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REVIEW : THE CHARACTERISTICS OF BALI CATTLE (*BOS JAVANICUS*) AND THE ALTERNATIVE OF IT'S CONSERVATION METHODS

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ABSTRACT

Bali cattle are an indigenous Indonesian cattle breed that originated from the domestication of the Banteng (Bos javanicus). A major challenge in their development is the breed's low quality, such as lower birth weight, growth rate, and weaning weight compared to Bos taurus cattle, which is believed to result from inbreeding and suboptimal management practices. Genetic and crossbreeding impacts often lead to losses such as reduced endurance, fertility, and birth weight. In response, the government has made efforts to introduce high-quality bulls into breed source areas, regulate cattle release including controlling the culling of productive female cattle, and accurately monitor the number of Bali cattle released to maintain population balance. Consequently, conservation efforts through both in-situ and ex-situ methods are essential. This study indicates that documentation, reproductive and production evaluations, and initiatives to improve Bali cattle's genetic quality in Indonesia have been conducted, although these efforts remain limited in scope.

Keywords : *Bali cattle, animal genetic resource, reproduction production.*

Introduction

Currently, the local cattle supply for beef farming faces shortages because population growth does not keep pace with national meat demand, leading to imports of feeder cattle and beef (Putu et al., 1997). Indonesia's beef supply comes from three main sources: smallholder farms (local livestock), the smallholder beef fattening industry (using imported feeder cattle), and meat imports (Oetoro, 1997). Beef cattle exhibit high diversity and are found in nearly every country, including Indonesia (Lelana et al., 2003). In Indonesia, three major beef cattle breeds predominate: Ongole, Bali, and Madura, along with their crossbreeds (Talib and Siregar, 1998; Kusumaningsih, 2002). These breeds are distributed across the archipelago from Sumatra to Maluku, with about 50% concentrated on Java Island (Talib and Siregar, 1998). The Bali cattle population in Indonesia is approximately 2,632,125 heads, representing about 26.92% of the total national beef cattle population, thus expected to contribute significantly to national meat supply (Tanari, 2001).

Bali cattle are an indigenous Indonesian beef breed originally domesticated from Banteng (*Bos javanicus*) (Hardjosubroto, 1994) and are naturally distributed on Bali Island (Payne and Rollinson, 1973). They are favored in Indonesia due to high reproductive capacity, usefulness as draft animals in farming (Putu et al., 1998; Moran, 1990), high carcass percentage, lean meat, strong positive heterosis in crossbreeding (Pane, 1990), high adaptability to diverse environmental conditions, and generally superior reproductive performance compared to some crossbreeds (e.g., higher pregnancy and calving rates) reported in recent reproductive studies of Bali cattle (Amu et al., 2025). However, they also have drawbacks such as slow growth and vulnerability to Jembrana disease, malignant catarrhal fever, and Bali ziekte (Darmadja, 1980; Hardjosubroto, 1994).

Optimal management of livestock genetic resources relies on genetic diversity. Genetic differences between species, breeds, and groups allow producers to select gene sets suitable for specific goals and environments (Subandriyo, 1997). While preserving genetic diversity is crucial, certain steps must be taken for effective genetic resource management, starting with characterization. This process involves documenting breed existence and performance under varied environmental conditions. Then comes evaluation, which compares between breeds or crossbreeds. Next is developing breeding programs, tailored to specific situations but informed by documentation, evaluation, and industry structure. Finally, conservation is considered based on documentation and evaluation outcomes (Turner, 1981). This paper discusses the genetic characterization of Bali cattle, a local Indonesian breed, in relation to preservation efforts undertaken for this breed in Indonesia.

Bali Cattle

Bali cattle (*Bos javanicus*), which originated from the domestication of the Banteng, show strong adaptability to their local environments. Similarly, when introduced beyond their original breeding areas, Bali cattle (*Bos javanicus*) demonstrate stable reproductive performance and strong adaptability across different agro ecosystem conditions. Several studies have reported favorable conception rate, service per conception, and calving rate under artificial insemination programs, indicating that Bali cattle maintain normal reproductive function even under varying environmental conditions (Habaora et al., 2019; Nubatonis & Dethan, 2021; Muslimiah et al., 2023). Presently, the distribution of Bali cattle has expanded across all of Indonesia, including Java, except for the Jakarta province. The highest populations are found in South Sulawesi, Timor Island, Bali, and Lombok (Tanari, 2001). The population in South Sulawesi and Timor Island has even surpassed that of their original home in Bali Island (Soehadji, 1990). Outside Indonesia, Bali cattle are also present in zoos and safari parks, and in the wild, they can be found in tropical forests of Southeast Asia and northern Australia (Talib et al., 1998).

From a taxonomic perspective, Bali cattle belong to the Bovidae family, genus Bos, and species *Bos javanicus* (D'Alton, 1823). According to Williamson and Payne (1978), wild Banteng, the species from which Bali cattle originate, is classified under the Bovidae family, genus Bos, and sub-genus Bibos. Bali cattle have distinctive features such as reddish-brown hair, with adult males turning black (Hardjosubroto, 1994). Another notable characteristic of Bali cattle is the sexual dimorphism in coat coloration, where young males initially display darker pigmentation that may lighten with age. Studies indicate that variations in adult coat color are associated with differences in growth performance and may reflect underlying physiological and hormonal influences, including those related to sexual maturation (Suhendro et al., 2024).

Other key characteristics of pure Bali cattle include white markings on the inside of the thighs, upper lip edges, and lower legs from the tarsus and carpus to the upper hoof edge. The tail tip has black hair, inside ears are white, and a clear black stripe runs along the upper back. Male horns ideally have the "silak congklok" shape, growing slightly outward from the base, curving upward, then curving outward again at the tips. Female horns ideally have the "manggul gangsa" shape, growing in line with the forehead, curving slightly downward and backward, with tips turning down and inward. These horns are black in color (Hardjosubroto, 1994).

Evaluation of Bali Cattle

Linear Body Measurements of Livestock

A key challenge in developing Bali cattle farming is the low quality of breeding stock, which is believed to result from inbreeding and inadequate management practices. Genetic factors and crossbreeding often lead to negative effects such as decreased resistance, fertility, and birth weight (Sariubang et al., 1998). This aligns with Mikema's (1987) assertion that inbreeding increases the proportion of heterozygous gene loci but causes inbreeding depression, reducing resistance, fertility, and birth weight. Warwick et al. (1983) noted that inbreeding in cattle can reduce body weight by 2.5-5.0 kg for every 10% increase in inbreeding.

In response, the government introduced superior bulls in breeding source areas during 1989-1990. Initially, one bull type (semen) was introduced per area, but with greater access and choice, multiple breeds were distributed across regions (Sitorus et al., 1995). Despite a high proportion of pure Bali cattle genotypes among farmers, crossbreeding using artificial insemination is now common, driven by the higher market value of crossbred calves compared to purebred Bali calves. This trend suggests the need to evaluate the performance of crossbred calves, using production indicators like body weight and weight gain, or body size measurements correlated with weight (Handiwirawan et al., 1998). Hardjosubroto (1994) noted that body dimensions such as shoulder height, chest girth, and body length are indicators of cattle weight.

Sariubang et al. (1998) reported that introducing external bulls into the Bali cattle population in Barru, South Sulawesi, increased average birth weight by 1.92 kg in the first generation (F1), along with chest girth and shoulder height improvements, though body length was unaffected. Table 1 shows a significant impact of superior bulls ($P<0.05$) on calf birth weight, with differences between JU x BL compared to JL x BL and JL x BDS, but no significant difference between JL x BL and JL x BDS.

Further findings showed that body size growth from birth to breeding age (2 years) was greater in offspring of external bulls than local bulls (Table 2), consistent with Lasley's (1978) finding that heavier birth weights correlate with weaning weight.

The exterior traits of Bali cattle, similar to other ruminants, serve as indicators of productivity and reproduction. Chest girth strongly correlates with body weight (correlation coefficient 0.90-0.98) (Lana et al., 1979) and is influenced by factors like sex, age, environment including altitude, and feed availability (Prabowo et al., 1992).

Lubis and Sitepu (1998) reported that Bali cows aged 2-2.5 years averaged 112-114 cm in shoulder height, 115-116 cm in body length, and 151-154 cm in chest girth. Handiwirawan et al. (1998) found that Bali cattle have lower shoulder height compared to Brahman x Bali (Brahbal), Limousin x Bali (Limbal), and Simmental x Bali (Simbal) crossbreeds. Among calves under 31 days, Bali cattle had a shoulder height of 63.20 ± 6.34 cm, while Limousin and Simmental crosses were 70.00 ± 2.16 cm and 70.80 ± 5.02 cm, respectively. At 61-90 days, Brahman crosses had the highest shoulder height (86.67 ± 6.09 cm) compared to Limousin and Simmental crossbreds. Bali cattle had the shortest body length at under 31 days (56.00 ± 5.60 cm), with Limbal crossbreds the longest (65.00 ± 4.14 cm). Brahbal cattle showed the fastest growth in body length between 61-90 days (82.00 ± 6.45 cm) compared to Limbal cattle (80.42 ± 8.76 cm). Chest girth size under 31 days was slightly larger for Limbal cattle (78.62 ± 3.07 cm), though at 61-90 days, Brahbal, Limbal, and Simbal crossbreds exhibited similar chest girth measurements (106.83 ± 12.09 cm; 105.00 ± 11.92 cm; 106.00 ± 9.84 cm respectively, Table 3).

Table 1. Birth weight, shoulder height, chest girth, and body length of crossbred Bali cattle in Barru and Luwu Regencies, South Sulawesi (Sariubang et al., 1998).

Parameter	Birth Weight (kg)	Observation		
		Shoulder Height (cm)	Chest Girth (cm)	Body Length (cm)
JL x BL	11,83	61,33	61,71	42,47
JU x BL	13,77	63,96	63,91	42,91
JL x BDS	11,95	58,90	57,45	41,51

Description: JL = Local male, JU = Superior male, BL = Local female, BDS = Below-standard female.

Table 2. Average linear body measurements of Bali cattle at 2 years of age (Sariubang et al., 1998).

Body Measurements	Sex	JL x BL	JU x BL	JL x BDS
Body Lenght (cm)	Male	108,8 ± 3,4	105,8 ± 7,0	107,7 ± 6,9
	Female	104,0 ± 0,2	103,0 ± 1,8	100,6 ± 7,1
Shoulder Height (cm)	Male	104,4 ± 2,1	103,2 ± 1,9	109,4 ± 9,2
	Female	100,4 ± 4,8	98,6 ± 3,6	101,2 ± 9,8
Chest Girth (cm)	Male	148,5 ± 4,2	141,7 ± 5,3	149,8 ±10,2
	Female	133,2 + 8,0	131,1 + 7,6	137,7 + 9,2

Tabel 3. Shoulder height, body length, and chest girth measurements of Bali cattle and their crossbreeds in East Lombok Regency, West Nusa Tenggara (Handiwirawan et al., 1998).

Semen Type	Cow	Shoulder Height (cm)		Body Length (cm)		Chest Girth (cm)	
		<31 days	61-90 days	< 31 days	61-90 days	< 31 days	61-90 days
Bali	Bali	63,20+6,34 (10)	76,73+9,33 (11)	56,00+5,60 (10)	71,73+8,11 (11)	69,80+5,90 (10)	91,18+9,92 (11)
	Cross	-	-	-	-	-	-
Brahman	Bali	68 (1)	86,67+6,09 (6)	56 (1)	82,00+6,45 (6)	75 (1)	106,83+12,09 (6)
	Cross	77,50+6,36 (2)	-	69,50+9,19 (2)	-	87,50+0,71 (2)	-
Limousin	Bali	70,00+2,16 (13)	82,42+7,60 (12)	65,00+4,14 (13)	80,42+8,76 (12)	78,62+3,07 (13)	105,00+11,92 (12)
	Cross	72,40+2,61 (5)	89,50+5,89 (6)	67,00+6,21 (5)	92,83+9,33 (6)	83,20+6,22 (5)	110,67+9,16 (6)
Simental	Bali	70,80+5,02 (5)	83,67+8,39 (12)	59,00+9,33 (5)	84,25+8,19 (12)	76,80+6,30 (5)	106,00+9,84 (12)
	Cross	79,67+3,20 (6)	89,36+5,84 (11)	73,00+1,10 (6)	90,64+12,51 (11)	85,00+2,10 (6)	117,27+21,91 (11)

Note: numbers in parentheses indicate the number of cattle measured.

Livestock Reproduction

In efforts to enhance the Bali cattle population, reproductive failure is a common issue encountered. Field observations reveal this through signs such as delayed sexual maturity, high service per conception (S/C) rates, prolonged calving intervals, and extended post-partum estrus periods (Majestika, 1998). Reported S/C values for Bali cattle are 1.22 (Davendra et al., 1973), between 1 and 2 (Lubis and Sitepu, 1998), and 1.35 (Anonymous, 1979). The gestation period ranges around 287 ± 0.7 days (Davendra et al., 1973), 286 ± 15 days (Darmadja and Sutedja, 1976), 9.55 months (Pastika and Darmadja, 1976), and between 276 to 295 days (Lubis and Sitepu, 1998). The average interval for cows to return to estrus after calving varies from 106 to 165 days (Lubis and Sitepu, 1998). Meanwhile, the calving interval is recorded between 15.48 to 16.28 months or 15.88 ± 0.4 months (Davendra et al., 1973), 373 to 683 days or 528 ± 155 days (Darmadja and Sutedja, 1976), and 351 to 440 days (Lubis and Sitepu, 1998). The ideal calving interval is approximately 12 months (Bozwort et al., 1971) or between 12 to 14 months (Jainudeen and Hafez, 1987). This implies that cows should be bred or inseminated again within 60 days postpartum to become pregnant. The calving interval serves as a key metric for assessing livestock production efficiency (Bozwort et al., 1971) and reflects the reproductive performance of cattle (Fonseca et al., 1983).

Livestock Productivity

Productivity refers to the output produced by an individual livestock within a specific period (Hardjosubroto, 1994). In beef cattle, productivity is generally viewed as a function of reproductive performance and growth rate (Seiffert, 1978). According to Wodzicka-Tomaszewska et al. (1988), an animal's production aspects cannot be separated from its reproductive capabilities, implying that production cannot occur without reproduction. Moreover, the level and efficiency of livestock production are constrained by the reproductive efficiency (Djanuar, 1985). Improving beef cattle productivity can be achieved either by modifying environmental conditions or enhancing genetic quality, although in practice, a combination of both methods is applied (Djanuar, 1985).

Beef cattle productivity is influenced by multiple interrelated components, including reproductive performance (pregnancy rate, calving rate, and calving interval), pre-weaning and post-weaning growth traits (weaning weight and yearling weight), mortality rate, and average daily gain. These parameters are widely recognized as key biological and economic indicators in beef production systems (Dickerson, 1970; Jenkins & Ferrell, 1994; Patterson et al., 1992). Previous studies on the production potential of Bali cattle report birth weights ranging between 15-17 kg (Djagra et al., 1979), pre- and post-weaning mortality rates of 7-27% (Darmadja and Sutedja, 1976; Sumadi et al., 1982; Nggobe et al., 1991), and adult mortality of 2.7% (Sumbung et al., 1978).

Furthermore, Putu et al. (1998) found that supplementing Bali cattle feed with 3 kg of concentrate per head daily during the seventh month of gestation resulted in higher daily weight gain after 47 days compared to the control group (0.53 vs. 0.14 kg/head/day). The birth weights of the calves were also higher in the supplemented group (22.93 vs. 20.21 kg). Mortality before 47 days old was higher in the control group without concentrate supplementation (12.5%) compared to the supplemented group (6.3%). The main causes of calf mortality are environmental and genetic factors, including low birth weight, poor physical condition, low maternal milk production, short lactation duration (4 months), and feed shortages at weaning (Talib et al., 1998).

Bahar and Rakhmat (2003) reported that the daily weight gain of Bali cattle grazing on local forage ranged from 0.05-0.1 kg/head/day during the dry season and 0.2-0.4 kg/head/day during the rainy season. Therefore, to boost Bali cattle productivity particularly in the dry season, it is important to optimize the use of agricultural waste such as rice straw, peanut straw, and sweet potato vines, along with leguminous leaves for nutritional improvement. Vercoe and Frisch (1980) emphasized that livestock production and reproduction traits are influenced by factors including cattle breed, soil condition, pasture quality, disease, and management practices, including feeding and husbandry. Consequently, beef cattle improvement should focus on enhancing productive and reproductive traits supported by sound zootechnical and bioeconomic management.

Efforts to Preserve Bali Cattle

In efforts to conserve and develop the Bali cattle population, which represents a valuable local genetic resource in Indonesia, it is crucial to focus on breeding factors. The breeding program for Bali cattle can be implemented through crossbreeding selection, with its execution dependent on thorough documentation and evaluation under particular conditions. Although genetic improvement through selection typically progresses slowly, selection must continue to preserve the breed purity and support conservation efforts through effective management of Bali cattle. The distribution of Bali cattle has expanded across nearly all regions of Indonesia, with the largest populations concentrated in South Sulawesi, Timor Island, Bali, and Lombok. However, breed purity is maintained primarily in Bali Island, which serves as the seed stock center managed by the Bali Cattle Breeding and Development Project (P3-Bali) (Tanari, 2001). The government has also taken initiatives to improve Bali cattle's genetic quality by means of selection, including programs to establish breeding centers in rural areas (village breeding centers). For developing Bali cattle farming enterprises, the government applies two approaches: the Self-Supporting Pattern and the Partnership Pattern. The Self-Supporting Pattern relies on the farmers' own resources, either individually or in groups, while the Partnership Pattern (PIR-NAK) establishes cooperation between core companies and farmers as plasma partners. In this partnership model, all activities from pre-production, production, to post-production are jointly carried out by both plasma and core parties (Bank Indonesia, 2003).

The sustainable conservation of Bali cattle (*Bos javanicus domesticus*) requires the integration of advanced assisted reproductive technologies (ART), which provide both genetic security and reproductive efficiency within managed populations. Among these, cryopreservation of germplasm particularly semen, oocytes, and embryos, represents a cornerstone approach for maintaining and propagating genetic diversity in this indigenous breed. Cryogenic storage facilitates the long-term preservation of valuable genetic resources from elite sires and dams characterized by superior production traits, reproductive performance, or disease resistance (Susilawati et al., 2022; Witri et al., 2025). Moreover, this technology ensures the continuity of breeding programs even under population decline or biosecurity restrictions and enables genetic exchange between regions or countries without transporting live animals, thereby minimizing disease transmission risks (Ismirandy et al., 2020; Sawitri et al., 2021).

Empirical studies in Indonesia have demonstrated the successful application of semen cryopreservation in Bali cattle using various extenders, such as Tris-egg yolk, AndroMed, and Bioxcell, with significant improvements in post-thaw motility, viability, and acrosome integrity (Novita et al., 2021; Sawitri et al., 2021). Furthermore, in vitro embryo cryopreservation and transfer trials conducted by the Lembaga Penelitian Peternakan (LPP), currently known as Balai Penelitian Ternak (Ciawi, Indonesia), and other national laboratories have reported satisfactory conception rates, supporting the potential of assisted reproductive technologies (ART) in national genetic conservation programs (Ismirandy et al., 2020; Susilawati et al., 2022). Collectively, these efforts highlight that cryogenic preservation serves as both a biotechnological and strategic framework for safeguarding the genetic heritage of Bali cattle while enhancing their contribution to future sustainable livestock development in Indonesia.

Table 4. Production and reproduction performance of Bali cattle after being fed concentrate feed (Putu et al., 1998).

Parameter	**Sapi Bali**							
	Control (C)				**Treatment (T)**			
	n	**Min**	**Max**	**Average**	**n**	**Min**	**Max**	**Average**
Initial weight (kg)	16	184	301	247,5	16	199	319	247,56
Body Condition Score	16	3	6	4,18	16	3	6	4,06
Weight on day-47 (kg)	16	186	308	255,38	15	240	344	273,67
ADG on day-47 (kg/ekor)	16	-0,64	0,70	0,14	15	-0,19	1,34	0,53
Calving Rate (%)	15	-	-	93,80	16	-	-	100,00
Return to estrus (%)	3	-	-	18,75	2	-	-	13,33
Birth weight (kg)	14	16	30	20,21	16	16	28	22,93
Female calf birth weight (kg)	8	16	23	18,60	8	16	23	19,50
Male calf birth weight (kg)	6	16	30	22,3	8	16	28	20,60
Calf mortality (%)	2	-	-	12,50	1	-	-	6,25

Additionally, managing the outflow of cattle is important in developing the Bali cattle population, especially controlling the removal of productive female cattle in order to maintain population balance within a region (Tanari, 2001). Table 5 illustrates the population dynamics of Bali cattle in their native province of Bali, showing an increasing trend until the end of 1997 followed by a population decline. According to Hardjosubroto (1994), maintaining a constant population equilibrium of beef cattle in an area depends on factors such as natural increase, mortality rates, replacement stock needs, number of culled cattle, incoming live animals, and projected population growth in that region.

Table 5. Population dynamics of Bali cattle livestock in Bali Province (1990- 2000) (Biro Pusat Statistik, 2000 cit Kusumaningsih, 2002).

Year	**Livestock Population (heads)**	**Population Change (%)**
1990	456.179	-
1991	435.789	- 4,68
1996	528.400	2,78
1997	538.800	1,93
1998	524.615	- 2,70
1999	526.013	0,27
2000	529.064	0,58

For successful development of Bali cattle in any area, it is also essential to have a plan for improving genetic quality (Winter, 2003). One method for sustaining genetic quality of Bali cattle and other breeds in source areas is to accurately calculate the number of cattle of various genetic qualities that can be sold or removed, balanced with the amount and quality of breeding stock to be preserved for replacement purposes. In addition, crossbreeding Bali cattle with other breeds can also be pursued. Crossbreeding Bali cattle with breeds such as *Bos indicus, Bos taurus*, and various newer crossbreeds like Santa Gertrudis, Droughtmaster, Belmont Red, Braford, and Brangus has shown a growth performance increase of 50–100% (Martojo, 1989).

The importance of conserving Bali cattle genetic resources is unquestionable, yet it requires clear organizational efforts and regulatory support for effective implementation. In-situ conservation involves multiple stakeholders because local farmers, livestock owners, and surrounding communities play significant roles (Setiadi et al., 1998). Therefore, combining in-situ and ex-situ conservation approaches is recommended for better results. Approaches preventing Bali cattle extinction should consider technical, economic, socio-cultural, and political criteria to be successful.

In situ conservation of Bali cattle (*Bos javanicus*) refers to a genetic resource preservation strategy implemented directly within their natural habitat and traditional management systems of local communities. This effort includes community-based breeding programs in their native areas such as Bali and Nusa Penida Islands, population management by farmers through controlled breeding systems (farmer-managed breeding programs), as well as the protection of local environments and husbandry practices that maintain adaptive phenotypic and genetic traits. This approach is crucial for maintaining the natural genetic dynamics and ecological adaptations that have developed through both natural and socio-cultural selection among Balinese farmers. According to Mohamad et al. (2012), Bali cattle originated from the domestication of wild banteng (*Bos javanicus*) in Southeast Asia approximately 5,000–10,000 years ago, and molecular analyses indicate traces of genetic introgression from zebu (*Bos indicus*), highlighting the importance of preserving the genetic diversity and local identity of this population. Therefore, in situ conservation plays a vital role in maintaining genetic integrity, resilience to tropical stressors, and adaptive traits that make Bali cattle well-suited to marginal environments.

In contrast, ex situ conservation is carried out outside the natural habitat and serves as a genetic reserve when in situ populations face the risk of decline. This approach includes the maintenance of Bali cattle populations in conservation facilities such as zoological parks and closed breeding units (captive breeding), as well as the application of conservation biotechnologies through the collection and cryopreservation of semen, oocytes, and embryos in gene banks. As emphasized by FAO (2012), "gene banking is a long-term effort that needs to be viewed in terms of decades rather than years," underscoring the strategic role of germplasm preservation in long-term genetic security. Practical applications can be observed in ex situ conservation facilities in Indonesian zoos and research centers, where Bali cattle are maintained for educational, biogenetic research, and germplasm backup purposes (Fauziah et al., 2024). The in vitro storage of semen and embryos also enables the recovery of genetic variability among populations and supports selective breeding programs in the event of decreased field performance.

The integration of in situ and ex situ conservation represents a synergistic and essential strategy for ensuring the genetic sustainability of Bali cattle. This integrated approach involves (1) establishing nucleus herds in native habitats to preserve adaptive alleles; (2) collecting and storing superior genetic material in cryobank facilities; (3) applying assisted reproductive technologies such as artificial insemination and embryo transfer to enhance field genetic variability; and (4) periodically monitoring genetic diversity using molecular markers such as microsatellites and mitogenomes. This integrative framework is particularly critical because recent genomic evidence indicates low levels of genetic variability in both Bali cattle and wild banteng populations, characterized by "uniformly low genetic diversity in banteng and Bali cattle". Consequently, the combination of in situ and ex situ conservation approaches provides the most effective means to prevent genetic erosion, preserve local adaptive value, and ensure the long-term sustainability of Bali cattle as Indonesia's indigenous genetic resource (Agung et al., 2019).

Conclusions

Characterization of Bali cattle genetic resources through documentation and evaluation has been carried out, although still very limited. The government has made efforts to develop breeding programs using selection via the Bali Cattle Breeding and Development Project (P3-Bali) and village breeding centers, but in general, results have not met expectations. Efforts to improve the genetic quality of Bali cattle through crossbreeding have long been undertaken in Indonesia; however, these efforts were generally less successful due to lack of systematic implementation and failure to maintain the adaptation of imported breeds to the Indonesian environment. Furthermore, conservation and development of Bali cattle should be pursued through a combined approach of in-situ and ex-situ methods. It is also necessary to widely disseminate education and extension services regarding sustainable conservation and utilization of genetic resources (plasma nutfah) to farmers and the broader community.

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