Chapter

Breeds and Breeding System of Indigenous and Crossbred Goats in Nepal

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Abstract

Goats are the indispensable component of rural economy in Nepal where 10.98 million goats accounting for 45.3% of total ruminants contribute to 20.3% of the total meat production and 49.2 million US dollar in the national economy. Being popular as "poor man's cow" and "living cheque," they significantly contribute to food, nutritional, and economic security of the marginalized farmers creating employment opportunities in the country. This chapter has tried to review the existing breeds, their breeding systems, challenges and way forward to enhance production and productivity of goats. Findings revealed that Nepal is endowed with four major indigenous genetic resources of goats and their crosses with Boer, Jamnapari, Barbari, Sirohi, etc. Occasionally, native goat breeds of Nepal were crossed with Kiko and Damascus as well. Breeding of goats in Nepal is mainly based on selection, pure breeding within indigenous flock, and crossbreeding to the available exotic breeds. There have been some biotechnological approaches applied in goat breeding and evaluation of native breeds. Estrus synchronization followed by artificial insemination is currently being practiced. Goats, being the most popular and easy source of household income and family nutrition in Nepal, could be the important source of national revenue provided with improved breeding and other husbandry practices.

Keywords: goats, indigenous, breeds, growth, nucleus, multiplier herd

1. Introduction

Livestock production is the most important source of livelihood for about 120 million pastoralists worldwide [1], which provides draught power for more than 320 million hectares of farmland. Animal enterprise is one of the principal agricultural sub-sectors in Nepal that contributes about 11% to the national gross domestic product (GDP) and 27% to agricultural GDP [2]. According to the Ministry of Agriculture and Livestock Development [3, 4], goat alone contributes about 5% of AGDP. Goats therefore are the indispensable component of livestock in the country with 10.25 million goat population that accounts for 45.3% of the national ruminant population. Goat population has increased by 3.52% per annum from 2012 to 2017 and placed itself as the second largest consumed meat (20.3%) after the buffalo meat [3, 5], which is about 49.2 billion rupees in the national

economy. Being popular as "poor man's cow" or "living cheque," it significantly contributes to food and nutritional and economic security of the marginalized smallholder farmers and provides good employment and self-employment opportunities in the country.

There are four indigenous breeds of goats in Nepal, namely, Chyangra (in mountain), Sinhal (in high hills and low mountains), Khari (in hills and mid hills), and Terai mostly distributed in lower plains. The largest concentration of goats is topographically in the hills (52.2%) and regionally in central development region. Chyangra and Sinhal are the means of livelihood and family nutrition in high hills and mountain ecosystem where there are about 1% Chyangra and 15% Sinhal [3]. The most popular exotic breeds of goats are Boer, Jamnapari, Barbari, and Beetal which are mainly used for crossbreeding and upgrading of indigenous Khari and Terai breeds of goats.

In recent years, indigenous breeds of goats are preferred less by the commercial goat entrepreneurs. The major reason is considered to be the low production and productivity potential of native as compared to other exotic breeds. For five decades, studies are being made on various dynamics of goat production mainly aiming at increasing its production and productivity by improved feeding, breeding, health, and other management practices. With regard to the genetic improvement of goats, selection within the native breeds was popular among the herders in the past years. However, upgrading of the native goats by crossbreeding with the exotic breeds such as Boer and Jamnapari is being commonly practiced by the farmers since few decades expecting significantly increased production and productivity within a short time period.

With the country's entrance into the global market, many great opportunities resulted. It was also soon evident that foreign organizations flooded our country and took advantage of our lack of expertise in global promotion and marketing, since the Nepalese goat AnGR did not have documentation of the evidence of its potential and, therefore, failed effective marketing of its genetic materials. As a consequence, the population of the indigenous AnGR is diminishing drastically. The chapter aims to promote these valuable AnGR and to rectify the situation and to review the existing breeds of Nepalese goats and their breeding systems, challenges, and future way forward to enhance production and productivity of goats through scientific breeding practices.

2. Materials and methods

This chapter is mainly based on the information gathered and compiled through desktop review of available scientific publications including journals, proceedings, annual progress reports of various national institutions, technical bulletins, statistical year books, master and doctorate dissertations, project compilation reports, etc. This chapter covers general introduction, materials and methods, population and its distribution of goats, and diversity of goat genetic resources in Nepal. In addition, present review includes breeding management, variation in genetic parameters, and biotechnological approaches for goat development. Authentication of data available from different sources was carefully checked while preparing this chapter. Quantitative information used in this chapter were retrieved from authentic sources including published journals and reports of the Central Bureau of Statistics, Ministry of Agriculture and Livestock Development, Department of Livestock Services, Nepal Agricultural Research Council, universities, and other government organizations. For the validation of information collected for this chapter, authors also tried to triangulate the data from different sources.

3. Population and its distribution of goats in Nepal

According to the livestock census 2015/2016, the total goat population in Nepal was 10.98 million [6]. Province-wise goat population and distribution of goats per unit of area in Nepal is presented hereunder (see **Table 1**). Distribution of goat population was highest for Province No. 1 (2.28 millions—20.8%) followed by Province No. 3 (2.11 millions—19.2%) and 5 (1.96 millions—17.8%) with lowest for Province No. 6 (1 million—9.2%). However, the density of goats per unit area was found highest for Province No. 2 (146 goats/km^2) with lowest density for Province No. 6 (36 goats/km^2).

Similarly, 65,583 Mt of goat meat was produced in 2016 which was about 20.4% of total meat production in the country [6]. The largest amount of goat meat was produced from Province No. 5 followed by Province No. 1 and 3 with 14,595, 12,243, and 10,367 Mt meat productions, respectively. But the percentage contribution to total meat production was observed highest for Province No. 6 (25.9%) followed by Province No. 2 (24%) and was found lowest for Province No. 3 (14.3%).

More than 50% (5.74 millions) of the total goat population was distributed in mid-hill regions with 36 (3.98 millions) in Terai and 11.5% (1.26 millions) in high hills and Himalayan regions of Nepal (**Table 2**). However, according to percentage contribution related to meat production, in total goat meat contributes about 20.4% standing in second position after Buffalo meat (54%).

Province No.	Area (km^2)	Goat population	Density of goats per unit area (no./km^2)	Percentage of total population	Goat meat production (Mt)	Total meat production (Mt)	Percentage contribution
1	25,905	2,285,180	88.2	20.8	12,243	62,932	19.5
2	9661	1,406,039	145.5	12.8	10,012	41,748	24.0
3	20,300	2,108,581	103.9	19.2	10,367	72,253	14.3
4	21,504	1,144,030	53.2	10.4	6416	37,422	17.1
5	22,288	1,958,984	87.9	17.8	14,595	59,083	24.7
6	27,984	1,005,011	35.9	9.2	5058	19,515	25.9
7	19,539	1,078,290	55.2	9.8	6893	29,107	23.7
Total	147,181	10,986,114	—	100	65,583	322,059	20.4

Source: [6, 7].

Table 1.
Province-wise distribution of goat population, density of goats per unit area, meat production (Mt), and its contribution in Nepal.

Agroecological zones	Goat population	Percentage distribution	Goat meat production (Mt)	Total meat production (Mt)	Percentage contribution
Terai	3,983,886	36.3	30,117	145,798	20.7
Midhills	5,736,831	52.2	29,109	153,265	19.0
High hills	1,265,397	11.5	6357	22,996	27.6
Total	10,986,114	100	65,583	322,059	20.4

Source: [6].

Table 2.
Agroecological zone (AEZ)-wise distribution of goat population (number) and goat meat production (Mt) in Nepal.

4. Diversity of goat genetic resources in Nepal

4.1 Existing indigenous genetic resources

In Nepal, four indigenous breeds of goat have been identified and characterized. These breeds are distributed across various ecological domains of the country. They include Chyangra, Sinhal, Khari, and Terai [8–12] (see **Figure 1**). Characterization of these breeds is done based on morphological traits and mitochondrial DNA study (**Table 3**). Terai goats are predominantly found across southern plains and inner Terai (100–500 masl) from east to west of the country. Khari goats, also known as hill goat, are the principal goat breed found across the mid-hill region of Nepal at an altitude of 500–1500 masl. Kuwar [14] reported three distinct strains (small, medium, and large) existed among Khari population. Sinhal goats are abundantly available in high hills and mountain regions from 1500 to 2400 masl, whereas Chyangra goats are the dominant breeds across northern trans-Himalayan regions from an altitude of 2500–5000 masl from east to west.

4.1.1 Terai

Terai goats are found in the Terai region and inner valleys (tropical and subtropical climate) of the country and are reared as the meat-type animals [9]. They have been characterized at phenotypic, chromosomal, and mitochondrial levels [4, 12, 15]. They are heavily crossed with Indian breeds including Jamnapari, Barbari, Ajmeri/Sirohi, and Beetal; and thus population of pure Terai goats is at risk from the conservation point of view. This breed constitutes 27% [16] or less than that of the total goat

Figure 1.
Indigenous goat breeds of Nepal (photo courtesy: Animal Breeding Division, NARC).

Breeds	Positive attributes	Distribution	Status	Characterization
Terai	Hardy, good size, suitable for Terai	Across the Terai	Population declining	Phenotypic + chromosomal + mtDNA
Khari/ Hill	Principal breed, suitable for hills, hardy, prolific, meat animal	Across the midhills	Population declining	Phenotypic + chromosomal + mtDNA
Sinhal	Hardy, suitable for high hills, pack animal, large size	Across the high hills	Population declining	Phenotypic + mtDNA
Chyangra	Hardy, suitable for transhumance system, multipurpose (meat, pack, and pashmina)	Across the Himalayas	Population declining	Phenotypic + mtDNA

Source: [12, 13].

Table 3.
Positive attributes, distribution, and population status of Nepalese goats.

population of the country. Body color of Terai goats varies from pure white to pure black with mixed patches of different colors. Its compact body weight is around 30 kg with 60 cm body length, 65 cm chest girth, and 58 cm wither height. Body weight varies from 30 to 35 kg for male and 25–30 kg for female.

4.1.2 Khari

Khari goats (hill goats) are the principal goat breed and are found across the hills and midhills from east to west of the country. They are prolific with higher twinning ability and shorter kidding interval and good for meat purpose. They are hardy and well adapted to local environments and represent more than 50% of the total goat population in the country [16, 17]. They have been characterized at phenotypic, chromosomal, and mitochondrial DNA levels [12, 18]. They are normal from a conservation point of view.

Khari goats have great variation in coat color from white to black. It has been reported that there are six sub-types within Khari goats based on coat color. They are Seti (pure white), Kali (pure black), Khairi (brown), Ghorli (brown with white and other color patches), Singari (black with white stripes on face), and Dhobini (ash color) [19]. Dhobini sub-type is bigger in size than the other five sub-types, weighing around 30 kg, with 63, 65, and 56 cm length, chest girth, and wither height, respectively. Khari goats from different clusters of eastern, western, and midwestern regions of Nepal show that the Khari goats' body size are heavier in midwestern (Salyan and Surkhet) from those found in western and eastern regions (see **Table 4**).

4.1.3 Sinhal

Sinhal goats are the heaviest native goat breed and represent 16% of the total goat population [16] and are the predominant breeds of high hills in Nepal. They are good for meat production and transportation as pack animals under transhumance system provided with low-input management system. They are large-sized hardy and well-adapted animals to local harsh conditions. They have been characterized at phenotypic and mitochondrial levels. The farmers are conserving them in situ, but an increased focus is needed on better management practices on breeding, feeding, housing, and health. They are at risk from conservation point of view.

Parameters	Cluster A (46)	Cluster B (70)	Cluster C (73)
Body length (cm)	69.3 ± 0.3[a]	66.5 ± 0.2[b]	64.9 ± 0.2[c]
Wither height (cm)	66.9 ± 0.2[a]	64.7 ± 0.1[b]	59.2 ± 0.2[c]
Heart girth (cm)	69.9 ± 0.3[a]	66.5 ± 0.2[b]	65.9 ± 0.2[c]
Flank girth (cm)	81.7 ± 0.2[a]	80.1 ± 0.2[b]	71.4 ± 0.1[c]
Flank height (cm)	68.9 ± 0.2[a]	67.3 ± 0.1[b]	61.1 ± 0.2[c]
Ear length (cm)	15.6 ± 0.2[a]	13.3 ± 0.2[b]	13.3 ± 0.1[b]
Horn length (cm)	16.7 ± 0.6[a]	10.7 ± 0.5[b]	11.3 ± 0.3[b]
Adult weight (kg)	38.6 ± 0.8[a]	31.8 ± 0.4[b]	27.7 ± 0.5[c]

Note: Number in parenthesis indicates the number of observations. Cluster A, goats from midwestern region (Salyan and Surkhet); Cluster B, goats from west (Lumle and Bandipur); and Cluster C, goats from east (Sindhuli and Pakhribas) of Nepal. Means with different superscripts differ significantly. Source: [14].

Table 4.
Khari goats from different clusters of eastern, western, and midwestern regions of Nepal.

Sinhal varies in its coat color from black to white, where gray, black, and white mixed are the common coat colors of this breed. Average adult body weight of Sinhal is reported as 35 kg for male and 29 kg for doe, with 69 cm body length, 78 cm heart girth, and 59 cm wither height on an average.

4.1.4 Chyangra

Chyangra goats are the mountain goat originating from Tibet reared in trans-Himalayan region along with Bhyanglung, a type of sheep in high mountain and trans-Himal region 2500 meters above sea level. They have been reared in situ condition by farmers themselves. They are suitable for meat and pack and are popular for high value as well as fine quality called *Chyangra* fiber known as *Pashmina* [20]. Their population is declining and hence needs attention. They have been characterized at phenotypic and mitochondrial levels. Chyangra fiber has high market potentials, as they have unique blend and qualities and hence are popular within and outside the country. Chyangra population is estimated to be around 1% of the total goat population, i.e., 0.11 million heads in Nepal [6]. Body color varies from pure white to pure black with mixed patch of different colors. Its compact body weighs around 30 kg with body length of 62 cm and chest girth of 71 cm. Wither height is 62 cm. Body weight varies from 29 to 32 kg for females and 35–40 kg for males. The morphological variation of four indigenous breeds of goats in Nepal is presented hereunder (see **Table 5**).

Owing to the remoteness, harsh climatic condition and transhumance system of management Chyangra goat are not getting due consideration from public and private institutions. Thus, productivity and population of this breed is dwindling rapidly. The goat is used for meat and for pack purpose in mountain terrace where road facilities are seldom. The breed is also used for production of precious *pashmina* (Chyangra cashmere). Besides their incomparable contribution in mountain farming system, the breed has not been understood completely in the sense of their quantitative and qualitative attributes. Limited information are available on morphological characteristics and growth traits. The breed is not fully utilized for its Chyangra cashmere production, and this is an area of importance where focus is required [25].

4.1.5 Chitwan local goats

Apart from above indigenous breeds, there are niche specific breed studied at inner Terai region, that is, Chitwan District of Nepal, referred to as Chitwan local

Parameters	Terai	Khari	Sinhal	Chyangra
Body length	60.6 ± 0.87	63.1 ± 0.39	68.7 ± 0.44	62.3 ± 0.36
Heart girth	65.2 ± 0.44	65.5 ± 0.37	77.8 ± 0.44	71.3 ± 0.37
Height at wither	57.9 ± 0.32	55.9 ± 0.28	59.2 ± 1.06	62.4 ± 0.23
Height at hip bone	60.8 ± 0.73	51.5 ± 1.76	M: 51.7 ± 1.27 F: 53.3 ± 0.72	M: 60.8 ± 0.78 F: 58.7 ± 0.85
Head length	18.3 ± 0.25	15.5 ± 0.56	16 ± 0.4	15.1 ± 0.6
Tail length	13.4 ± 0.2	12.6 ± 0.3	12.0 ± 0.4	15.1 ± 0.6
Horn length	8.37 ± 0.2	11.5 ± 1.3	15.3 ± 0.84	18.2 ± 0.7
Ear length	18.7 ± 0.30	16.2 ± 0.4	14.5 ± 0.5	10.5 ± 0.4
Neck length	25.7 ± 0.45	20.5 ± 0.56	20.7 ± 0.76	20.2 ± 0.7
Loin girth	74.1 ± 0.65	72.8 ± 0.53	73.5 ± 1.19	70.3 ± 0.43
Barrel girth	84.7 ± 5.8	86.7 ± 3.3	53.2 ± 4.7	75.3 ± 1.4
Fore legs above knee	19 ± 0.52	17.8 ± 0.47	18.7 ± 0.49	16.1 ± 0.51
Fore legs below knee	16.2 ± 0.3	16 ± 0.57	16.3 ± 0.33	15.2 ± 0.65
Rear legs above knee	23.2 ± 0.61	22 ± 0.58	23.2 ± 0.65	18.3 ± 0.54
Rear legs below knee	22.6 ± 0.49	19.8 ± 0.4	21.2 ± 0.3	17.8 ± 0.45
Adult body weight (kg)	F: 23.3 ± 0.1 M: 30–35	F: 24.1 ± 0.34 M: 28–40	F: 34.8 ± 0.12 M: 28–42	F: 29.1 ± 0.69 M: 35–40

Source: [16, 21–24].

Table 5.
Comparative morphometric measurements of indigenous breeds of goat (values are means in cm ± standard errors).

goats. Very limited information is available about this breed to date. These breeds have a medium-sized body having heavier body weight than Khari and Terai goat breeds with dominant white color with distribution of brown, black, and mixed color. It has been reported that the age at first conception, age at first kidding, gestation length, kidding interval, and postpartum estrus were 211, 356, 147, 236, and 87 days, respectively, for adult does of Chitwan local goats. The adult does of Chitwan local (31.1 kg) were significantly heavier ($p < 0.001$) than that of Terai goat (25.9 kg) and Khari goats (23.5 kg). It had been observed that the mean birth, weaning, and postweaning (8 months) weight for these breeds of goats were 2.48, 13.22, and 17.64 kg, respectively. Apart from above findings, it is also reported that the mean litter size at birth were 2.0, 1.53, and 1.48 kids per doe and at weaning were 1.94, 1.49, and 1.28 kids per doe for Chitwan local, Terai, and Khari goats, respectively [26, 27].

4.2 Popular exotic breeds of goats in Nepal

4.2.1 Jamnapari

Jamnapari is a breed of goat originating from the Indian subcontinent. It is a dual-purpose breed kept for both milk and meat. Jamnapari goats were mainly introduced in Nepal to upgrade and improve body weight of local Khari and Terai goats. Adult Jamunapari goat has a body weight of 45 kg for bucks and 38 kg for does along with wither height between 75 and 78 cm, body lengths of 75–77 cm, and heart girth of 76–79.5 cm (**Table 6**). Yearling weight of these goats in research stations was about 21 kg. The average age at first kidding and kidding interval in Jamnapari goats is 770 and 428 days, respectively.

Production performances	Jamnapari		Barbari		Beetal	
Birth weight (kg)	4.3		1.7		2.8	
Yearling wt (kg)	29.6		14.5		15.0	
Adult weight (kg)	44.7	38.0	35.8	22.6	59.1	35.0
Body length (cm)	77.4	75.2	70.4	56.2	85.5	70.4
Hearth girth (cm)	79.5	76.1	75.5	64.3	86.0	73.7
Wither height (cm)	78.2	75.2	70.7	56.2	91.6	77.1

Source: [28].

Table 6.
Comparative productive performance of exotic breeds of goat in Nepal.

4.2.2 Barbari

The Barbari goats are a meat-type breed that is found in Mathura District of Uttar Pradesh, in addition to Gujrat, Jhelum, and Sargodha districts in Punjab Province. Barbari goats are popular for its compact and small body with average adult weight ranging from 23–36 kg (**Table 6**). Body color is mainly white with brownish red spots and coat is short. The head is small, with small upward-pointing ears and small curled horns. Does have good reproductive performance and produce well in intensive system and at dry areas. Average age at first kidding and kidding interval in Barbari goats is 588 and 274 days, respectively. Triple kidding and early maturity are common features of these goats.

4.2.3 Sirohi/Ajmeri

The Sirohi and Ajmeri goats are a meat-type breed that is found in Sirohi District of Rajasthan. This breed also extends to Palanpur in Gujarat. Mature males weigh around 50 kg but females weigh only 25–30 kg (**Table 6**). These are compact, medium-sized animals. Coat color is predominantly brown, with light or dark brown patches; a very few individuals are completely white. Most animals are wattled. Ears are flat and leaf-like and medium-sized and have a drooping ear length of 18.8 cm. Both sexes have small horns, curved upward and backward. Tail is medium in length and curved upward. Udder is small and round, with small teats placed laterally. Some commercial farms and lead farmers have imported this breed and crossbred with Khari and Terai goats, but the information regarding the productive and reproductive performance is still to come.

4.2.4 Boer

The Boer is an improved breed with some infusion of European, Angora, and Indian goat breeding developed in South Africa in the early 1900s. The Boer goat is primarily a meat goat with several adaptations to the region in which it was developed. It is a horned breed with lop ears and showing a variety of color patterns. The most common color of this breed is white body with red head and large, muscular frame. The Boer goat is being popular for its browsing ability and limited impact on the grass cover. Producing weaning rates in excess of 160%, the Boer goat doe is a low-maintenance animal that has sufficient milk to rear a kid that is early maturing. The mature buck weighs between 110 and 135 kg and does between 90 and 100 kg. Performance records for this breed indicate exceptional individuals are capable of average daily gains over 200 g/day in feedlot. More standard performance would be 150–170 g/day.

The ovulation rate for Boer goats ranges from one to four eggs/doe with an average of 1.7. A kidding rate of 200% is common for this breed. Puberty is reached early, usually about 6 months for the males and 10–12 months for the females. The Boer goat also has an extended breeding season making possible three kids every 2 years.

It was introduced in Nepal from a private sector to improve growth performance of local goats. Recently, projects funded by the World Bank (WB) and International Fund for Agriculture Development (IFAD) implemented by the Ministry of Agriculture and Livestock Development specifically Agriculture Food Security Project (AFSP) and Kisan Ka Lagi Unnat Bui Bijan Karyakram (KUBK), respectively, are working on producing crossbreds with the local Khari/Hill goat, government, and breeders' farmers

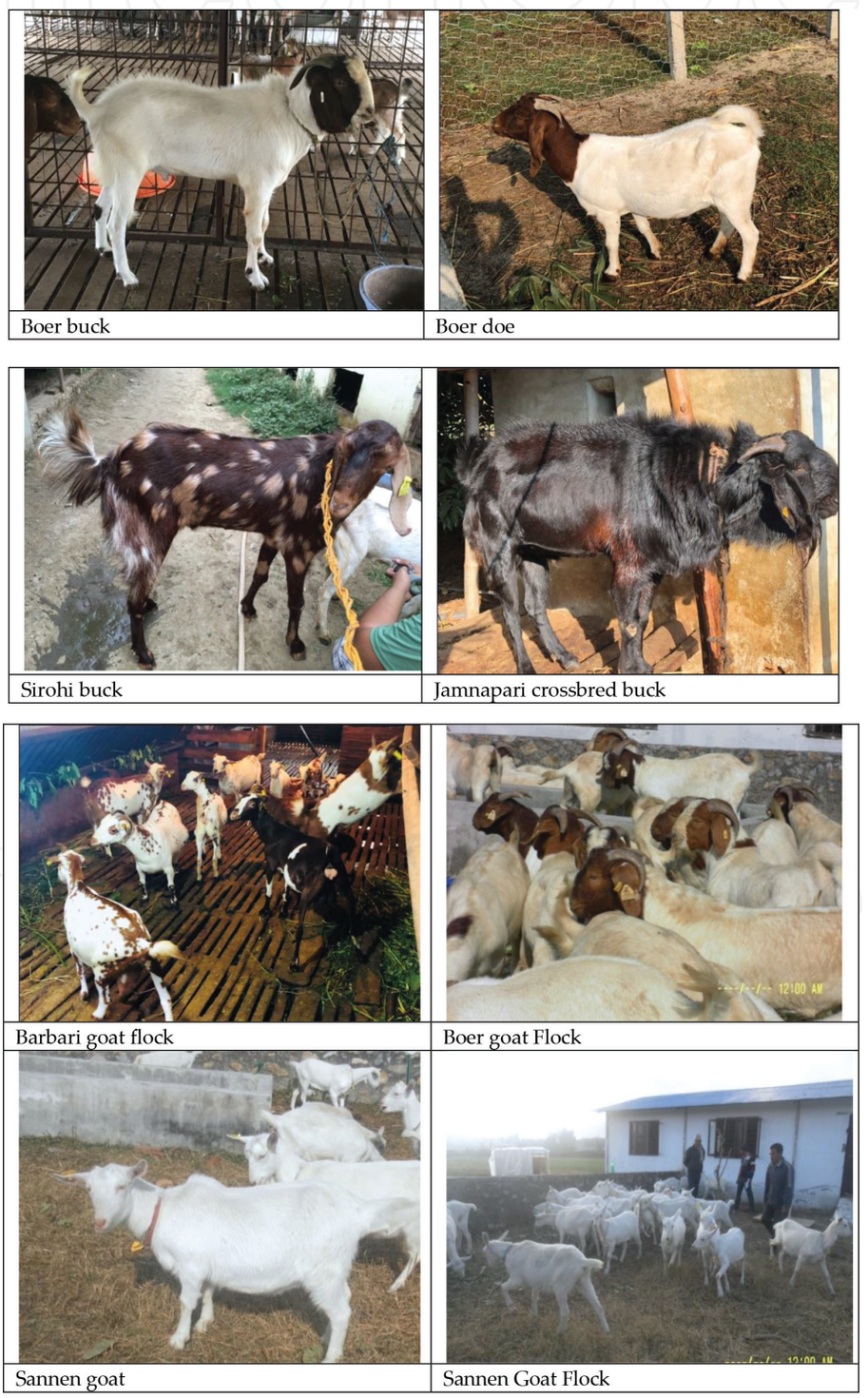

Figure 2.
Different exotic goat breeds available in Nepal (photo courtesy: Animal Breeding Division, NARC).

of mid- and far-western regions. Goat Research Station, Bandipur; RARS, Khajura; and GDF, Budhitola, are the government-owned farms with nucleus herd of Boer goat in Nepal. However, a comprehensive study on survivability, growth, and reproductive performances as well as efficiency (economics) needs to be investigated.

4.2.5 Saanen

Saanen goats are dairy goats originating from Switzerland, in the Saanen Valley. Saanen does are heavy milk producers (on an average of 4 L/day) and usually yield 3–4% milk fat. It is medium to large in size (female weighing approximately 65–70 kg and males weighing about 80–90 kg) with rugged bone and plenty of vigor. Saanen goats are white or light cream in color, with white being preferred. The hairs are short and fine, although a fringe over the spine and thighs is often present. Ears are erect and alertly carried, preferably pointing forward. The face is straight or dished. A tendency toward having a Roman nose is being discriminated against. The breed is sensitive to excessive sunlight and performs best in cooler conditions.

4.2.6 Beetal

The Beetal is a breed used for meat and milk production found in Punjab, Pakistan, and India. The Beetal is usually black and the males have long twisting horns. The breed is similar to the Jamnapari but smaller. The adult male weighs around 60 kg and females are 35–40 kg (**Table 6**). The coat is short and lustrous. The face line is convex, with a typical Roman nose but not as prominent as in Jamnapari. Ears are long and flat, curled, and drooping with ear length of 24.8 cm. The udder is large and well developed, with large conical teats. Pictorial presentation of popular exotic breeds in Nepal is provided in **Figure 2**.

5. Breeding management

5.1 Selection

Genotype of an individual is determined by the genes received from the buck and doe at fertilization (union of sperm and ova) and remains the same throughout life except in few circumstances. Therefore improving genetic superiority of kids depends on the careful selection of superior bucks and does and mating them appropriately. Thus, selection is the most basic and common tool being practiced for genetic improvement in the major economic traits of goats. It is the process of choosing superior goats (male and female) from the herd that are likely to be the parents of the next generation.

Selection, whether based on individual, family, or pedigree, is dependent upon the economically important traits (meat, milk, pashmina, etc.) of the selected genes. Goats in Nepal have been mostly selected for meat production. However, the mountain goats are also being selected for pashmina (fiber) production, and in very rare cases, they are being selected for increased milk production. These traits are quantitative and are influenced by many genes (additive, dominance, and epistatic). Chyangra goats produce up to 2–3 kg pashmina fiber annually.

There is potential to develop dual-purpose meat and fiber producers but only under improved nutritional conditions compared to present day. Thus, there is great possibility of developing Chyangra as a dual-purpose goat breed in mountain ecosystem.

In selecting for fiber, one is interested in both quantity (weight) and quality of fiber (length, fineness, style, character, absence of Kemp, etc.). In addition to fiber, one must be concerned with traits that contribute to the survival or viability (soundness, fertility, etc.) of the individual and flocks.

The selection of any breed for a particular ecological domain may not give the desired result if the required care is not paid in selecting genetically superior individual as parents of future generation. Indigenous goat breeds (Chyangra, Sinhal, Khari, and Terai goats) and exotic breeds (Jamnapari, Barbari, Beetal, Saanen, Damascus, Kiko, etc.) have their own importance. Nepal government has focused mainly on selection and mating of the best to the best individuals within the existing indigenous goat population. However, recommendation of the appropriate breeds for the specific ecological belt of Nepal is not consistently working at farmers' level.

Here are the important selection criteria breeders are following to select the goats in general for their genetic for improvement:

- High growth rate (greater finishing weight at slaughter age)
- Prolificacy (twining)
- Kid rearing (less kid mortality—milking ability of does)
- Resistance to internal parasite—good growth
- Early age at maturity and regular kidding (3 times in 2 years)—good fertility
- Carcass yield and quality

Chyangra goats are being selected by the breeders and/or herders to some extent for improving:

- Quantity of pashmina fiber
- Quality of the fiber (fineness, length, color also matters)
- Body size and weight trait (correlated response larger body size—larger surface area and more Pashmina yield)

Selection for pashmina fiber quality includes primarily fiber diameter (finer fibers preferred), length (4 inches minimum), freedom from Kemp (coarse, brittle, chalky white hair mixed in the fleece), and desirable lock formation.

Selection for quantity of pashmina fiber is accomplished efficiently by using fiber weights of Chyangra goats which are being considered as breeding animals. However, history indicates that most producers practice visual selection. In this case the predicting indicators of fleece weight are:

- Size of the animal
- Completeness of cover
- Length of fiber
- Diameter fiber
- Differences in density

Traits	Genetic gain/year (a)	R	Genetic gain/year (b)	R
Birth weight (g)	105	6.4	58	3.5
Weaned weight (g)	289	4.0	159	2.2
6-month weight (g)	276	3.4	152	1.9
36-week weight (g)	295	2.9	162	1.6
48-week weight (g)	394	3.2	216	1.8
LS at birth (no)	0.008	0.5	0.005	0.3
LS at weaning (no)	0.008	0.6	0.004	0.3
LW at birth (g)	120	4.6	66	2.5
LW at weaning (g)	247	2.5	136	1.4

(a) When both selected bucks and does are used; (b) when only selected bucks are used. R = response to selection per year (%). Source: [29].

Table 7.
Predicted response to selection for both growth and reproductive traits in Khari goat breed.

Genetic gain and response to selection have been studied for some weight and litter traits of Khari goats [29], and it is reported that these selection parameters were higher when both males and females are selected than when only males were selected (see **Table 7**).

5.2 Pure breeding

Pure breeding within the indigenous goat population is common practice among the herders especially in the mountain and high hill region. Thus, Chyangra and Sinhal goats are bred within themselves for maintaining genetic purity without losing the adaptation potentials of the flock. In some areas where goat improvement interventions are not implemented by the government and/or development agencies, pure breeding of Khari goat is common as well. This system of breeding helps maintain the genetic purity of native breeds un-deteriorated and could be conserved for long.

5.3 Crossbreeding

In the last few decades (1990s), Khari goats were massively crossed with the Indian Jamnapari and Barbari goat breeds for increasing growth and productivity of native breed, assuming that the crosses of Jamnapari and Barbari goats with Khari would give the better result. After some research works carried out by the Nepal Agricultural Research Council (NARC) at its agricultural research stations (ARSs), the Department of Livestock Services (DLS) again convinced that the Khari could be the best breed for meat production because of its better production characteristics, especially higher twinning percentage, prolificacy, lower kidding interval, efficient average daily gain (ADG), higher resistance against the diseases and parasites, etc.

Now, Khari goats are being crossbred with Boer either naturally or through artificial insemination with frozen semen in hilly regions across the country through the initiation of leading private goat entrepreneurs (Bagmati Goat Seeds Pvt. Ltd., Dhadhing; Bagaichha farm house, Nawalparasi; Jagatput Agro, Chitwan, etc.), Ministry of Agriculture and Livestock Development, and internationally funded projects including Agriculture and Food Security Project (AFSP) funded by the World Bank, Improved Seeds Program for Farmers (KUBK/IFSP) funded by IFAD, etc.

Breed	Body weight kg (mean ± SE)				
	At birth	4 M	6 M	9 M	12 M
Khari	1.75 ± 0.38	7.57 ± 2.33	11.02 ± 4.31	15.23 ± 6.17	19.24 ± 5.67
Sinhal	1.87 ± 0.10	11.22 ± 3.49	14.03 ± 3.12	17.34 ± 4.67	22.05 ± 5.68
Barberi	1.43 ± 0.42	7.35 ± 1.01	10.48 ± 1.88	14.40 ± 3.89	19.38 ± 4.89
50% Jamnapari	2.32 ± 0.65	9.11 ± 2.74	14.69 ± 4.60	18.38 ± 4.44	21.27 ± 5.06
50% Barberi	1.73 ± 0.28	6.87 ± 2.32	10.31 ± 1.26	14.35 ± 3.63	18.43 ± 4.21
50% Kiko	1.83 ± 0.72	7.86 ± 1.10	12.27 ± 3.68	17.81 ± 4.38	20.0 ± 3.97
50% Boer	2.20 ± 0.61	13.80 ± 3.29	17.85 ± 4.36	25.25 ± 5.88	34.10 ± 8.62

Source: [30].

Table 8.
Growth performance of indigenous and crossbred goats at Goat Research Station (GRS), Bandipur.

Fixed factors	No.	Birth (BWT)	Pre-weaning (PWW)	Weaning (WWT)	6 months (SMW)
Grand mean	772	2.48 ± 0.03	7.04 ± 0.12	12.09 ± 0.22	20.52 ± 0.16
25% Boer:75% Khari:0% JP	232	2.38 ± 0.04^{b}	7.03 ± 0.14^{ab}	11.72 ± 0.26^{ab}	20.70 ± 0.15^{b}
25% Boer:50% Khari:25% JP	10	2.21 ± 0.09^{c}	6.37 ± 0.30^{b}	10.53 ± 0.55^{c}	20.63 ± 0.90^{b}
50% Boer:50% Khari:0% JP	218	2.69 ± 0.04^{ab}	7.68 ± 0.14^{a}	13.45 ± 0.26^{a}	23.40 ± 0.19^{a}
50% Boer:25% Khari:25% JP	16	2.86 ± 0.10^{a}	7.55 ± 0.33^{a}	13.62 ± 0.60^{a}	23.91 ± 0.58^{a}
0% Boer:100% Khari:0% JP	296	2.26 ± 0.04^{b}	6.58 ± 0.15^{b}	11.11 ± 0.27^{bc}	18.05 ± 0.11^{c}
Significance		***	***	***	***
CV		9.73	10.30	11.12	9.34
R^2		0.61	0.53	0.54	0.58

****Significant at 0.1% level of significance.*
JP = Jamnapari. Source: [31].

Table 9.
Growth performance of Khari and its crossbred kids at different growth stages under farmers' field.

The preliminary results suggest that crossbreeding Boer with native Khari breed would give a better result with respect to higher growth rate maintaining twinning ability of the crossbred female kids. The growth and reproductive performance of Khari goats crossbred with different exotic breeds is presented hereunder (see **Tables 8** and **9**).

Growth performance of Khari and its crossbred kids with different blood levels of Boer and Jamnapari breeds were studied [31], and it was reported that there was a significant difference ($p < 0.001$) between the crossbred kids of different blood levels with respect to birth, pre-weaning, weaning, and 6 months weight at their respective ages. Accordingly, the crossbred kids of a three-way cross with 50% Boer:25% Khari:25% Jamnapari blood level has the best result in the weight traits at different stages as compared to other blood levels (see **Table 9**).

At Goat Research Station, Bandipur, under Nepal Agricultural Research Council, 50% crossbred kids of Khari and Boer were evaluated. Preliminary results suggested

Age	Male		Female		Overall
	Weight (kg)	ADWG (g)	Weight (kg)	ADWG (g)	weight (kg)
Birth	2.92 ± 0.66		2.44 ± 0.83		2.68
Weaning (4 months)	16.37 ± 3.5	109.5	14.96 ± 1.95	102.25	15.66
Postweaning (8 months)	29.48 ± 1.32	109.37	25.32 ± 1.46	94.29	27.40
Yearling (12 months)	42.32 ± 1.49	107.09	38.87 ± 1.29	99.12	40.59

Source: [32].

Table 10.
Growth performance of 50% Boer kids from birth to yearling age at Multiplier Herd, GRS, Bandipur.

S N	Reproductive traits	Khari × Jamnapari	Khari × Barbari	Khari × Kiko	Khari × Sannen	Khari × Boer
1	Age at first kidding (d)	577	564	576	423	
2	Kidding interval (d)	319	286	496	257	
3	Twinning percentage	45.50	58.33	33.00	91	
4	No of kids/doe/ annum	1.79	2.09		2.6	2.55
5	No of kids weaned per doe per annum	1.28	1.60	1.14		
6	Live weight gain per doe per annum (kg)	19.14	16.15	18.37		

Source: [28, 33].

Table 11.
Some reproductive parameters of crossbred goats in Nepal.

Figure 3.
Crossbred goats at Goat Research Station, Bandipur (photo courtesy: Goat Research Station, Bandipur, Nepal).

that there is great scope and possibility of enhancing growth and productivity (average daily weight gain) of native Khari goat in later generation by producing crossbred kids of Boer goat. Body weight of 50% Boer crossbred kids at different stages of growth from birth to yearling age is presented hereunder (see **Table 10**).

Furthermore, reproductive traits of Khari and its crossbred female kids are expressed differently in different genotypes (see **Table 11**). The trait value for important reproductive traits of female kids of different crosses is presented hereunder. Pictorial presentation of different crossbred goats in Nepal is provided in **Figure 3**.

6. Variation in genetic parameters

6.1 Heritability

Limited research has been carried out to estimate the genetic parameters of goat flocks in Nepal. Findings indicate that most of the desirable economic traits of goats in Nepal are moderately to highly heritable (see **Table 12**). Moderate to high heritability of the weight traits of *Khari* goat kids [17] indicated a relatively large contribution of additive genetic variance and potentiality for improving body weight in goats by selection. Similarly, increasing heritability of body weights of kids at the later stages of growth indicated that environmental factors have more influence on birth weight than on the weights achieved on the later stage of growth.

6.2 Genetic and phenotypic correlation

Past studies have revealed the genetic correlation among the weight traits at different stages of growth of *Khari* goat kids ranging from 0.61 to 0.96 (see **Table 13**). The high and positive genetic correlations of weaning weight at 6, 9, and 12 months of *Khari* goat kids indicate that they are all being controlled by similar genes, and thus selection for any one of these traits would lead to positive changes in the other [35, 36].

Traits	Heritability (Harvey)
Birth weight	0.37 ± 0.12 [17]
Pre-weaning weigh	0.42 ± 0.13 [17]
Weaning weight	0.42 ± 0.13 [17]
6-month weight	0.46 ± 0.14 [17]
9-month weight	0.44 ± 0.13 [17]
12-month weight	0.40 ± 0.12 [17]
15-month weight	0.39 ± 0.12 [17]
Litter size at birth	0.10 ± 0.093 [34]
Litter size at weaning	0.05 ± 0.097 [34]
Litter weight at birth	0.44 ± 0.155 [34]
Litter weight at weaning	0.66 ± 0.202 [34]
Kidding interval	0.03 ± 0.099 [34]
Gestation length	0.21 ± 0.118 [34]

Source: [17, 34].

Table 12.
Heritability estimates for different traits of hill goat.

Body weight at	Body weight at						
	Birth	Pre-weaning	Weaning	6 months	9 months	12 months	15 months
Birth	—	0.61**	0.71**	0.72**	0.76***	0.79***	0.78***
Pre-weaning	0.64**	—	0.81***	0.80***	0.75***	0.65**	0.55*
Weaning	0.67**	0.80***	—	0.95***	0.86***	0.78***	0.68**
6 months	0.68**	0.75***	0.91***	—	0.93***	0.85***	0.76***
9 months	0.71**	0.69**	0.81***	0.92***	—	0.96***	0.85***
12 months	0.70**	0.62**	0.75***	0.83***	0.94***	—	0.95***
15 months	0.72**	0.56*	0.66**	0.76***	0.86***	0.94***	—

*Significant at 5% level (i.e., $p < 0.05$).
**Significant at 1% level (i.e., $p < 0.01$).
***Significant at 0.1% level (i.e., $p < 0.001$).
Source: [17].

Table 13.
Genetic correlation (above diagonal) and phenotypic correlation (below the diagonal) between the weight traits of Khari *goat kids at different stages of growth in Nawalparasi, Nepal.*

Similarly, phenotypic correlation among the weight traits at different stages of growth of *Khari* goat kids ranged from 0.56 to 0.94 (see **Table 13**). Strong positive association among the weight traits of kids at all stages of growth indicates that selection for increased weight at earlier age will result in increased weight of kids at later stage of growth as reported by earlier studies [37].

7. Biotechnological approaches

Biotechnological advances particularly estrus synchronization, artificial insemination (AI), and embryo transfer (ET) have not been exploited widely so far in the country and could be the avenue of future goat development program. Lack of goat breeding centers for quality seed and ever-increasing demand on breeding stocks and chevon strongly justify the massive use of AI and ET in goat. National Livestock Breeding Center, Pokhara, and Animal Breeding Division, NARC, are being stepped up in the direction.

7.1 Estrus synchronization and artificial insemination

Synchronization of estrus allows the farmers to shorten the breeding season of their flock by bringing all of their does into heat around the same time so that they will kid at the same time. Other advantages of this technique include reducing the time required to check heat, reducing the time required for intensive care of the herd or flock, and pregnancy being able to be shifted to coincide with favorable marketing patterns. Controlled Internal Drug Release (CIDR) device is being used in conjunction with gonadotropin (pregnant mare serum gonadotropin) hormone to bring does into estrus.

Artificial insemination, in the developed countries, is the good example of how tremendous improvements can be made in both genetics and reproductive management of goats by using synchronization methods. In Nepal, frozen Boer goat semen (both pellet and straw) is being imported from India and Australia to upgrade Khari goats through AI at research stations, government farms, and multiplier herd identified

at mid- and far-western regions of Nepal. However, the result of AI and conception obtained till date is not so convincing due to lack of skilled technicians, timely unavailability of liquid nitrogen at remote areas, and improper husbandry practices followed by farmers (grazing and feeding). Thus, AI program needs to be reviewed and practiced on station first to improve the conception rate before wide dissemination.

7.2 Embryo transfer

The Government of Nepal has established embryo transfer facilities at National Livestock Breeding Office (NLBO), Pokhara. Works have been started in dairy cattle and importation of live embryo, and transferring them to the recipient is being practiced occasionally in this species. However, this technology is not being tested in the case of goats to date in the country.

7.3 Biochemical analysis

It has been reported that the Khari/Hill goats across the mid-hill region from east to west of the country has three distinct types with respect to genetic distance. The goats of the midwestern are bigger in body size followed by western region with eastern region having a smaller body size. Also a report on protein analysis indicated that hemoglobin was polymorphic in Khari/Hill goats with two genotypes, HbAA and HbAB, in the sampled population. The gene frequency of HbA was higher than HbB, which was more in the goats sampled from eastern Nepal. Also, it has been reported that the four genotypes of transferrin, TfAA, TfAB, TfBB, and TfAC, were found in the Khari/Hill goats with decreasing frequencies. The gene frequency of TfA was the highest followed by TfB and TfC. The gene frequencies of TfB and TfC were higher in the goats of eastern Nepal. Both polymorphisms of these two principal blood proteins including differences in gene frequencies between the populations of Khari/Hill goats found in different locations indicated the genetic variation in Khari/Hill goats [38].

7.4 Mitochondrial DNA study

Nepal has a sizeable indigenous goat population with four identified breeds (Chyangra, Sinhal, Khari, and Terai) and many nondescript goats. The study on genetic diversity and phylogeography of these identified breeds' mitochondrial DNA (mtDNA) hypervariable (HVI) region has shown high mtDNA diversity among Nepalese goat breeds with haplotype diversity ranging from 0.86 to 0.99, and all haplotypes could be classified into four haplogroups (A–D) (see **Figure 4** and **Table 14**). mtDNA haplogroup A was observed in most of the Nepalese goat populations, whereas only one breed (Chyangra) contained all four haplogroups [12]. Chyangra has been classified in the haplogroup B2 which is found in Tibetan goats which exhibits their genetic relationship. The four mtDNA haplogroups A–D found in Nepalese goats further supported the previous view of multiple maternal origins of domestic goats. These results indicated that there was no correspondence between the geographic regions of origin and relationships among goat breeds. These sequences were compared with published data of other domestic goats from neighboring countries (Bhutan, India, Pakistan, and China) to determine the relationship of Nepalese goats among goat resources of the region. The study revealed certain level of gene flow among the neighboring goat populations. The complex mtDNA diversity and structure identified among indigenous Nepalese goats can be explained by the gene flow through ancient trading and current "free" movement of goats from/to the geographic vicinities in India and China.

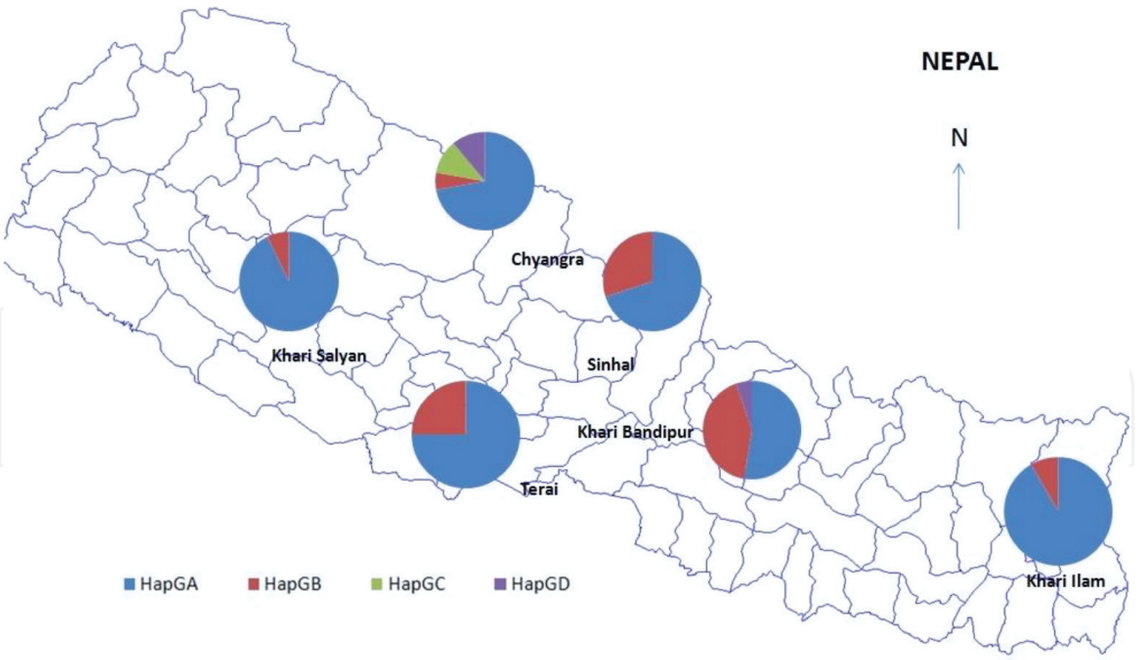

Figure 4.
Haplogroups of Nepalese goats (haplogroups A–D). Source: [12].

Breed/population	No. of goats per haplogroups					Haplotype diversity (h ± SD)	Nucleotide diversity (π ± SD)
	A	B1	B2	C	D		
Chyangra	13	—	1	2	2	0.99 ± 0.02	0.03 ± 0.01
Sinhal	7	3	—	—	—	0.87 ± 0.09	0.03 ± 0.01
Khari—Ilam	11	1	—	—	—	0.86 ± 0.08	0.02 ± 0.01
Khari—Bandipur	10	8	—	—	1	0.94 ± 0.04	0.03 ± 0.03
Khari—Salyan	13	1	—	—	—	0.95 ± 0.05	0.02 ± 0.01
Terai	15	5	—	—	—	0.97 ± 0.03	0.03 ± 0.02

Source: [12].

Table 14.
Distribution of mtDNA haplogroups in Nepalese goat breeds/populations.

These sequences were further compared with the published sequences of Asian domestic and wild goats to determine the relationship of Nepalese goats among goat resources in the region (Bhutan, Pakistan, India, and China). The results suggested that the genetic diversity and structure in mtDNA genome among indigenous Nepalese goats have been shaped not only by the intensive and continuous gene flow among goats distributed in middle and lowland in Nepal and geographical vicinity in India but also by the exchanges between goats found in high hill of Nepal (e.g., the B2 haplotype present in Chyangra goats) and Tibetan goats in China.

8. Conclusions

Goat industry in Nepal is becoming popular among the commercial farmers, and it is assumed that the future prospects of the species are quite promising. Goats, as an animal with multiple utilities, have high adaptability in diversified climatic condition right from extreme hot to extreme cold. However, goats in Nepal have limitations in

terms of body weight gain and market weight. There is opportunity for improving productivity of existing goats without increasing the total population based on the application of animal breeding technology along with advances in husbandry and disease control measures that have demonstrated success, worldwide. The need to reorient development activities by adding value to indigenous breeds must be focused. Crossbreeding of native goat breeds such as Chyangra and Sinhal in the mountain region is not gainful so far. Selection and mating of the best male to the best doe is only the option to improve the genetic potentiality of these breeds in the region. The importation of exotic breeds for crossbreeding particularly in the hill and mid-hill regions may not be meaningful unless provision for feed with increased nutrient requirements and disease control measures are readily available to the herders.

- Genetic gain depends upon the selection difference, response to selection, heritability, and generation interval.

- Heritability of the reproductive traits is lower (<0.15), production traits such as milk production are medium (0.15–0.30), and growth-related traits are higher (>0.3).

- Selection can be one of the tools, but only selection cannot improve all the economic traits of goat.

- Attention should be given in the selection process for the appropriate traits, pedigree recording, feeding, health care, and management for the goat productivity enhancement in Nepal.

- Crossbreeding of Nepalese hill goat with Boer goat is giving a better result with respect to growth and reproductive performance initially. However, further evaluation is needed for valid conclusion.

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Conflict of interest

Authors do not have any conflict of interest.

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