economic advantage associated with larger-framed breeds is not
701 consistently realised in actual cattle sales. Kamuanga et al. (1999) found that price
702 differences become apparent when breeds are compared under optimal conditions. A similar
703 pattern appears to exist in Kunene North, where AB/CB breeds perform well only during
704 favourable years. Herders' accounts suggest that the market advantage of larger-framed
705 breeds may become more apparent under favourable conditions, when these animals are
706 better able to realise their growth potential . However, in the variable conditions of Kunene
707 North, breed alone is not sufficient to secure a good price, as other factors, including age-sex
708 class, season, market distance, and buyer type, also play a role.

709 In Kunene North, adult animals (oxen and cows) irrespective of breed, command higher
710 prices than younger animals. This trend is consistent with previous studies showing that
711 buyers primarily value animal size, weight, and body condition (Kamuanga et al. 1999;
712 Jabbar and Diedhiou 2003; Ruto et al. 2008; Kassie et al. 2011). In Kunene North the
713 differences in body size-condition between the breed groups may be minimal. Specifically,

714 the less well-adapted AB/CB cattle may fail to meet their nutritional requiremnts and
715 therefore not reach their full growth potential. In contrast, the indigenous Nguni cattle may
716 maintain good body condition despite their smaller frame, resulting in only minor differences
717 in market value compared with larger-framed but less well- conditioned AB/CB cattle. These
718 findings highlight the importance of cattle-rangeland interaction in shaping market prices.

719 ***Other factors influencing cattle prices in Kunene North***

720 Interestingly, the highest average price was observed during the dry season (August-
721 October). This may be explained by the higher percentage proportion of oxen sold during this
722 period (43%) compared to the wet season (33%), as oxen generally command higher prices.
723 Herders may preferably sell oxen during the dry season because they are fully grown, can
724 typically maintain good body condition due to fat deposition following castration, and can
725 access distant mountain pastures without needing to return daily to the homestead.

726 In pastoral areas, cattle prices are usually lower during the dry season. Barret et al. (2003)
727 noted that in northern Kenya, animal prices are at their lowest during the dry season and
728 reach their peak when forage and water are abundant, as pastoralists purchase animals for
729 restocking after losses incurred during the dry season. Barret et al. (2003) also observed that
730 low and unstable prices discourage herders from selling animals during periods of stress.
731 Although Himba herders face similar prices fluctuations, they often have to sell animals
732 irrespective of the season due to urgent cash needs and limited alternatives. Selling well-
733 conditioned oxen during the dry season may therefore partly offset the generally lower
734 seasonal prices.

735 Although buyer type was not statistically significant, herders perceived that Ovambo buyers
736 generally offer better prices than buyers from Kunene. According to the herders, Ovambo
737 buyers are accustomed to the higher cattle prices in their home region and maintain similar

738 purchasing behaviour in Kunene North. Furthermore, sales to Ovambo buyers often occur
739 directly with the end purchaser, either in Ovamboland or when buyers travel to Kunene
740 North. In contrast, Kunene buyers typically act as middlemen who must resell the cattle for
741 profit.

742 While Ovambo buyers generally offer better prices, poor road infrastructure in Kunene North
743 increases transport costs, and limits direct market access. Similar constraints have been
744 reported in other pastoral systems; Kyeyemwa et al. (2008) observed in their study on
745 increasing cattle offtakes for rural farmers in Uganda that, despite farmers' preference to sell
746 at local markets for higher prices, they often sell at farm gates at lower prices due to bad state
747 of roads, which prolong the time required to reach the market. Consequently, many Himba
748 herders continue to sell cattle to local speculators or traders who offer lower prices, arguing
749 that transportation costs and weight loss during the long journey to distant markets reduces
750 animals' value.

751 **Conclusions**

752 The findings show that higher productive potential does not automatically translate into better
753 overall performance when cattle are evaluated under the environmental and husbandry
754 conditions in which they are actually kept. Himba pastoralists value introduced and crossbred
755 cattle for higher milk production, larger body size and meat yield, while Nguni cattle are
756 particularly adapted to local rangeland conditions.

757 The reproductive results illustrate this trade-off. Nguni cows calved earlier than acquired
758 breeds and had shorter inter-calving intervals than both acquired and crossbred cattle.
759 Herders' accounts further indicate that the productive advantages of introduced cattle are
760 most readily realised under favourable conditions, whereas their higher nutritional and

management requirements constrain performance during dry periods and droughts as cattle interact with available forage, terrain, mobility and pastoral husbandry practices.

A similar pattern emerged for economic performance. Although larger-framed cattle were perceived by herders to have higher market value, breed group was not significantly associated with realised sale price in the full model. Prices were also shaped by age-sex class, season and sale location, indicating that the expected economic advantage of larger body size is conditional on the circumstances under which animals are raised and sold.

Breed diversification in Himba herds should therefore not be understood simply as a transition from indigenous to supposedly improved cattle. Rather, pastoralists maintain cattle with different and complementary traits to balance production opportunities with reproduction, environmental adaptation, labour demands and risk. In highly variable pastoral environments, livestock improvement strategies should consequently evaluate cattle within the production systems in which they are expected to perform, rather than defining improvement primarily in terms of potential milk and meat output.

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Data availability

The data is available from the corresponding author upon request.

Declarations

Ethics approval The research was conducted under a research permit issued by the National Commission on Research, Science and Technology (NCRST), Namibia, in accordance with the Research, Science and Technology Act, 2004 (Act No. 23 of 2004) and the Research, Science and Technology Regulations, 2011. It followed ethical principles for qualitative social-science research. Participation was voluntary, and informed consent was obtained from all participants before interviews and research activities, including taking and using photographs where applicable. Participants were informed of the research purpose, intended data use, and their right to decline participation or withdraw at any time. Confidentiality and

anonymity were maintained. The study did not involve activities requiring clinical trial registration.

Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Abera M (2016) Reproductive and Productive Performances of Crossbred and Indigenous Dairy Cattle under Rural, peri-urban and Urban Dairy Farming Systems in West Shoa Zone, Oromia, Ethiopia. MSc thesis, Jimma University College of Agriculture and Veterinary Medicine, Jimma, Ethiopia

African Union Commission (2010) Policy Framework for Pastoralism in Africa: Securing, Protecting and Improving the Lives, Livelihoods and Rights of Pastoralist Communities. African Union Commission, Addis Ababa, Ethiopia

Barrett CB, Chabari F, Bailey D, Little PD, Coppock DL (2003) Livestock Pricing in the Northern Kenyan Rangelands. J Afr Econ 12(2):127–155. https://doi.org/10.1093/jae/12.2.127

Behnke RHJ (1999) Stock movement and range management in a Himba community in north-western Namibia. In: Niamir-Fuller M (ed) Managing Mobility in African Rangelands: The Legitimation of Transhumance. Intermediate Technology Publications, London, UK, pp 184–216.

Bereda A, Agune B, Yilma Z (2024) Performance and farmers preferred traits of Jersey × local cows in the tropics: The case of Angolelana Tera district, North Shewa zone, Ethiopia. Cogent Soc Sci 10(1):2368948. https://doi.org/10.1080/23311886.2024.2368948

Bester J, Matjuda LE, Rust JM, Fourie HJ (2002) The Nguni: A Case Study. Animal Improvement Institute, Agricultural Research Council (ARC), Irene, South Africa

Bollig M (1997) Risk and Risk Minimisation among Himba Pastoralists in Northwestern Namibia. Nomadic Peoples 1(1):66–89. https://doi.org/10.3167/082279497782384758

Bollig M (2006) Risk Management in a Hazardous Environment: A Comparative Study of Two Pastoral Societies. Springer, New York

Crandall DP (1998) The Role of Time in Himba Valuations of Cattle. J R Anthropol Inst 4(1):101–114. https://doi.org/10.2307/3034430

Crandall DP (2002) Himba Animal Classification and the Strange Case of the Hyena. Africa 72(2):293–311. https://doi.org/10.3366/afr.2002.72.2.293

Creswell JW (2007) Qualitative Inquiry and Research Design: Choosing Among Five Approaches. Sage Publications, Thousand Oaks, CA, USA

Green M (2017) Dairying as Development: Caring for "Modern" Cows in Tanzania. Hum Organ 76(2):109–120. https://doi.org/10.17730/0018-7259.76.2.109

Hangara N, Kavari JU, Tutjavi EPK (2020) Ozongombe mOmbazu ya Kaoko: Cattle Culture of the Kaoko Ovaherero. University of Namibia Press, Windhoek, Namibia

Houessou SO, Vanvanhossou SFU, Diogo, RVC, Dossa LH (2022) Dynamics of changes in the breed composition of pastoral and agro-pastoral cattle herds in Benin: Implications for the sustainable use of indigenous breeds. Heliyon 8(4):e09229. https://doi.org/10.1016/j.heliyon.2022.e09229

Ilatsia ED, Roessler R, Kahi AK, Piepho HP, Zárate V (2012) Production objectives and breeding goals of Sahiwal cattle keepers in Kenya and implications for a breeding programme. Trop Anim Health Prod 44(3):519–530. https://doi.org/10.1007/s11250-011-9928-8

Jabbar MA, Diedhiou ML (2003) Does Breed Matter to Cattle Farmers and Buyers? Evidence from West Africa. SSRN J 45:461–472. https://doi.org/10.2139/ssrn.297082

Kamuanga M, Tano K, Pokou K, Jabbar M, Swallow B (1999) Farmers' preferences of cattle breeds, their market values and prospects for improvement in West Africa: a summary review. In: Sones KR (ed) Proceedings of the 25th Meeting of the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC). Stockwatch Ltd, Nairobi, Kenya, pp 271–298.

Kassie GT, Abdulai A, Wollny C (2011) Heteroscedastic hedonic price model for cattle in the rural markets of central Ethiopia. Appl Econ 43(24):3459–3464. https://doi.org/10.1080/00036841003670614

Köhler-Rollefson I, Rathore HS, Mathias E (2009) Local breeds, livelihoods and livestock keepers' rights in South Asia. Trop Anim Health Prod 41(7):1061–1070. https://doi.org/10.1007/s11250-008-9271-x

Köhler-Rollefson I, Mathias E (2010). Livestock Keepers' Rights: A Rights-based Approach to Invoking Justice for Pastoralists and Biodiversity Conserving Livestock Keepers. Policy Matters 17:113–115.

Krätli S, Schareika N (2010) Living Off Uncertainty: The Intelligent Animal Production of Dryland Pastoralists. Eur J Dev Res 22(5):605–622. https://doi.org/10.1057/ejdr.2010.41

Kyeyamwa H, Speelman S, Van Huylenbroeck G, Opuda-Asibo J, Verbeke W (2008) Raising offtake from cattle grazed on natural rangelands in sub-Saharan Africa: A transaction cost economics approach. Agric Econ 39(1):63–72. https://doi.org/10.1111/j.1574-0862.2008.00315.x

Lepen JM (1996a) Breed characterization studies in Namibia. Agricola 9:21–23

Lepen JM (1996b) The evaluation of breeding strategies with the objective of enhancing sustainable beef production in Namibia. Agricola 9:25–28.

Maichomo MW, Kosura WO, Gathuma JM, Gitau GK, Ndung'u JM, Nyamwaro SO (2009) Economic assessment of the performance of trypanotolerant cattle breeds in a pastoral production system in Kenya. J S Afr Vet Assoc 80(3):157–162. https://doi.org/10.4102/jsava.v80i3.194

Mapiye C, Chimonyo M, Muchenje V, Dzama K, Raats JG (2007) Potential for value-addition of Nguni cattle products in the communal areas of South Africa: A review. Afr J Agric Res 2(10):488–495

886 Marius LN, Togarepi C, Seibeb I (2022) Evaluation of the Bull Scheme: An Open Nucleus
887 Breeding System in the communal livestock farming areas of Namibia. Afr J Rural Dev
888 7(1):53–67
889 Marshall K, Salmon GR, Tebug S, Juga J, MacLeod M, Poole J, Baltenweck I, Missohou A
890 (2020) Net benefits of smallholder dairy cattle farms in Senegal can be significantly
891 increased through the use of better dairy cattle breeds and improved management
892 practices. J Dairy Sci 103(9):8197–8217. https://doi.org/10.3168/jds.2019-17334
893 Martinez-Boggio G, Lema M, Aguilar I, Gimeno D, Ravagnolo O (2021) Reproductive
894 performance of Angus, Hereford, Salers and Nellore crossbred females: Additive and
895 non-additive effects. J Anim Breed Genet 138(6):688–697.
896 https://doi.org/10.1111/jbg.12553
897 Masama E, Kusina NT, Sibanda S, Majoni C (2003) Reproduction and Lactational Performance
898 of Cattle in a Smallholder Dairy System in Zimbabwe. Trop Anim Health Prod
899 35(2):117–129
900 Meatco Foundation (2016) Meatco foundation helps communal producers improve cattle quality.
901 Retrieved on 26 March 2026 from
902 https://www.meatcofoundation.com/news/124/Meatco-Foundation-Helps-Communal-
903 Producers-Improve-Cattle-Quality/
904 Namibia Statistics Agency (2024) Namibia 2023 Population and Housing Census: Main Report.
905 Namibia Statistics Agency, Windhoek, Namibia
906 National Planning Commission (2015) Kunene Regional Development Profile 2015. National
907 Planning Commission, Windhoek, Namibia.
908 Pradhan R, Nakagoshi N (2008) Reproductive Disorders in Cattle due to Nutritional Status. J Int
909 Dev Coop 14(1):45–66
910 Ruto E, Garrod G, Scarpa R (2008) Valuing animal genetic resources: A choice modeling
911 application to indigenous cattle in Kenya. Agric Econ 38(1):89–98.
912 https://doi.org/10.1111/j.1574-0862.2007.00284.x

Samkange A, Kandiwa E, Mushonga B, Bishi A, Muradzikwa E, Madzingira O (2019) Conception rates and calving intervals of different beef breeds at a farm in the semi-arid region of Namibia. Trop Anim Health Prod 51(7):1829–1837. https://doi.org/10.1007/s11250-019-01876-4

Schoeman J (1989) Recent research into the production potential of indigenous cattle with special reference to the Sanga. S Afr J Anim Sci 19(2):55-61

Scoones I (2023) Confronting Uncertainties in Pastoral Areas: Transforming Development from Control to Care. Soc Anthropol 31(4):57–75. https://doi.org/10.3167/saas.2023.04132303

Ssekibaala G, Ilukor J, Bagamba F (2025) Perceptions of pastoral communities on cattle breed improvement: Insights from Uganda's community-based breeding scheme. Front Anim Sci 6:1596891. https://doi.org/10.3389/fanim.2025.1596891

Tamou C, De Boer IJM, Ripoll-Bosch R, Oosting SJ (2018) Understanding roles and functions of cattle breeds for pastoralists in Benin. Livest Sci 210:129–136. https://doi.org/10.1016/j.livsci.2018.02.013

The Namibian (2014) Meatco helps communal producers improve cattle quality. Retrieved on 26 March 2026 from https://www.namibian.com.na/meatco-helps-communal-producers-improve-cattle-quality/

Topographic-map.com. Topographic map of Kunene region. Retrieved on 13 August 2026 from https://de-be.topographic-map.com/map-3fmn9m/Kunene/

Traoré SA, Reiber C, Megersa B, Zárate AV (2018) Contribution of cattle of different breeds to household food security in southern Mali. Food Secur 10(3):549–560. https://doi.org/10.1007/s12571-018-0795-2