Indigenous Livestock Breeds of Nepal

A Reference Book

Authors

Neena Amatya Gorkhali
Saroj Sapkota
Nirajan Bhattarai
Bhoj Raj Pokhrel
Shishir Bhandari

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Bhoj Raj Pokhrel

Shishir Bhandari

Government of Nepal
Nepal Agricultural Research Council
National Animal Science Research Institute
National Animal Breeding & Genetics Reseach Centre
Khumaltar, Lalitpur

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Email: nabgrc.narc@gmail.com

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Preface

Nepal has vast resources of livestock and poultry, out of which only twenty-six breeds (seven cattle including yak, four buffaloes, four goats, four sheep, three pigs, three poultry and one horse) were identified so far and many are still remain non-descript. All of them have been characterized at phenotypic level, most of them at chromosomal level and a few of them have been characterized at molecular level. So far 26 indigenous breeds of domesticated livestock species that have been characterized, are registered in Food and Agriculture Organization (FAO) Global breed database. The ingenuity of national animal breeders to utilize this not only to further characterize most of them in phenotypic, molecular and production level but also to utilize it in developing new synthetic breeds of the highest quality or of high socio-cultural value. Furthermore, Nepal also has introduced high quality foreign genetic material of the exotic breeds which are well-adapted in the country's various environments.

With the country's entrance into the global market, many great opportunities resulted. It was also soon evident that foreign organizations flooded into our country and took advantage of our lack of expertise in global promotion and marketing. Since the Nepalese Animal Genetic Resources (AnGR) did not have documentation of the evidence of its potential and therefore, failed effective marketing of its genetic materials. As on a consequence, the population of the indigenous AnGR is diminishing drastically. The aim of this book is to promote these valuable AnGR and to rectify the situation. Copies of this handbook will be distributed to all foreign embassies, government organizations, non-government organizations, farmers (in Nepali), research institutions, education institutions, libraries and other stakeholders.

The authors of this book intent to describe in detail all identified breeds, in addition to adapted breeds and some new populations which have good number and have possibility to develop as a breed. All breeds have both strong and weak points. Breeders can do research all these points and make noticeable improvement in overcoming weak points. Furthermore, if there is high range of productivity within the breed, can be improved using the simple selection tools. Apart from few breeds such as Lulu cattle, Achhami cattle, Siri cattle, all identified goats, all identified sheep, Chwanche pig, and Sakini chicken, molecular characterization yet to be performed in Nepalese AnGR. This is the pre-requisite for promoting Nepalese breeds in global arena. The data reviewed and compiled are from reliable scientific publications, which will undoubtedly feature in the reference lists of future scientific and semi-scientific publications.

The authors are grateful to Dr. Deepak Bhandari, Executive Director for NARC; Dr. Swoyam Prakash Shrestha, Director, Livestock and Fisheries Research, Dr. Yug Nath Ghimire, Director, Planning and Coordination; Mr. Nabin Prakash Poudel, Director, Admin and Dr. Krishna Kumar Mishra, Director for Finanace for continuous support and facilitation The authors' team acknowledges Asian Food and Agriculture Cooperation Initiative (AFACI) project under Korean Government and Nepal Agricultural Research Council for the financial support to publish this book.

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Message from Executive Director

Nepal is endowed with wide range of animal genetic resources along its diverse agro-ecological zones in relation to its size. In spite of the richness in the livestock genetic resources, a very limited research has been conducted for the genetic studies as well as characterization of the available resources as of need with the Nepalese scenario. In the present context, data shows that only 25 indigenous breeds of various domesticated livestock germplasms have been found characterized that had been registered in A Global Animal Genetic Data Bank of Food and Agriculture Organization (FAO).

The indigenous livestock genetic resources are found with somehow low production potentiality in comparison to exotic breeds in terms of milk, meat, eggs, fiber production. Even though their productivity is low, they possesses various useful traits like hardiness, wide adaptability even in harsh environmental conditions, various diseases resistive attributes, produce even in low input system as well as various other useful genetic characteristics. In this regard, indigenous livestock genetic resources can be well-utilized in future genetic improvement programs that will help emphasize the importance of diverse indigenous animal genetic resources of Nepal. In the last few decades, we accounted with huge genetic erosion as well as diversity loss in Nepalese AnGR in an unprecedented pace with the wide use of crossbreeding. In this regard, the issues for the conservation of pure indigenous livestock genetic resources have been well-recognized by Nepalese government. Hence, National Animal Breeding and Genetics Research Centre (NABGRC) under Nepal Agricultural Research Council (NARC) have been conducting conservation programs for indigenous AnGR especially the endangered domestic animal breeds in Nepal.

With regard to above scenario, this book, enriched with necessary information for various breeds of Nepalese indigenous AnGR, focused on characterization in multi aspects, status of each breed, useful and adoptive attributes as well as future prospects relevant for the utilization of those breeds, will be very useful for the farming communities, extension workers, academicians, researchers and the policy makers of the concerned sector.

Last but not the least, I would like to thank the concerned scientists and technical staffs for their crucial contribution for the publication of such an informative book targeting farming communities and concerned stakeholders. Finally, I express my sincere gratitude to Asian Food and Agriculture Cooperation Initiative (AFACI), Korea for their technical as well as financial support concerned with the accomplishment of the project.

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Deepak Bhandari, PhD
Executive Director
Nepal Agricultural Research Council (NARC)
Singhadurbar Plaza, Kathmandu, Nepal

Dedicated to

Farmers who Conserve Indigenous Animal Genetic Resources

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ACRONYMS AND ABBREVIATION

ABD	Animal Breeding Division
ADS	Agriculture Development Strategy
AFACI	Asian Food and Agriculture Cooperation Initiative
AFU	Agriculture and Forestry University
AGDP	Agriculture Gross Domestic Products
AI	Artificial Insemination
AnGR	Animal Genetic Resources
APP	Agriculture Perspective Plan
BGIP	Buffalo Genetic Improvement Project
BS	Bikram Sambat
CBD	Convention on Biological Diversity
cm	Centimeter
CV	Coefficient of Variation
DLS	Department of Livestock Services
DNA	Deoxyribonucleic Acid
DoAR	Directorate of Agricultural Research
ET	Embryo Transfer
FAO	Food and Agriculture Organization
FTAI	Fixed Time Artificial Insemination
GDP	Gross Domestic Products
GoN	Government of Nepal
GWAS	Genome-wide Association Study
IAAS	Institute of Agriculture and Animal Science
ILRI	International Livestock Research Institute
ITK	Indigenous Traditional Knowledge
LSM	Least Square Mean
masl	Meters Above Sea Level
MoAD	Ministry of Agricultural Development
MoALD	Ministry of Agriculture and Livestock Development
MoFSC	Ministry of Forest and Soil Conservation
MoLD	Ministry of Livestock Development
MS	Mean Squares
MT	Metric Ton
NABGRC	National Animal Breeding and Genetics Research Centre
NARC	Nepal Agricultural Research Council
NCA	National Commission on Agriculture
PCR	Polymerase Chain Reaction
RNA	Ribonucleic Acid
SARP	Swine and Avian Research Program
SE	Standard Error
SGRP	Sheep and Goat Research Program
SNP	Single Nucleotide Polymorphisms
Wt.	Weight

Executive summary

This book summarizes the AnGR of Nepal and effort on conservation and sustainable utilization which could contribute to improved management of AnGR. This book also highlights the importance of conservation, existing native livestock breeds and species, their production and reproduction performances, characterization at phenotypic and molecular level, positive attributes, and future strategies for conservation. The Agriculture Development Strategies (ADS) and 27 points commitments issued by Ministry of Livestock Development (MoLD, 2017) has also emphasized on conservation, utilization and promotion of native livestock breeds. The total population of cattle, buffalo, goat, sheep, pig and poultry are 7.24 million, 51.78 million, 10.17 million, 0.79 million, 1.19 million and 48.07 million respectively of which about 50% of these breeds exists in pure form with another 50% covered by exotic or crossbreds.

Livestock contributes about 11% to the total Gross Domestic Product (GDP) of which 63% comes from milk and milk products, 32% comes from meat and meat products and 5% comes from eggs. Livestock are mainly raised since time immemorial for daily consumption of animal proteins like meat, milk, eggs and also for the production of non-food items as hides, skins, wool, transportation and fuel (from dung) in some communities.

Nepal is rich in livestock and poultry resources, out of which only twenty-six breeds (seven cattle including yak, five buffaloes, four goats, four sheep, four pigs, four poultry and one horse) were identified so far and many are still remain non-descript. Identified indigenous breeds of domesticated livestock species have been characterized and registered in Food and Agriculture Organization (FAO) Global breed database. All of them have been characterized at phenotypic level, most of them at chromosomal level and a few of them have been characterized at molecular level.

Indigenous breeds are low producing than the exotics in terms of milk, meat, eggs and fiber production. However, they have several other positive attributes such as hardiness, adaptability to local harsh conditions and can produce in low input system. It is observed that these positive attributes are not duly recognized rather exotics breeds are unnecessarily given preference over them. During a last few decades, genetic diversity loss in Nepalese AnGR occurred in an unprecedented pace with the wide use of crossbreeding and with the progressive availability of better job opportunity. The issue of the conservation of domestic animals and genetic resources has been well-recognized by Nepalese government. Hence, National Animal Breeding and Genetics Research Centre (NABGRC) of Nepal Agricultural Research Council (NARC) has established a gene bank consisting of cryopreserved animal semen, DNA and tissues for indigenous AnGR especially the endangered domestic animal breeds in Nepal. This book includes introduction of all Nepalese indigenous AnGR breeds, detail information on the characterization (phenotypic, chromosomal, biochemical and molecular level), status of each breed, positive attributes and future prospects.

1. IMPORTANCE OF ANIMAL GENETIC RESOURCES

1. IMPORTANCE OF ANIMAL GENETIC RESOURCES

Background

The term animal genetic resources (AnGR) is used to include all animal species, breeds and strains (and their wild relatives) that are of economic, scientific and cultural interest to humankind in terms of food and agricultural production for the present or in the future (Rege and Gibson, 2003). There are more than 40 species of animals that have been domesticated (or semi-domesticated) during the past 10,000-12,000 years which contribute directly or indirectly to agricultural production (FAO, 2000). Common species include cattle, sheep, goats, chickens, pigs, horses and buffalo, but many other domesticated species such as camels, donkeys, and elephants, various poultry species, reindeer, rabbits, etc. are important to different cultures and regions of the world. These AnGR are vital to the economic development of the majority of countries in the world. In developing countries, they also play an important role in the subsistence of many communities and the sustainability of crop-livestock systems. Globally, domestic AnGR supply about 30% of total human requirements for food and agricultural production (FAO, 1999). They are particularly vital to subsistence and economic development in developing countries. Only in the developing world about 46 % of AnGR diversity resides and these livestock make the greatest contribution to human livelihoods and food security (FAO, 2007).

Livestock and livelihood

They provide year-round flow of essential products, sustain the employment and income of millions of people and contribute draught power and manure for crop production. In rural areas, livestock are an important source of food and cash, and hence are crucial for the purchase of consumer goods and procurement of farm inputs.

Livestock and health

Livestock are also a source of high value animal protein and micro-nutrients important especially in the diets of children and lactating women (Delgado et al., 1999). For example, studies have demonstrated substantial improvements in growth and health of infants and young children provided with milk or milk products in Mexico (Allen et al., 1995), Sudan (Zumrawi et al., 1981), Malaysia (Chen, 1989), India (Alderman, 1994) and Kenya (Nicholson and Thomton, 1999). In some communities, livestock also serves as a source of non-food items such as hides, skins, and wool, as well as transportation and fuel (from dung). Ruminant livestock also converts non-value crop residues and fibrous materials into high-quality protein. They also make it easier to use marginal lands with little or no value for crop agriculture. The asset and security functions of livestock are also important in some of these production systems. These refer to their role as a capital investment that yields interest, such as milk. They are the only long-term means of storing wealth, which is especially important in areas where there is no financial system to perform this function. With respect to environmental and disease stresses in the tropics, only locally adapted livestock can serve these purposes, especially in low-input smallholder systems. In addition to these roles in traditional society, livestock are a major source of revenue and export earnings for many countries as measured by the livestock sector's contribution to the gross domestic product (GDP) in many developing countries.

Livestock and environmental health

Livestock can also contribute towards environmental sustainability in well-balanced mixed farming systems (de Haan et al., 1997). This may be through provision of draft power, and manure and urine as fertilizer. In addition, owning ruminants encourage smallholders to plant browse trees, shrubs, leguminous forages/all of which control erosion, promote water conservation and increase soil fertility. Moreover, farm yard manure from these livestock reduces the use of chemical fertilizer, which affects human as well as soil health. However, it must be acknowledged that, where population pressure and poverty coincide, such as in pastoral areas, poor management of livestock can and does result into land degradation. These pressures call for new policies, institutions and markets and require the development and adaptation of new technologies to make livestock environmentally more benign (Steinfeld et al., 1997).

Livestock and socio-cultural functions

The value of livestock in social and cultural functions in traditional society is the most difficult to quantify. These involve social exchanges of livestock within or between families or communities. Examples include marriage gift for girl (*pewa* in high-altitude society in Nepal), dowry payments and slaughtering for traditional feasts or religious ceremonies. Indeed, the use of some breeds, e.g. the black pig of Nepal, in traditional society in eastern Nepal, is principally for social functions. In addition, cows are taken as a Goddess Laxmi and worshipped them.

Livestock and poverty reduction

Over 1.3 billion people (about 30% of the population in developing countries) live below the so-called 'poverty line' (less than US$1 per day). About 75% of the poor live in rural areas. World population is expected to increase to 7.7 billion by 2020 (United Nations, 1996), equivalent to an average annual compound growth rate of 1.2% for the period 1995-2020. Total food supply must increase at least at this rate to maintain current per capita food supplies. About 95% of the predicted population increase will occur in developing countries where 77% of people live (Pinstrup-Andersen, 2000) and where the recent trend of increased per capita consumption of meat, milk and eggs is predicted to continue (Delgado et al., 1999).

Specifically, while only marginal increases in consumption of meat and milk are expected in developed countries, increases of 114 and 133% are projected to 2020 for meat and milk, respectively, in developing countries (Delgado et al., 1999). This explosion in demand is expected to result from increased human population, urbanization and increased incomes in these regions. To meet these demands, production will have to increase by 108% for meat and 145% for milk (Delgado et al., 1999). In the developing world, it is the mixed crop-livestock systems that have the largest number of rural poor (ILRI, 2000). It is estimated that 70% of the world's rural poor depend on livestock as a component of their livelihood and it has been suggested that focusing on improving the sustainable livelihoods of these people can do more to reduce poverty than increasing productivity in intensive industrial systems (Livestock in Development, 1999). The majority of the rural poor in these production systems are livestock keepers. Furthermore, the rural poor, especially women, derive a larger share of their income from livestock than do the relatively wealthy (Delgado et al., 1999).

Poor people in rural areas, with little land and poor access to capital, have few opportunities to increase their income. The increasing demand for livestock products offers them an opportunity to benefit from a rapidly growing market (ILRI, 2000). Using common-property resources such as feeds collected from roadside verges, grazing on communal land and family labor, even the landless livestock owners can produce high value outputs for sale or home consumption. All this is possible primarily because of the diversity in livestock (species and breeds), allowing specific populations to be utilized in areas where they are uniquely adapted and readily available.

Importance of conservation of AnGR

The process of domestication of animals, initiated some 10,000-12,000 years ago, involved only some 40 out of the estimated 40,000 species of vertebrates. The selected species accompanied human populations across the earth, evolving through a combination of natural and human selection to adapt to, and be productive in, all but the most inhospitable environments inhabited by humans. The current enormous genetic diversity of AnGR represented in today's breeds and strains, is the result of this 12,000 years process. Once lost, such diversity will be all but impossible to recreate. Existing AnGR thus represent a massive past investment which, if managed appropriately, can provide insurance against an unknowable global future. However, different species tend to perform particular functions, often in specific environments that have limited overlap with other species and livestock species are unlikely to become extinct. Thus, the focus on conservation of AnGR has to be within species. Moreover, the variation between breeds is likely to be much higher when a global perspective is taken, and when more extreme traits such as adaptation to harsh environments and disease resistance, are considered. But a more important consideration is the rapidity with which AnGR can be exploited to deliver new levels of production and adaptation, including disease resistance.

Within breeds, the amount of genetic change that can be made per unit time is a function of genetic and environmental variance, whereas the rate of change between breeds is a function of range rather than variance. Allowing for this, for the majority of traits and production systems, it is clear that the most valuable resource in terms of providing rapid adaptation to the huge diversity of existing production systems, and for providing flexibility to respond to changing systems and environments, is the variation between breeds.

Threats to AnGR

Although much less talked about, genetic erosion in farm AnGR is much more serious than in crops because the gene pool is much smaller and very few wild relatives remain. An estimated 82% of the total contribution of AnGR to global food and agricultural production comes from only 14 species (FAO, 2000). Since the turn of the last century, some 16% of uniquely adapted breeds are believed to have gone extinct (Hall and Ruane, 1993). A further 32% are at risk of becoming extinct and the rate of extinction continues to accelerate (FAO, 2000).

Genetic dilution or eradication through use of exotic germplasm, example is the global impact of the North America Holstein Friesian cattle on other dairy breeds. In some instances, this breed replaced the entire cattle breeds of the country. Intense marketing, emphasis on a single trait (milk production) and widespread use of artificial insemination and, more recently, embryo transfer, have led to a situation where not only is the breed replacing others, but the diversity within the breed itself is rapidly diminishing because only a limited number of supposedly superior bulls is being used globally. This is demonstrated by a recent finding that 50% of the almost 5000 Holstein bulls born in 1990 in 18 countries were bred by only five sires (Wickham and Banos, 1998). Many factors underlie these threats to AnGR.

- Changes in production systems leading to change in breed use or crossbreeding.

- Changes in producer preference, usually in response to changes in socio-economic factors.
- Droughts, famine, disease epidemics, civil strife/war and other catastrophes and/or political instability.

In some cases, changes in production systems and consumer preferences reflect natural evolution of developing economies and markets. In other cases, production systems, breed choice and consumer preferences are distorted by local, national and international policy.

Use of exotic germplasm has sometimes been heavily promoted by breeding companies from developed countries seeking markets for excess product, in some cases supported by development agencies, which often promote use of their national products within development projects. While such factors are readily discernable in broad terms, little is known about the relative importance of these various factors and there is a need for such understanding as a first step toward implementation of policies that promote utilization of appropriate germplasm.

Farm AnGR in Nepalese context

Directorate of Livestock Services (DLS) and Nepal Agricultural Research Council (NARC) jointly prepared and submitted country report on FAnGR during 2004 and 2014 to Food and Agriculture Organization (FAO). Apart from the information submitted to FAO, with the initiation of National Animal Breeding and Genetics Research Centre (NABGRC), then Animal Breeding Division (ABD), NARC, Khumaltar, *ex-situ* and *in-vivo* conservation of different indigenous breeds which are listed as endangered and at the verge of extinction, till date three breeds of cattle namely Lulu from Mustang district, Achhami from Achham district and Siri from Taplejung district; one breed of buffalo namely Gaddi from Dadeldhura district; three breeds of goat namely Sinhal, Khari and Terai; three breeds of Sheep namely Baruwal from Rasuwa district, Lampuchhre from Rupendehi district and Kage from Lalitpur district; two breeds of pig namely Hurrah from Eastern Nepal and Bampudke from Far-western region of Nepal; two breeds of chicken namely Sakini and Ghanti khuile from different altitudes of Nepal. Along with this ex-situ, in-vitro conservation semen from Lulu and Achhami cattle has already been cryo-preserved in gene bank under National Animal Breeding and Genetics Research Centre, NARC, Khumaltar. In addition, District Livestock Services (DLS) also has prioritized programs on *in-situ* conservation of the endangered livestock breeds.

Positive attributes of AnGR

Indigenous AnGR are an important asset for many reasons, but particularly because, over time, they have developed unique combinations of adaptive traits to best respond to pressures of the local environment. These adaptive traits include:

- tolerance/resistance to various diseases
- tolerance to fluctuations in availability and quality of feed resources
- tolerance to extreme climatic factors (harsh and rugged environment)
- adaptation to low capacity management conditions and
- ability to survive, produce and reproduce for long periods of time

Status of indigenous AnGR of Nepal

Detailed status of each breed of indigenous AnGR is given in Table 1.1 and the cause for declination of each commodity is given in each chapter.

Table 1.1 Summary of information of indigenous farm AnGR of Nepal

S. N.	Breeds	Scientific name	Home tract	Population status	Characterization	Positive Attributes
1. Cattle						
1.1	Terai Cattle	*Bos indicus*	Across the Terai	Normal	Phenotypic+DNA	Suitable for Terai plain land, hardy, good draught breed
1.2	Pahadi Cattle	*Bos indicus*	Across the hills	Normal	Phenotypic	Suitable for the low and mid-hills across the country, hardy
1.3	Khaila	*Bos indicus*	Far western region (Dadeludhura, Doti and Baitadi districts)	Population decline	Phenotypic	Suitable for mid-hills, good temperament, draught breed
1.4	Lulu	*Bos taurus*	Mustang, Dolpa, Manang	Population declining	Phenotypic+Chromosomal+DNA	Hardy, suitable for cool and dry climate, good for low input system
1.5	Achhami	*Bos indicus*	Far western region (Achham, Bajhang, Bajura and Doti districts)	Risk	Phenotypic+Chromosomal+DNA	Suitable for hills, smallest breed of the world, produce in low input
1.6	Siri	*Bos indicus*	Ilam, Panchthar and Taplejung district	Nearly Extinct	Phenotypic+DNA	High yielding, suitable size for hills
1.7	Yak / Nak	*Poephagus grunniens*	Mountain regions	Population decline	Phenotypic+DNA	Hardy, can survive at high altitudes, pack use in high mountains
2. Buffalo						
2.1	Lime	*Bubalus bubalis* (Type: Riverine)	Hilly areas; specially the Gandaki Province.	Population declining, requires attention	Phenotypic+Chromosomal	Good milk yielder, adapted to harsh climatic environments, good meat quality, adapted to low and mid hills
2.2	Parkote	*Bubalus bubalis* (Type: Riverine)	Hilly areas; specially the Gandaki Province.	Population declining but not yet at risk	Phenotypic+Chromosomal	Suitable for hills, good milk yielder, adaptable to harsh environments
2.3	Gaddi	*Bubalus bubalis*	Far-western hills	Population declining and at risk	Phenotypic+Chromosomal	Suitable for hills, high milk yielder, adaptable to harsh

S. N.	Breeds	Scientific name	Home tract	Population status	Characterization	Positive Attributes
		(Type: Riverine)				environments
2.4	Terai Buffalo	*Bubalus bubalis* (Type: Riverine)	Eastern Terai region of; specially Moran and Sunsari districts	Population declining but not yet at risk	Phenotypic+DNA	Suitable for tropical climate, good meat quality
3. Goat						
3.1	Terai Goat	*Capra hircus*	Across the terai region	Population is declining and pure line hardly exists	Phenotypic+Chromosomal+DNA	Suitable for terai conditions, hardy, good meat breed
3.2	Khari	*Capra hircus*	Across the hill region (mainly in low to mid hills)	Normal	Phenotypic+Chromosomal+DNA	Hardy, prolific, suitable for hill conditions, good for low input system, good meat type
3.3	Sinhal	*Capra hircus*	High hills and mountains	Population declining	Phenotypic+Chromosomal+DNA	Hardy, suitable for high hills, largest indigenous goat breed, produce in low input, good for pack
3.4	Chyangra	*Capra hircus*	High hills and mountains	Population declining	Phenotypic+Chromosomal+DNA	Hardy, suitable for high hills and mountains, good pack breed, can produce *pashmina*
4. Sheep						
4.1	Lampuchhre	*Ovis aries*	Terai districts (Banke,Bardia, Dang, Kapilbastu, Nawalparasi, Sunsari)	Risk	Phenotypic+Chromosomal+DNA	Suitable for terai conditions, hardy, good fighting quality, meat type
4.2	Kage	*Ovis aries*	Across the lower hills, inner valleys	Population declining	Phenotypic+Chromosomal+DNA	Suitable for lower hills, hardy, coarse wool type suitable for making *radi/pakhi*
4.3	Baruwal	*Ovis aries*	Across the mid hills	Normal	Phenotypic+Chromosomal+DNA	Suitable for hills, hardy, wool suitable for *radi/pakhi*, principal breed, good grazing instinct
4.4	Bhyanglung	*Ovis aries*	High hills and mountains in Transhumance system	Population declining	Phenotypic+Chromosomal+DNA	Hardy, suitable for high hills and mountains in Transhumance system, carpet

S. N.	Breeds	Scientific name	Home tract	Population status	Characterization	Positive Attributes
						type wool
5. Pig						
5.1	Chwanche	*Sus domesticus*	Across the hills	Population declining but not yet at risk	Phenotypic+Chromosomal+DNA	Suitable for hills, disease resistant, hardy, suitable for backyard rearing
5.2	Hurra	*Sus domesticus*	Across the Terai	Population declining but not yet at risk	Phenotypic+Chromosomal+DNA	Suitable for Terai, strong body, hardy, suitable for backyard rearing
5.3	Bampudke	*Porcula salvania*	Few terai districts near Chure hills (Nawalparasi, Chitwan, Dang, Kailali etc.)	Risk (about to be extinct)	Phenotypic+Chromosomal+DNA	Smallest hog breed, both wild and domestic, quality of meat
6. Chicken						
6.1	Sakini	*Gallus gallus domesticus*	Throughout the country	Normal	Phenotypic+Chromosomal+DNA	Hardy, suitable for scavenging, dual purpose, tasty meat
6.2	Ghanti Khuile	*Gallus gallus domesticus*	Throughout the country in a limited pockets	Risk	Phenotypic	Hardy, suitable for scavenging, dual purpose, tasty meat
6.3	Pwakh Ulte	*Gallus gallus domesticus*	Throughout the country in a limited pockets	Risk	Phenotypic	Hardy, suitable for scavenging, dual purpose, tasty meat
7. Horse						
6.1 Jumli	Jumli Horse	*Eqqus ferus caballus*	High hill districts like Jumla, Dolpa. Seasonal migration to terai districts like Dang, Bake, Kailali, Kanchanpur etc.	Population declining but not yet at risk	Phenotypic	Suitable for hills and mountains, hardy, strong and sure-footed, disease resistant, adaptable to harsh environments

Source: MoALD, 2021

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2. INDIGENOUS BUFFALO BREEDS OF NEPAL

Lime buffalo

Parkote buffalo

Gaddi buffalo

Terai buffalo

Arna buffalo

Terai buffalo herd

Lime buffalo calves

Lime Parkote buffaloes

2. INDIGENOUS BUFFALO BREEDS OF NEPAL

2.1 Zoological classification of buffalo

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Artiodactyla
Family	Bovidae
Sub-family	Bovinae
Genus	*Bubalus*
Species	*bubalis*

2.2 Overview of buffalo in Nepalese context

Nepal is the third highest for buffalo population with 5,257,591 heads (MoAD, 2020) heads and the fifth highest buffalo milk producing amongst the buffalo milk producing countries (worldatlas.com, 2020). Buffalo is found in all parts of the country where most common in the tropical belt followed by sub-tropical region of the country (MoALD, 2019). Economical contribution of buffalo comes the second after rice (ADS, 2015). Contribution of buffalo milk to the country's total milk production is 60 % (Appendix 1; MoALD, 2019). Thirty-five percent of the total population is exotic (either pure or crossbred) and rest (65%) is indigenous (Neopane, 2006). Indigenous buffaloes are still contributing as traditional provider of food (milk and meat) to human beings, power for agricultural operations (draught and pack) and manure for maintaining or/and enhancing soil fertility. Besides, buffalo pelts are the major source of income for leather industries as well as foreign earnings for the Nation (DLS, 2020). Moreover, buffaloes have cultural, social and religious values for certain ethnic community such as Newar community from Kathmandu valley sacrifice male buffaloes in many important festivals.

Buffalo occupies the most important place in the agricultural economy of the country. Buffaloes alone contribute 52.9 % of the livestock share in the national gross domestic products (APP, 1995) through 70% of total milk and 64 % of total meat production (MOAD, 2014). More than 45% of the households (48.5 %) in the country keep buffaloes for their regular farm activities. It is distributed throughout the country from Terai plain land of southern border (64 m asl) to high mountains of northern hills (2500 m asl; Rara taal, Panchthar) across the country. Their distribution in such a large territory of the country itself verifies their commendable importance and in addition, Agriculture Development Strategy (ADS, 2015) has put buffalo in the second important agriculture commodity after maize in term of contribution to national economy. Due to its immense involvement in the national economy, Buffalo Genetic Improvement Project (BGIP) is initiated in 2008 with collaboration of District Livestock Services and National Animal Breeding and Genetics Research Centre under Nepal Agricultural Research Centre (NARC) to create buffalo herd database. This chapter of the book includes characterization on phenotypic and chromosomal levels, production performances and future prospects of the buffalo farming.

Table 2.1 Contribution of buffalo in Nepalese economy

Provinces	Population (No.)	Milk production (MT)	Meat Production (MT)
Province 1	850,013	193,745	30,603
MADHESH	826,851	234,591	29,757
Bagmati	894,926	250,570	32,247
Gandaki	677,490	185,365	24,381
Lumbini	1,185,676	320,258	42,746
Karnali	302,893	65,499	10,994
Sudurpachhim	519,742	130,572	18,788
TOTAL	**5,257,591**	**1,380,600**	**189,517**

Source: MoALD, 2020

2.3 Origin of Nepalese buffalo

The wild form of buffalo Arna (*Bubalus bubalis arnee*) is are found in the Koshi Tappu Wildlife Conservation Area in Sunsari district of eastern Nepal. These wild buffaloes carry five of six river-specific alleles and are phenotypically swamp type (Zhang et al., 2011). In historical times, *B. arnee* ranged across a large part of India and east into mainland south-east Asia and south China (Cockrill, 1984). Remnant populations are thought now to occur at various sites including southern Nepal (Koshi Tappu National Park area), southern Bhutan, western Thailand, eastern Cambodia, northern Myanmar and several sites in India (Hedges et al., 2008). Archaeological, anatomical and historical evidences support the contention that both river and swamp domestic buffaloes (*Bubalus bubalis*) are descended from *B. arnee* (Cockrill, 1984), and genetic evidence clearly points to independent domestications of the two types (Lau et al., 1998; Kumar et al., 2007; Lei et al., 2007; Yindee et al., 2010). The time of divergence of the river and swamp types has been estimated in various studies as from at least 10,000 years ago to 1.7 M years ago, but most probably about 128,000–270,000 years ago (Kumar et al. 2007), although even given this uncertainty, divergence occurred well before domestication.

Their morphological characteristics showed the rounded forehead with large horn and dark black body color. There are tufts of hair on the forehead, over the eyes, and on the knees. They measure 3.2 m long from mouth to root of the tail and 1.7 m high at shoulder. They weigh 900 kg and/or over. Very little is known about productive performances of this population (Shrestha, 1995). These buffaloes are strongly built and could be an important genetic reservoir for the development of meat type buffalo breed in the country and elsewhere.

2.4 Indigenous buffalo breeds of Nepal

Three breeds of buffalo *viz.* Lime, Parkote and Gaddi are reported as Nepalese indigenous buffalo breeds in the country report published by FAO (2014). Recently, Terai buffaloes with typical phenotypic characteristics is identified in eastern plain region of Nepal (Sapkota et al., 2017).

2.4.1 Demographic distribution of indigenous buffalo breeds of Nepal

Lime buffalo

Lime buffaloes are distributed in low to mid hills whereas predominantly found in foot hills and river basins areas of the western region of the country. Lime buffaloes are widely distributed from an elevation of more than 1500 masl where temperature varies from -2 to 15 degree Celsius in winter to 25-33 degree Celsius in summer. Annual rainfall in these location ranges from > 5600 mm per year with humidity ranges from 90-97%.

Parkote buffalo

Parkote buffaloes are distributed from low to high hills of the western region of the country and found predominantly in the mid hills. Lime and Parkote buffaloes together make up of 58% of the National buffalo population (Neopane, 2006). Parkote buffaloes are widely distributed from an elevation of more than 1500 masl where temperature varies from -2 to 15 degree Celsius in winter to 25-33 degree Celsius in summer. Annual rainfall in these location ranges from > 5600 mm per year with humidity ranges from 90-97%.

Gaddi buffalo

Gaddi buffaloes are located in the far western mid to high hill region of the country. This breed is named after a tribe called Gaddi residing in that area. Gaddi buffaloes are widely distributed in an area of 5482 sq. Km ranging from an elevation of 1500 to 4500 masl where temperature varies from 18.8 degree Celsius in winter to 28 degree Celsius in summer. Annual rainfall in these location ranges from 860 mm to 1242 mm.

Terai buffalo

Terai buffaloes with peculiar horn shape and body confirmation is the newly identified buffalo breed and are found in the eastern terai of Nepal. Terai buffaloes are widely distributed from an elevation of 800-1200 masl where temperature varies from 10 to 20 degree Celsius in winter to 22-32 degree Celsius in summer. Annual rainfall in these location ranges from 2000-2500 mm per year.

2.4.2 Status of the Nepalese buffalo breeds

A study performed in the western hills of Nepal showed that amongst the existing population of buffaloes at the zone, around 64 % were indigenous and their intermediate types (Rasali and Joshi, 1998). The scenario is equally effective for other zones of the country. Introduction of exotic breeds for uplifting the milk productivity is causing reduction of their blood level thus resulting in declination of pure indigenous population at a faster rate. Furthermore, there is a negative selection in the population as superior male calves are either used for meat purpose after emasculation or used for draught power (Farm animal genetic resources management and utilization, policy and strategy, 1997). For instance, in the far western zone of the country, population of pure breed Gaddi buffalo is at risk due to various reasons such as above reasons as well as out migration of the male members of the family. The status of the breeds based on their population and in relation to its conservation aspects is presented in Chapter 1 Table 1.1.

2.4.3 Positive attributes

Indigenous buffalo has a wide adaptation capacity ranging from tropical wet or dry land to near sub-alpine region of Himalayas. The adaptation across different agro-ecological zone reflects tremendous digestion ability of forage and wild grasses. Besides, existence in low plane of nutritional regime, cold tolerance and can be easily raised in low external input system are the unique characteristics of the indigenous buffalo.

Body size of indigenous buffaloes is relatively smaller and sturdier. They, therefore, are highly suitable to thrive on narrow and stiff topographical hills and mountains, which covers about 70

% of total area of the country. They are excellently adapted to local harsh environmental conditions in which the depletion of nutritional status has been a continuous feature. These features certainly emphasize the superiority of indigenous buffaloes over the exotic ones and their crossbred which is reflected by resilience in economically important diseases.

Research has already discovered a wide variation in productivity of indigenous buffaloes in terms of milk production showed their unexploited genetic potential (Amatya et al., 2000). Moreover, indigenous buffaloes produce comparatively similar milk yield than even exotic and crossbred animals in farmers' household. Nevertheless, buffalo covers the major demand of meat in the country as well. Positive attributes of indigenous buffalo are presented in Chapter 1 Table 1.1.

2.4.4 Socio-cultural significance

Even though Nepal is declared as secular after the country officially became the Federal Democratic Republic of Nepal, beef is still not openly used in Nepal as more than eighty percent of the people follow Hinduism. Cara-beef (buffalo meat) is therefore popular in Nepal especially with Newar ethnic group whose food culture and festivals are mainly depend on buffalo. Furthermore, buffalo meat is considered a healthier alternative containing less fat and cholesterol, and more protein than beef; filled with nutrients, especially B vitamins, water buffalo is unique and delicious alternative to other meats.

2.4.5 Characterization of indigenous buffalo breeds

All identified indigenous buffalo breeds have been characterized both on phenotypic and chromosomal level while Terai buffalo and wild buffalo are also characterized in molecular level.

2.4.5.1 Phenotypic characterization of indigenous buffalo

2.4.5.1.1 Physical characteristics of indigenous buffalo

Lime buffalo

- External characteristics of Lime buffalo resembles swamp type buffaloes.
- Lime buffalo is grey in colour and its skin colour shades from whitish brown to grey.
- Eyebrows are white.
- It has typical distinguishing characteristics with chevron of grey or white hair below the jaw and around the brisket region.
- It has whitish or greyish colour as leg marking below knee.
- They have relatively small sickle shaped horns curved towards the neck.
- They have relatively smaller body with shorter body length.
- Among the identified indigenous breeds of buffalo, Lime is the smallest one in terms of body size and weight.
- Its temperament is semi wild.

Parkote buffalo

- Parkote buffalo is mainly black in colour, but occasionally they are found in brown and light brown colour.
- There is absence of chevrons in the body.
- They may or may not have leg markings.
- They have black muzzle.
- They have a long face and flat head.
- Horns are sword shaped directed towards the back of the body.
- They have medium sized body with longer body length.
- Its temperament is semi wild.

Gaddi buffalo

- Gaddi buffalo is black in colour with white round patches on the forehead.
- Occasionally, they are also found in brown and light brown colour.
- They have a long face and flat head.
- Horns are long half curved.
- They are compact and massive with angular body shape and sloped hip position.
- This breed is the heaviest among other identified indigenous buffaloes of Nepal.
- They have well developed udders and prominent milk veins demonstrating the milch type morphological characteristics.

Terai buffalo

- Terai buffalo breeds have plain hair color pattern with black hair coat color. They have grey and dull but straight hair type.
- They have pigmented skin, muzzle, eye, eyelids and hoof color.
- They have mostly and dominantly white tail switch tips
- Black colored horn with fixed type horn attachment.

2.4.5.1.2 Morphological measurement of indigenous buffalo

Lime buffalo

Average body length, height at withers, height at hipbone and heart girth of this breed is 125±0.76 cm, 118.6±1.34 cm, 109±0.94 cm and 174±1.92 cm respectively. The average adult weight of this buffalo is 311±1.5 kg.

Parkote buffalo

Average body length, height at withers, height at hip bone and heart girth of this breed is 127.7±0.76 cm, 124.1±0.58 cm, 118.6±0.79 cm and 176±0.87 cm respectively The average adult body weight of this buffalo is 341.9±1.3 kg.

Gaddi buffalo

Average body length, height at withers; height at hip bone and heart girth of this breed is 141±1.63 cm, 131±1.1 cm, 123±1.07 cm and 195±1.8 cm respectively. The adult weight of this buffalo is 452±8.03 kg.

Terai buffalo

Average body length, height at withers and heart girth of this breed is 128.5cm body length, 132.4 cm and 170.5 cm respectively. The adult weight of this buffalo is 331±7.9 kg.

Table 2.2 Morphological measurements of indigenous buffalo (MV±SD cm)

Variables	Breeds			
	Gaddi[a]	Lime[b]	Parkote[b]	Terai[c]
Body length	141±1.6	125±1.5	128±0.8	128.5±3.1
Heart girth	195±1.8	174±1.9	176±0.9	170.5±4.6
Height at wither	131±1.1	119±1.3	124±0.6	132.5±4.3
Height at hip bone	123±1.1	109±0.9	119±0.8	NA
Head length	57.5±1.4	46±0.5	38±0.7	NA
Tail length	89±1.2	74±1.7	75±1.6	79.62±6.3
Horn length	44±1.5	44.3±1.3	47.8±1.9	32.8±2.2
Ear length	23±0.3	21.5±0.4	19.8±0.6	28.4±0.9
Neck length	44±0.8	41.5±0.9	43.5±1.1	NA
Loin girth	213±2.3	185±2.2	188±1.1	NA
Barrel girth	231±2.5	205±2.3	206±0.9	NA
Adult body weight (kg)	452±1.03	311±1.5	342±1.3	331±7.9

Source: [a]Pokharel et al., 1998; [b]Amatya, et al., 2000; [c]Sapkota et al, 2017

2.4.5.2 Characterization on chromosomal level

The cytogenic study of the identified Lime, Parkote and Gaddi breeds of buffaloes revealed that all the breeds are riverine type consisting of 25 pairs chromosomes (2n=50). Morphology of the chromosomes and its number in Lime, Parkote and Gadd are similar with 5 pairs of sub-metacentric autosomes, 19 pairs of acrocentric autosomes and one pair of sex chromosomes. In the female, a pair of X-chromosomes is the largest among acrocentrics. In male, X chromosome is the largest acrocentric while Y-chromosome is the smallest acrocentric chromosome with a special band at the terminal end of q-arm (Neopane, 2004). Terai buffalo is not characterized in chromosomal level but have been proven to be riverine type using molecular markers (Zhang et al, 2011).

Table 2.3 Description of metaphase spread of chromosomes

Breed	Sex chromosomes		Autosomes				Total
	X	Y	Acrocentric	Metacentric	Sub-metacentric	Telocentric	
Lime	Acrocentric	Acrocentric	38	-	10	-	50
Parkote	Acrocentric	Acrocentric	38	-	10	-	50
Gaddi	Acrocentric	Acrocentric	38	-	10	-	50
Terai	Not Available						

Source: Rasali et al 1998; Pokhrel et al 1998

2.4.5.3 Molecular characterization

Molecular study is only done in Terai, hybrid (Terai and wild) and wild buffalo. A study on genetic differentiation of water buffalo population in China, Nepal and South-East Asia using 18 microsatellite markers revealed the broader understanding of genetic relationships among the population and their demographic history. The dendrogram indicates the clear separation of swamp and riverine populations in the region (Figure 2.1). The dendrogram evident that Nepalese domestic and wild buffaloes belong to riverine group.

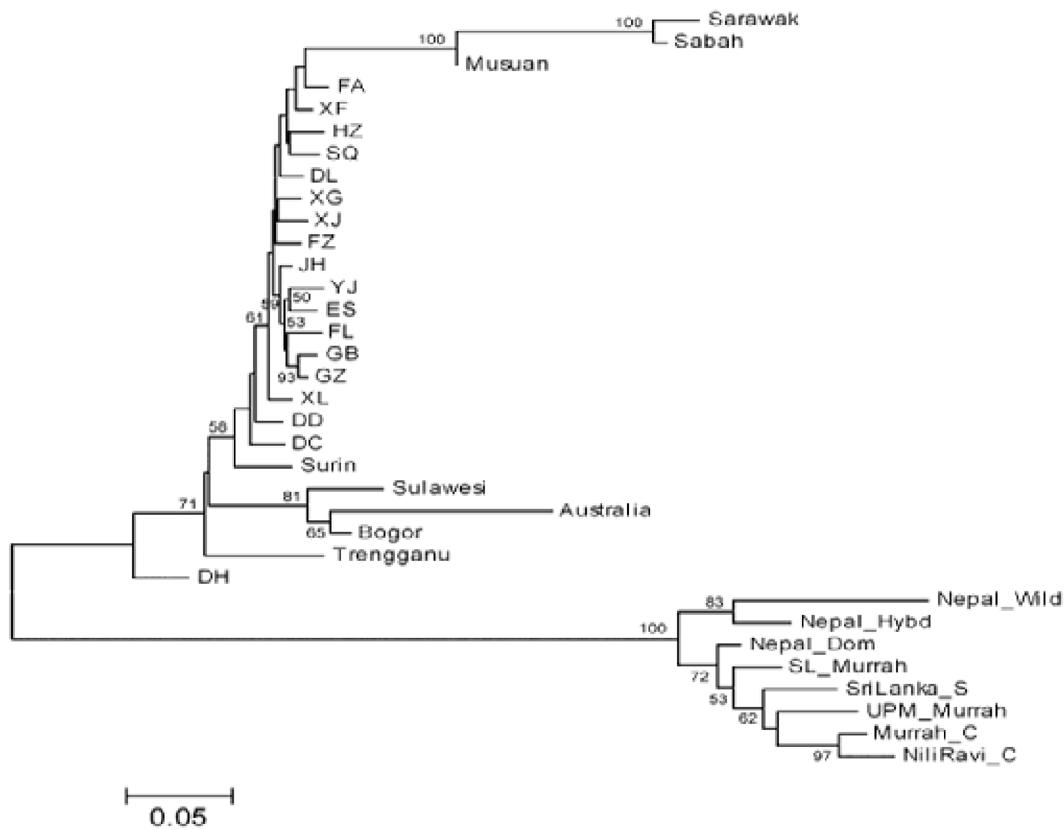

Figure 2.1 Dendrogram of relationships among buffalo population in Asian region

Source: Zhang et al., 2011

Similarly, structure analysis revealed that the buffalo population in the periphery of the Koshi Tappu National Park area has two distinct population: one is Terai buffalo and other is the hybrid of Terai buffalo and wild buffalo (Figure 2.2).

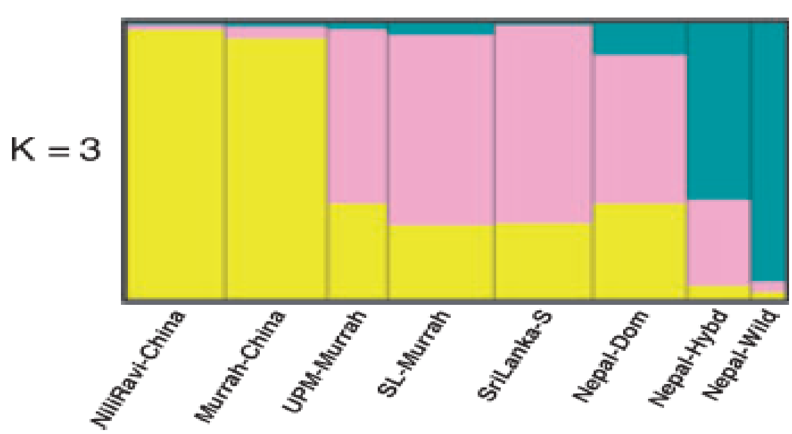

Figure 2.2 River population assuming K=3

Source: Zhang et al., 2011

Mitochondrial DNA analysis revealed all three riverine haplogroups (R1, R2, and R3) in Nepalese buffalo populations in different proportions (Figure 2.3). The samples in the study was taken from only one site that is from the periphery of Koshi Tappu National Park area which is the home tract of Terai buffalo (Zhang et al. 2016). More comprehensive analysis on mtDNA diversity need to be studied for more concrete conclusion.

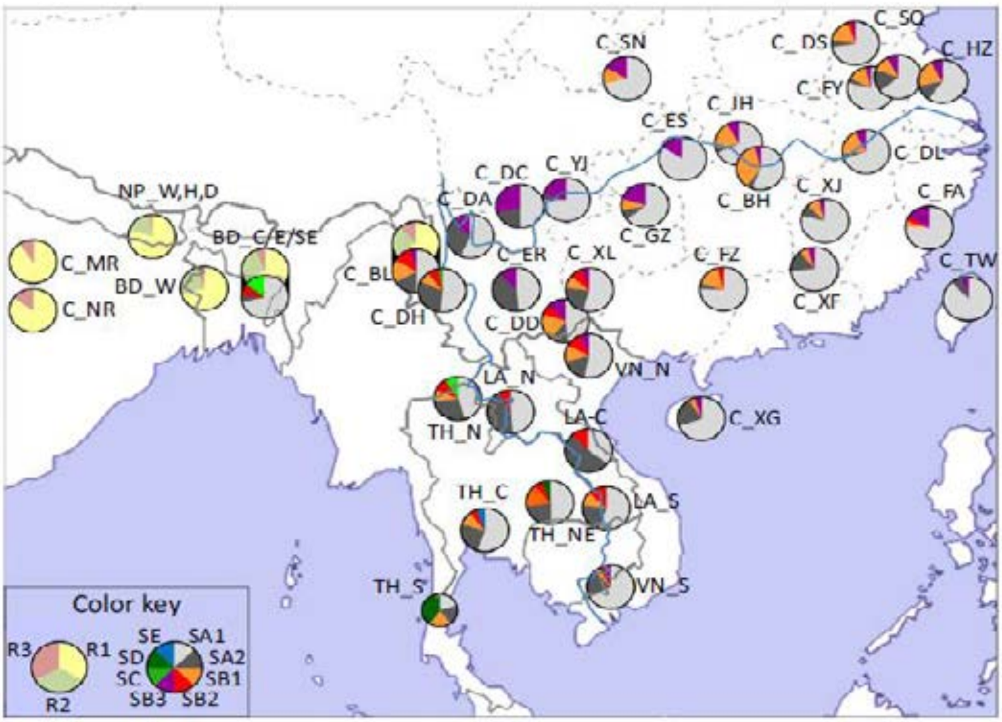

Figure 2.3 mtDNA haplogroup distributions of river and swamp buffalo. In the colour keys, SA1 to SE indicate swamp haplogroups, and R1 to R3 indicate river haplotypes

Source: Zhang et al., 2016

2.5 Production performance of indigenous buffalo

2.5.1 Milk production performance of indigenous buffalo

Lime buffalo

Lime is the smallest amongst the three identified Nepalese buffalo breeds. It is mainly kept for meat, manure and power. Milk production of this breed is comparatively lower than other breeds of buffaloes in the country. Average daily milk yield obtained from the buffalo was 2.5 lit while limit ranged from 2.0 to 4.0 lit (ABD Annual report, 2003). Similarly, Rasali and Joshi (1996) recorded higher average value with calculated 1048 lit milk production in the standard 305 days lactation period. A maximum milk yield per day was noted up to six litres in the farmers' household. The report of some very high yielding individuals among the indigenous population suggesting their further multiplication for genetic improvement of the flock. The research also revealed that the production is affected by different parameters such as the effect of parity, of the location (altitude) and of the season on the production. The milk production increases with the parity till seventh parity and drops gradually afterwards and lactation yield in high altitude is better than in low hills and river basin (Amatya et al., 2000). Monsoon calving buffaloes were recorded to give higher milk yield (Shrestha, 1996). This shows that availability of fodder and forage plays a vital role in production of the animals and this also proves that the genetic potential of the animals is not expressed unless good husbandry practices are followed. Milk fat contents of the Lime buffalo ranged from 6.5 to 7.5 % across parities.

Parkote buffalo

Parkote is the medium size breed. Body configuration of this buffalo represents its solely milch type breed. The buffaloes have well-developed udders and prominent milk veins. Average daily milk production of the breed was recorded 3.5 lit and ranged from 2.0 to 5.0 lit (Annual report, ABD, 2003). A standard lactation yield of 305 days in Parkote buffalo under farmers' management condition in mid hills was 1031 litres. However, it was found that the breed performs well in lower hills and river basin as well with daily milk yield ranged from 0.5 to 6.5 lit.

On station study revealed that the milk yield of Parkote breed were high in 4th to 7th parity in which the yield remained around 1000 litres showing the highest performance (1123 litres lactation yield) in 7th parity (Amatya et al., 2000). Out of total studied population of buffaloes, 12 per cent of the animals yield above 1000 litres per standard lactation which exhibits that simple selection can improve the productivity of indigenous buffalo population of Nepal. Milk fat contents of the Parkote buffalo ranged from 6.5 to 7.5 % across parities.

Gaddi buffalo

Gaddi buffalo is the highest milk yielder in comparison to other two hill buffaloes of Nepal. Morphological characteristics and body formation of the breed clearly shows milking ability of the buffaloes. The buffaloes calve in the middle of June to September and the lactation period varies from 14 to 22 months due to the feeding, management and economic status of the farmers. When the farmer restricts two teats for suckling of the newly born calf, the daily milk yield during the first three months is 4.7 lit average daily. Average milk yield of Gaddi buffaloes was found to be 3.5 lit ranging from 2.5 to 5.5 litres (Pokharel et al, 1998).

Terai buffalo

Local people consider Terai buffalo as meat breed with less than a litre milk production per day even in peak period of lactation (Sapkota et al., 2017). Comprehensive data on production performance is need to need to be recorded in farmers' household and on station.

Table 2.1 Production performances of native buffaloes (MV ± SE)

	Breeds			
Variables	**Lime**[a]	**Parkote**[a]	**Gaddi**[b]	**Terai**[c]
Age at 1st service (month)	51.6±0.6	51.8±0.55	45.6±0.7	34.0±0.6
Age at 1st calving (month)	61.2±0.5	62.2±1.6	68.4±0.4	44.0±0.14
Service period (days)	190	175	350	
Gestation length (days)	315±1.7	315±1.4	330±1.4	305±1.4
Calving interval (months)	21±0.8	20.6±1.0	23.4±0.5	
Average daily milk yield (liters)	3.0±0.1	2.77±0.2	3.5±0.08	1.6±0.08
Lactation length (days)	305±1.3	305±1.4	420±1.2	285±1.2

Source: [a]Amatya, et al. 2000, [b]Pokharel, et al. 1998, [c]Sapkota et al, 2017

2.5.2 Reproductive production performance of indigenous buffalo

Lime buffalo

Average age at first service, age at first calving and calving intervals of Lime buffalo were recorded 52.0±.06, 61.0±0.5, and 21.0±0.8 months respectively (Amatya et al., 2000).

Parkote buffalo

Age at first service, post-partum conception and calving interval of the Parkote buffaloes ranging from 51-55.2 months, 5.8 months and 17.6-21 months respectively (Amatya et al., 2000; Rasali and Joshi 1996).

Gaddi buffalo

Age at first service, age at first calving and calving interval of Gaddi buffalo was recorded to be 46.0±0.7, 68.0±0.4 and 23.0±0.5 months respectively (Pokharel et al., 1998).

Terai buffalo

Local people consider Terai buffalo as meat breed with less than a litre milk production per day even in peak period of lactation (ABD Annual Report, 2016). Comprehensive data on production performance is need to need to be recorded in farmers' household and on station.

2.6 Future prospects

***Variation on the production performance of indigenous buffalo to be exploited**:* Average milk production of buffaloes in the country is comparatively lower than their inherited potentiality. Different study on the productivity of indigenous buffalo showed that they can produce more than 1000 lit of milk in a standard lactation period if proper management and husbandry practices can be applied (Amatya et al., 2000; Shrestha et al., 2005). Shrestha and Shrestha (1998) reported wide variation of milk production potential ranging from 300 to 2500 litres per standard lactation period of 305 days. Despite having no influence of any critical selection, the performance of indigenous buffalo is very close to that of the exotic stock introduced in Nepalese environment. Considering the existing variation in milk production potential of indigenous stock, an effective measure needs to be taken for improving the productivity of buffalo through selective breeding programme. Moreover the most of the data reported were collected from the buffalo reared in the farmers' management condition. Under optimum management condition, most of the indigenous animal genetic resources have exhibited their high genetic potential in their production performances. Thus the study need to be conducted to determine the genetic potential of the indigenous buffaloes and promote them with the findings with scientific basis. Beside exhibition of milk production potentiality, there is a wide variation in almost all economic traits characteristics such as meat, draught and pack. Very little knowledge is available about its inheritance and their interaction. An investigation on the productive characteristics must be undertaken so that the full potential of these buffaloes can be exploited.

Improvement of buffalo productivity using crossbreeding: Despite the extensive crossbreeding programme in the country, the crossbred buffaloes is reported to be 35 % of the total buffalo population (Bhandari et al., 2017) which is however increased to that reported in 2001 (10%) (Sherchand, 2001). In western region, more than three fourth of the sampled farmers are using indigenous bull, while the rest prefers to cross (Rasali and Joshi, 1998). There may be some practical reasons for the preference of indigenous buffaloes over crossbred and it might be their acclimatization adaptability in the traditional husbandry practices. These attributes need to be studied and utilized effectively in the AGDP.

Negative selection of the buffalo bulls to be checked: In the western Nepal, there is a severe problem of male buffalo calf disposal at the early age (Rana et al., 2000). Farmers in these areas are disposing buffalo calves especially the males to save milk of their dam for home consumption and/or selling for immediate cash. The male calves that survive are the ones whose dam does not give milk without the calf, thus led to a negative selection. It's urgent to find the effective way to utilize these culled calves and stop negative selection in the herd. Furthermore, there is high demand of buffalo meat in Nepal and the buffalo fattening techniques developed by NARC need to be dessiminated throughout the country to be self reliant in the meat production in the country.

Genetics of association of milk and meat production of buffalo need to be studied: There is growing interest in the genetic of milk and meat production in the water buffalo but the research undertaken in this area is highly fragmented. The main focus of investigation is to establish various phenotypic and genetic parameters which could lead to develop the strategies of buffalo breeding system to some extent. Recently, National Animal Breeding and Genetics Research Centre is conducting the research to determine the association of milk production with molecular marker which later can be used for selection/ identification of high yielding cows.

Animal registration and performance recording program to be conducted to identify and utilize the animals with hight genetic merit: Programmes such as registration of high yielder buffaloes, identification of bull mothers, production of genetically superior bull and progeny testing programme for their extensive utilization through Artificial Insemination (AI) programme need to be intensified to improve the productivity of rural buffalo population by involving large number of rural buffalo producers. For the effective running of AI programme and improving the national herd average a herd of superior breeding buffaloes need to be established. Production of high genetic merit germplasm is a slow task as heritability of reproductive traits is quite low and the generation interval is comparatively long. It could only be possible through organizing buffalo producers to form breeding societies, sound AI service, and maintenance of proper record and selection of superior sires. Presently, rare examples are available for the development or selection of superior sires for breeding buffalo population. It is therefore essential to initiate a project to identify bull mothers for the production of progeny tested bulls for the improvement/development of indigenous herds.

Use of molecular markers for characterization, conservation and utilization of animal genetic resources: It is mandatory to explore the genetic architecture of a species to understand the biology that helps to manage its genetic variability, which is ultimately used for selective breeding and genomic selection. Chromosomal and molecular characteriazation revealed that all identified Nepalese buffalo breeds are riverine type with higher phenotypic diversity. Molecular markers are an indispensable tool to understand the genetic structures of populations. The availability of recent high-quality reference genome and genotyping marker panels has invigorated many genome-based studies on evolutionary history, genetic diversity, functional elements, and performance traits. Recent advancements in high-throughput technologies like whole-genome sequencing, genome-wide association study (GWAS), gene expression profiling, next-generation sequencing (RNA and DNA), and genome-wide CHIP-seq scanning are used to increase molecular knowledge associated with selective breeding which pave the way for genetic improvement in the climatic resilience, disease resistance, and production performance of water buffalo populations globally. Moreover, if pedigree information is not available, genetic markers can be used to approximate these criteria.

Study on reproductive physiology related research is warranted: Freezing and storage of buffalo semen require further studies. The conception rate on AI is uniformly lower in buffaloes than in cattle, thus reducing the speed of progress. Buffaloes show silent heat. This may be the reason for reduced conception rate. Heat synchronization using hormone was introduced which was not that effective in buffalo due to various reasons. Furthermore, Fixed Time Artificial Insemination (FTAI) is recently introduced and is in the process of verification.

Infertility and/or delayed fertility and reproduction related issued in buffalo need to be studied: Nutritional deficiencies and imbalances which are frequently associated with delayed maturity, infertility and abortions in females and reduced libido and decreased sperms concentration and motility in males also require concerted research efforts. Nepal Agriculture Research Council (NARC) has initiated a study on production parameters for determining the problems related with reproduction physiology under farmers' management condition. The principle questions related to female such as late age at first calving, the high incidence of postpartum anoestrus and high silent heat experienced in buffaloes need to be addressed. Similarly, a more systematic and comprehensive research programme on spermatogenesis, the metabolism of spermatozoa in epididymis, the nature and role of seminal plasma, the detailed biochemical characteristics of buffalo semen, the changes in semen undergo during freezing and thawing and metabolism of spermatozoa in reproductive tract of females need to be initiated.

Clear and specific breeding strategies for buffaloes need to be developed: Comparative low productivity of indigenous buffalo breeds are the major concern of the breeders. Several strategic programmes have been developed to improve the milk production through crossbreeding with imported Murrah and Nili Ravi breeds. Exploitation of AI programme has also been introduced. But little thought has been given to progeny testing programme or sire evaluation scheme. This is a long term breeding programme especially useful in dairy cattle and buffaloes. For selecting superior sires for production traits, Buffalo Genetic Improvement Project has been introduced recently in collaboration between NABGRC (then Animal Breeding Division), NARC and Department of Livestock Services, Government of Nepal. Clear breeding strategy for buffalo commodity is lacking for indigenous breeds as well as exotic breeds which are urgently recommended for the improvement of the productivity of buffalo commodity. Breeding programmes and optimal utilization require knowledge of genetic variability that is diversity within and among breeds and populations. Therefore data on magnitude of genetic differentiation and genetic relationships among breeds and populations are warranted for defining the best approaches to the conservation of genetic resources.

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3. INDIGENOUS CATTLE BREEDS OF NEPAL

Lulu cattle

Achhami cattle

Siri cattle

Khaila cattle

Pahadi cattle

Terai cattle

Yak

Siri cattle herd at NABGRC

3. INDIGENOUS CATTLE BREEDS OF NEPAL

3.1 Zoological classification of cattle

Kingdom	:	Animalia
Phylum	:	Chordata
Class	:	Mammalia
Order	:	Artiodactyla
Family	:	Bovidae
Sub-family	:	Bovinae
Genus	:	*Bos*
Species	:	*taurus/indicus*

<u>For domestic yak</u>

Genus	:	*Poephagus*
Species	:	*grunniens*

3.2 Overview of cattle in Nepalese context

Cattle are an important livestock commodity in Nepal. There are 7,458,885 million cattle in the country (MOAD, 2021). Cattle is found in all parts of the country from tropical to termperate and even in Alpine (Yak) (MoALD, 2019). Province-wise contribution of cattle and yak is given in Table 3.1. Nepal has the highest density of cattle with the population of human while the milking cattle is very low which is about 14%. 40% share the total milk production is from these milking cattle while 60% is contributed buffalo (26% of the total population) (Appendix 1; MoALD, 2019). Generally, Nepalese cattle are considered to be of poor quality in terms of milk production, and most of these animals are having small to medium compact body size which suggests to be useful for beef but due to their religious significance to the Hindu majority, these qualities together with their other positive attributes are nationally ignored. The indigenous livestock not just only play key role for nutritional security by providing animal source proteins in the form of milk; but also plays vital role in agriculture system providing power for agricultural operation and pack use, draft for transportation, manure for maintaining and enhancing soil fertility, biofuels for kitchen, as an instant source of cash and contribution for poverty reduction (Pradhanang et al., 2015).

Table 3.1 Province-wise contribution of cattle and yak

Province	Total cattle population	Milking cow	Milk production (Mt)	Total Yak/ Chauri Population
Province 1	1981755	321,753	284,940	21293
MADHESH	1247124	187,071	147,391	-
Gandaki Pardesh	1064349	168,930	135,800	11935
Gandaki	481865	76,656	61,247	13997
Lumbini	1162262	183,796	146,450	-
Karnali	504184	72,528	39,802	21761
Sudurpaschim	1017346	155,42	104,769	1003
Total	**7458885**	**1,166,156**	**920,399**	**69989**

Source: MoALD, 2021

Majority of the cattle reared by farmers are indigenous humped cattle (*Bos indicus*) except Lulu (*Bos taurus*) suggesting more contributions coming from the indigenous breeds compared with only 15% percent of exotic cattle of improved status (DLS, 2010). Despite their immense contribution in the agrarian economy of Nepal, population of indigenous breeds are in declining trend both in number and genetic makeup. Attempts made by government for increasing productivity of cattle through crossbreeding approaches by introduction of exotic breeds like Jersey, Holstein, Brown Swiss, Red Sindhi etc. without proper evaluation of indigenous breed under the optimum condition of health and management has contributed to some extent for the depletion of population and genetic makeup of indigenous breeds. Likewise, other factors like development of alternative employment opportunities, changes in farming environment, forest degradation and shortage of feeding materials, lack of proper evaluation of indigenous stock, lack of recognition of the importance of characteristics specifically suited to the different geographical setting of the country and failure to implement breed improvement and conservation plan could be responsible for the current outcomes (GoN-MoFSC, 2014 and GoN-MoFSC, 2018).

Efforts has been made both at national and international level for conservation and preservation of genetic resources. Nepal is no exception to the global phenomena and has committed for making a significant reduction in the rate of loss of biodiversity as a contracting party to the Convention on Biological Diversity (CBD) as per the Aichi target (GoN-MoFE, 2018). However, focus is more driven towards flora and fauna that are on the verge of extinction. With the extinction of Siri cattle and situation of some of the other endangered breeds have alarmed conservation with attempt made to study the phenotypic and genotypic characterization of animal and preservation of germplasm but is limited. The factor that genetic drift might result due to bottleneck effect if we don't make attempt to protect the breeds which number are in significant amount currently but can be depleting soon due to various social, climatic and genetic changes has been neglected. Also neither comprehensive baseline information are available, nor are more studies being carried out to understand and establish information pertaining to important traits of the existing indigenous cattle breeds like adaptability in harsh environment, disease resistant, productivity under poor feeding and management condition, climatic suitability etc.

Apart from the contribution of indigenous cattle, the exotic cattle is becoming important in the commercialization in cattle farming. Farmers are interested to cross the indigenous cattle with exotic with the expectation to increase milk production retaining the genetic qualities such as adaptation in the local environment and disease resistance. Therefore, even though the indigenous cattle population is declining in the number, the population growth of cattle is still growing in positive trend and same in milk production (Figure 3.1).

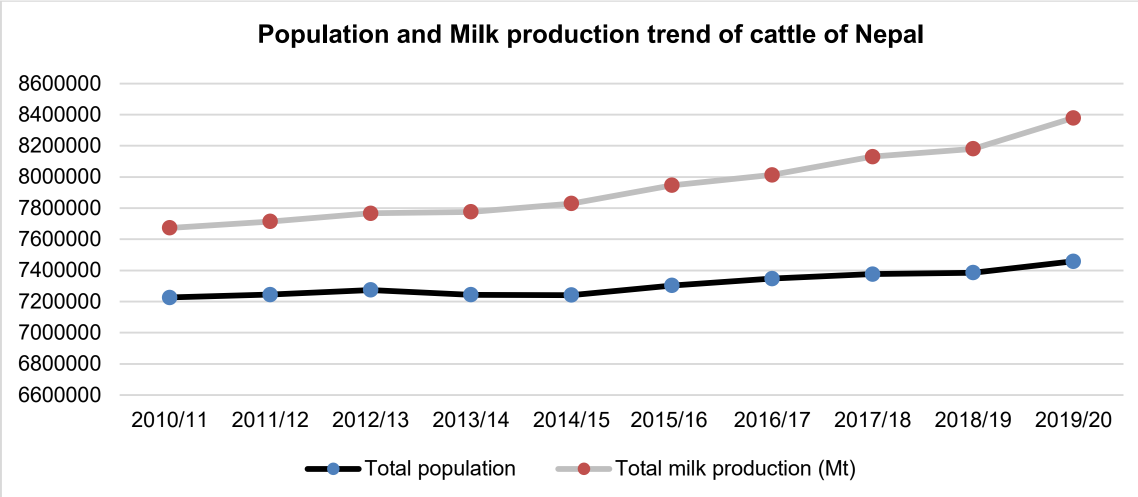

Figure 3.1 Trend of population growth and milk production

Source: MoALD 2021

3.3 Origin of Nepalese cattle

Cattle are scientifically indicated to be descended from the now-extinct aurochs (*Bos primigenius*). The earliest domestication occurred some 10,500 years ago in present day Iran. According to archaeological evidence, all tropically adapted zebu cattle (*Bos indicus*) were domesticated 8,000-9,000 years ago and spread over northern South Asia by 6,000 years ago (Patel, 2009; Pérez-Pardal et al., 2018). Out of six indigenous cattle breeds of Nepal, five breeds are zebu type except Lulu cattle. The farmers have been raising Lulu cattle for 500 years in Mustang district. These animals appear to have migrated from Europe to China and Mongolia, and finally to Tibet and Nepal (Shrestha and Shrestha, 1998).

Siri cattle are believed to be originated in Ilam district. Quinlan (1908) found that the Siri breed is located in Darjeeling, Sikkim and Bhutan, of which the latter country is supposed to be their home. Joshi & Phillips (1953) reported that animals of the Siri breed are found in the hill tracts around Darjeeling (Bengal, India) and in Sikkim and Bhutan. Bhutan is said to be the real home of this breed. Siri is said to be a prominent breed of cattle in Sikkim, the upper reaches of the Darjeeling district in West Bengal and Bhutan (Tantia et al., 1996). The breed tract lies between 1200 to 3000 m amsl. The Siri breeding tract has steep hills with narrow valleys. Ahlawat et al. (2009) reported that this breed is considered to have evolved on Indo-Bhutan border and Bhutan and Nepal both are having a much wider distribution of the breed. It is opined that Nublang which is Siri in Bhutani language is a stabilized breed, evolved from crossing of humped cattle of Indian plains with that of humpless cattle migrated to southern slopes of Himalayas from Tibet (Dorji et al., 2009).

Unequivocal evidence to link the modern yak to its earliest ancestors is not available. Fossil evidence suggests that yak were extensively distributed in north-eastern Eurasia in the late Tertiary period (2.5 million years ago) and that these are the forerunners of wild yak found as Pleistocene fossils in northern China, Inner Mongolia (China), eastern Siberia and northern mid-Asia and on a line roughly connecting these locations (Dyblor, 1957; Belyar, 1980; Flerow, 1980; Olsen, 1991). The scientific evidence revealed that wild yak migrated from northeastern Eurasia and adapted to life on the Plateau and domestication followed. Yak was probably domesticated in Tibet but has been introduced wherever there are people at elevations of 4,000–6,000 metres (14,000–20,000 feet), mainly in China but also in Central Asia, Mongolia, and Nepal.

3.4 Indigenous cattle breeds of Nepal

Six breeds of cattle *viz.* Lulu, Achhami, Siri, Khaila, Pahadi and Terai are reported as Nepalese indigenous cattle breeds in the country report published by FAO (2014). Indigenous cattle in Nepal are generally zebu types having humps except Lulu cattle.

3.4.1 Demographic distribution of indigenous cattle breeds of Nepal

The identified cattle breeds are Terai, Pahadi, Lulu, Achhami, Siri, Khaila and Yak. Indigenous cattle breeds being well-adapted and environmentally effective are reared throughout the country in all ecological zones ranging from tropical/subtropical to alpine.

Lulu cattle (*Bos taurus*)

Lulu, the only hump-less cattle found in the country has been adapted in high altitude dry cooler environment. Lulu cattle can thrive in the severe highland dry and cold and are found in Mustang district and few are found in some parts of Dolpa and Manang districts (Neopane et al., 2002). Lulu has wider range of adaptation between 2800 m amsl where they cross with zebu cattle to 4000 m amsl where they breed with yak (Pradhan et al., 1998; Fujise et al 2003; Takeda et al, 2004).

Achhami cattle (*Bos indicus*)

Also known by its other name *Sano Gai* or *Naumuthe Gai*, Achhami is claimed to be the world smallest breed of cattle with less than one meter in height at the withers (Epstein 1977; Neopane and Pokharel 2005; FAO country report, 2014). Population of Achhami cattle represents a small proportion of the total cattle population (less than 1000 heads of breeding animals) and is located in the western parts of hills in Achham, Bajhang, Bajura and Doti district (Shrestha and Shrestha, 1998; ABD Annual Report 2011). They have high altitudinal adaptation ranging from Sanfebagar (596 m amsl) to Khaptad (between 1,262 m to 3,276 m amsl).

Siri cattle (*Bos indicus*)

The home tract of Siri cattle was considered to be Ilam district of Nepal. With the government policy to improve the productivity of indigenous cattle, Siri was replaced by the exotic cattle breeds and later considered to be extinct from Nepal (FAO Country Report, 2014). In 2016, NABGRC (then Animal Breeding Division) rediscovered Siri cattle in remoteness of Taplejung district (Sablakhu rural municipality) which was evidenced by scientific studies (NABGRC Annual Report, 2020). Siri cattle breeding tract has steep hills with narrow valleys lies between 1200 to 3000 m amsl. This breed is considered to have evolved on Indo-Bhutan border and Bhutan and Nepal; both are having a much wider distribution of the breed (Ahlawat et al., 2009).

Khaila cattle (*Bos indicus*)

Khaila cattle are found from Siwalik range (400 m amsl) to high mountains (4000 m amsl) of the country (Neopane and Pokhrel, 2005). They are located mainly in far western hilly regions of the country and are a good draught breed. These cattle are well-adapted and can graze on the slopes of the hills and mountains. Since this cattle is also known as *Doteli Gai* indicating that the main habitat of this cattle is from Doti and Dadeldhura districts of Nepal.

Pahadi cattle (*Bos indicus*)

Majority of the cattle raised in hills of Nepal fall under the Pahadi category. These cattle are good draught purpose breed suitable for the hilly region where terraced landscape are present.

Terai cattle (*Bos indicus*)

Terai cattle are found in throughout tropical plains of Terai region of the country (Neopane and Pokharel, 2005).

Yak (*Poephagus grunniens*)

Yak and Nak are mountain cattle and are the iconic animal for the mountainous/ alpine regions/ no tree zone which are localized in northern belts of the country. They are very important commodity for mountain people. Yak and Nak are raised in trans-himal region above 3000 m amsl. Their numbers has been estimated to be going down and need consideration for conservation. The farmers have reared these animals themselves. They are characterized at phenotypic level (Neopane and Shaha, 2002). In the mountains, Yak (male) are crossed with female Hill cattle to produce Chauri (female) and Jhopkyos (male). Mating of Nak (female Yak) and male Hill cattle is also possible but not very commonly used. Chauries are good milk yielder and Jhopkyos are sterile and good for transportation as pack animals. Chauries and jhopkyos can come down to lower elevation than Yak and Nak. Based on the available information, Chauries and Jhopkyos production (kind of hybridization) in Nepal is unique in the world. They represent a small proportion of total cattle population in the country; however are very important commodity for mountain and high hill people (Shrestha and Shrestha, 1998).

3.4.2 Status of cattle breeds of Nepal

About 85 percent of the cattle in Nepal are indigenous. Since cattle throughout the mid hills and terai are considered as Pahadi cattle and Terai cattle respectively, the status of these cattle population is taken as normal whereas other four identified cattle populations (Siri, Achhami, Khaila, Lulu) are mostly endangered and/ or in the verge of extinction. The home tract of Siri cattle was considered to be Ilam district of Nepal and later declared to be extinct from Nepal (FAO Country Report, 2014). In 2016, NABGRC (then Animal Breeding Division) rediscovered Siri cattle in remoteness of Taplejung district (Sablakhu rural municipality) which was evidenced by scientific studies (NABGRC Annual Report, 2020).

Despite their immense contribution in the agrarian economy of Nepal, population of indigenous breeds are in declining trend both in number and genetic makeup. Attempts made by government for increasing productivity of cattle through crossbreeding approaches by introduction of exotic breeds like Jersey, Holstein, Brown Swiss, Red Sindhi etc. without proper evaluation of indigenous breed under the optimum condition of health and management has contributed to some extent for the depletion of population and genetic makeup of indigenous breeds. Likewise, other factors like development of alternative employment opportunities, changes in farming environment, forest degradation and shortage of feeding materials, lack of proper evaluation of indigenous stock, lack of recognition of the importance of characteristics specifically suited to the different geographical setting of the country and failure to implement breed improvement and conservation plan could be responsible for the current outcomes (GoN-MoFSC, 2014 and GoN-MoFSC, 2018).

3.4.3 Positive attributes

Indigenous breeds are low producing than the exotics in terms of milk production. However, they have several other positive attributes such as disease resistance, adaptability to local harsh conditions and can produce in low input system. It is observed that these positive attributes are not duly recognized rather exotics breeds are unnecessarily given preference over them.

3.4.4 Sociocultural signification of indigenous cattle

Cow is a Hindu sacred animal. Cow raising can be based on social, cultural, economic and religious significance from the Vedic period. About the infatuation of *Kamadhenugai* (*Kamadhenu cow*: is a mother of all cows) of Lord Krishna (the hero of the *Dwapar era*) with important products like milk, curd and ghee are mentioned in Bhagwat Gita, Krishnacharitra and other Hindu scriptures. Similarly, Lord Shiva's vehicle, *Nandi* (bull), is also included in Hindu scriptures. It is customary for the Hindus to worship the cow as a sacred animal and to consider milk, curd (yogurt), ghee, dung and urine (*panchakavyam*: mixture of those ingredients) as sacred things. Therefore, killing a cow is considered a punishable offense and cow slaughter is completely forbidden in Hinduism. Nepal with more than 80% of the Hindu population considered cow as National animal and Nepalese law forbids slaughter of cattle. The milk of the local cow is considered to be the most sacred and the cow dung is used to clean houses, temples, places of worship, Tulasiko Mairo or math (at the top, Tulasi or Basil is planted) and other sacred places. From time immemorial, the Brahmins and Chhetri of the Hindu Aryans have been raising at least one cow for sanctity, while most of the rural farmers still keep local cows for milk and milk product, manure, ploughing and carts.

Indigenous cow urine is also commonly used in Ayurvedic medicine for treatment of diabetes, blood pressure, asthma, psoriasis, eczema, heart attack, blockage in arteries, fits, cancer, AIDS, piles, prostrate, arthritis, migraine, thyroid, ulcer, acidity, constipation, gynecological problems (Mahajan et.al. 2020). Similarly, ghee from cow milk is used as a medicine to prevent colds (eating and body massage), aids in bone health and other health benefits like improve digestions, boost immunity, nourishes skin, nutrition supplements (vitamin A,D,E and K).

In has been scientifically proven that cow urine as bio-enhancer and bio-pesticides and increase soil fertility and nitrogen content of the soil. Therefore, cow urine is used extensively in organic farming (Pradhan et al., 2018).

Cultural festivals of Yak blood drinking: The festival is celebrated twice a year during April/May and July/August in Boksikhola, Mustang district of Nepal. Since yak live in high altitude where herb with different medicinal values are found. Since yak graze these herbs in the highland pastures, local people believe that yak blood have medicinal value which helps curing various diseases such as gastritis, jaundice and skin diseases, and relieves body sprain and swelling.

3.4.5 Characterization of indigenous cattle breeds

All identified indigenous cattle breeds have been characterized on phenotypic level; Lulu and Achhami are characterized in chromosomal level; and most of the cattle breeds except Pahadi and Khaila are not studied in molecular level.

3.4.5.1 Phenotypic characterization of indigenous buffalo

3.4.5.1.1 Physical characteristics of indigenous cattle

Lulu cattle

- Lulu cattle is the claimed as the smallest breed in the taurine cattle category.
- Lulu cattle is the only taurine type cattle which are humpless.
- Body colour varies shades and combination of black, brown, grey and white that is black, brown, grey, white, spotted black and white.
- In the habitat area of Lulu cattle, the hair of this cattle is found to be long, ruffled, densey, and dull.
- They have relatively medium (male) to small (female) sized horns which curve slightly forward.
- They have small body with short body length.
- Its temperament is semi wild.

Achhami cattle

- Achhami (*Bos indicus*) humped type cattle
- Achhami is the smallest breed of cattle in terms of body size and weight.
- Dominated body coat color is black and other colors are varies i.e. brown, grey, white, spotted black and white.
- Horns are small sized and are slightly curved forward. Horns are dominatingly black in color.
- Ear is medium sized and straight.
- Color of muzzle and hoof is commonly black.
- Its temperament varies from docile to semi wild.

Siri cattle

- Siri cattle (*Bos indicus*) humped type cattle.
- Siri cattle is medium body sized cattle breed.
- Siri cattle are found in different shades of body coat colour. Most cattle have white and black patches on their bodies and some are reddish color.
- Siri cattle are the highest milk yielders among the identified indigenous cattle and have well-developed udder which indicates good milking ability.
- They have wide flat forehead and a thuft of hair (*Furka*) in the middle of forehead.
- They have small and straight ears.
- They have sharp horns projecting forward and slightly upward.
- Its temperament varies from docile to semi wild.

Khaila cattle

- Khaila cattle (*Bos indicus*) humped type cattle.
- Khaila cattle are strongly built humped.
- They have medium sized body.
- Legs are well-developed and suitable for draught purpose.
- These cattle are black and white in colour.

- The horns are straight and upward in direction.
- It have straight hanging udder with elongated teats.
- Khaila have a wild temperament and are difficult to handle.

Terai cattle

- Terai cattle are humped (*Bos indicus*) type cattle.
- Male are good for transportation (cart) and ploughing of land.
- Terai cattle are light colored animals. They have mostly white-coated with black skin and occasionally found in black and other mixed color.
- Ear is straight.
- Its temperament varies from docile to semi wild.

Pahadi cattle:

- Pahadi cattle (*Bos indicus*) found in hills and mountain of Nepal.
- They are predominantly black in colour; occasionally found in blackish brown and sometimes mixed color.
- Male are good drought animals and capability to ploughing on narrow, sloppy, undulating terrain land.
- Pahadi cattle are small to medium sized.
- Compact cylindrical body, short legs, medium hump, horizontally placed ears and comparatively longer tail than other indigenous cattle.
- Horns are medium sized curved in lateral and upward direction.
- Its temperament is moderately wild.

Yak/Nak:

- Yak are mostly black colour but white and other colour (fawn) are also common.
- Body colour varies from black to white i.e. black, brown, grey, white, spotted black and white.
- Ear is straight and swampy switch tail.
- It have two types of wool i.e. coarse hairy and fine fleece and extremely dense, long fur that hangs down lower than the belly.
- Yaks are heavily built animals with bulky frames, sturdy legs, rounded and cloven hooves.
- Its temperament is wild.

3.4.5.1.2 Morphological measurement of indigenous cattle

Lulu cattle

Lulu are small size cattle suitable for hill conditions having average adult body weight of 125-150 kg and 114 cm of heart girth. They are shorter in height at withers (88 cm at wither) (Table 3.2). Ear is straight with an average length of 14 cm. The body length, chest girth, height at wither, height at hip bone, ear length and body weight of Lulu cattle were 99.4±1.2 cm, 114.2±1.1 cm, 87.2±0.8 cm, 87.7±0.7 cm, 13.8±0.1 cm and 124.7±3.7 kg respectively (Rana et al., 1996). The Lulu female is weighed higher than Lulu male, which may be due to better care and management of female calves than male. Body weight of most of the Lulu cows, aged from 2 to 18 years, averaged between 150 to 200 kg.

Takeda et al. (2001) reported a wider variation in body weight and body size depending on the elevation of the altitude. The least square means of the body weight of Lulu cattle in Jharkot village was 130.3±25.3 kg, 123.9±18.6 kg in Kagbeni, 156.6±44.2 kg in Chhairo and 185.6±49.3 kg in Tukuche.

Achhami cattle

Achhami cattle are the smallest breeds of cattle in the world. Ear is straight with an average length of 17 cm. The wither height of Achhami cattle was 110.8 ±1.9 cm at the age of 9 years. Similarly, maximum body weight and body length were 149.38±5.1 kg and 98.07±1.52 cm respectively at the age of 8 years (ABD Annual Report, 1995).

Siri cattle

Siri cattle are the medium breeds of cattle in the Nepal. Ear is small and an average length of 17.3 ±0.35 cm. The wither height of Siri cattle was 116.3 ±0.97 cm at the adult animals. Similarly, maximum body weight and body length were 286.5±7.5 kg and 127.1±1.24 cm.

Khaila cattle

Khaila cattle are larger indigenous cattle breed in the country (Table 3.2). Ear is medium size and an average length of 23.05±0.5 cm. The wither height of was 120±1.8 cm at the adult animals. Similarly, maximum body weight and body length were 298±1.1 kg and 128±1.6 cm (Kunwar et al., 1998).

Terai cattle

Terai cattle are medium indigenous cattle breed in the country. Ear is small size and an average length of 16.3±0.43cm. The wither height of was 104.1±1.15 cm at the adult animals. Similarly, maximum body weight and body length were 210±1.5 kg and 107.5±1.37 cm.

Pahadi cattle

Pahadi cattle are madium size cattle suitable for hill conditions and an average adult body weight of 165.6±1.8 kg and 129.7±1.89 cm of heart girth. An average length of ear was 17.7±0.50 cm. The body length and height at wither of Pahadi cattle were 102.6±1.63 cm and 102.1±1.20 cm respectively

Yak

Average adult body weight of yak is recorded 355 kg and for Nak is 325 kg. At the breeding age, these animals reach 70 % of the adult weight. It produces 2 types of wool: Coarse hairy and fine fleece. Wool production from Yak and Nak is 1.2 and 0.7 kg respectively.

Table 3.2 Morphological measurements of indigenous cattle (MV ± SE cm)

Parameters	Lulu	Achhami	Siri	Khaila	Yak	Terai	Pahadi
Body length	99.4±1.2	92.1±1.23	127.1±1.24	128±1.6	114.6±2.2	107.5±1.37	102.6±1.63
Heart girth	114.2±1.1	118.6±1.4	154.4±1.4	162±1.8	132.2± 2.1	134.6±1.70	129.7±1.89
Height at wither	87.2±0.8	90.8±0.96	116.3±0.97	120±1.80	104.4±2.8	104.1±1.15	102.1±1.20
Height at hip bone	87.7±0.7	88.5±0.76	112.8±0.76	118±1.60	102.2±2.3	102.7±1.19	99.7±1.03
Head length	34.6±0.3	33.2±0.54	49.9±4.0	48±0.6	41.74±3.7	42.8±0.55	39.6±0.96
Tail length	50-60.0	72.42±1.26	105.3±1.5	99±2.3	39.65±5.9	58.9±0.13	51.14±0.78
Horn length	15.8±0.7	3.0	15.5±2.5	18±1.2	37.8±8.23	11.2±0.99	15.77±0.7
Ear length	13.8±0.4	16.8±0.28	17.3±0.35	23±0.5	14.0±1.4	16.3± 0.43	17.7±0.50
Neck length	29.1±0.53	30.8±0.66	36.4±1.6	41±1.0	31.6±4.2	34.6±0.08	37.0±0.97
Loin girth	109.4±1.36	115.4±1.65	160.8±1.43	170±3.5	133.2±12.3	138.1±2.33	125.5±2.93
Barrel height from ground	40.7±0.46	44.8±0.72	-	56±2.1	40.63±2.9	43.2±0.08	52.9±1.27
Fore legs above knee	28.1±0.35	32.1±0.46	35.6±0.51	85±0.9	53.15±2.3	32.5± 0.88	30.9±0.82
Fore legs below knee	24.6±0.28	26.7±0.42	30.7±0.48	32±0.6	36.5±0.58	29.1±0.03	27.2±0.75
Rear legs above knee	34.2±0.39	34.8±0.53	46.4±0.98	68±1.2	47.0±2.04	37.5± 0.87	39.2±0.94
Rear legs below knee	35.3±0.34	32.8±0.46	45.9±0.78	43±0.9	36.6±0.41	40.9± 0.66	35.1±0.82
Adult body weight (Kg)	124.7±1.8	125.1±7.46	286.5±7.5	298±1.1	192.9±2.1	210±1.5	165.6±1.8

Source: Annual report, ABD (1997); Shrestha and Shrestha (1998); Kunwar et al. (1998); Neopane et al. (2002); Shrestha (1996); Shrestha et al. (1996a); Shrestha et al. (1996b); Rana et al. (1996)

3.4.5.2 Characterization on Chromosomal level

The chromosome karyotype of domestic cattle and yak were studied by methods of peripheral blood lymphocytes culture. Karyotyping study of cattle revealed that Lulu cattle have 60 chromosomes in diploid. Male had a large sub-metacentric X-chromosome and a small sub-metacentric Y-chromosome. Karyotyping results indicated that the Lulu cattle chiefly belong to the taurus type (Takeda et al, 2004). Similarly, the study of the Achhami cattle population has also revealed the similar karyotype as Lulu (Dhakal, 2008). Unlike the metacentric Y-chromosome of *Bos taurus* were detected in Lulu cattle, Achhami harbored submetacentric most probably telocentric Y-chromosomes of *B. indicus* (Dhakal, 2008). The diploid chromosome number of domestic yak is 2n=60. The autosome is subterminal chromosome.The sex chromosome is submetacentric chromosome. These yak and cattle can be crossed easily to produce *Chauri* (Yak hybrids) (Joshi, 1982).

3.4.5.3 Molecular Characterization

Mitochondrial DNA (mtDNA) is instrumental in identifying maternal inheritance and is highly variable within species. Specifically the control region of mtDNA evolves very rapidly compared with nuclear DNA. Furthermore, it also tells the recent demographic processes acting on the populations (Bruford et al., 2003). Mitochondrial DNA has been widely used to explore the maternal origin of the cattle by various researchers. A mitochondrial DNA (mtDNA) studies demonstrate that the Asian cattle may have three origins: *Bos taurus*, *Bos indicus* and *Bos grunniens*, of which *B. taurus* and *B. indicus* have the major influence (Yu et al., 1999). Takeda et. al., (2004) found three mtDNA types of Lulu cattle: majority were phenotypically Lulu with *B. taurus* mtDNA; some were phenotypically Lulu with *B. indicus* mtDNA; and a few were phenotypically Lulu with *Bos grunniens* mtDNA (Figure 3.10). Lulu have been hybridized with *Bos indicus* in lower elevation region in their maternal lineage and with *Bos grunniens* in high altitude northern regions indicating the wide range of altitude. Three mtDNA genotypes were detected in these animals.

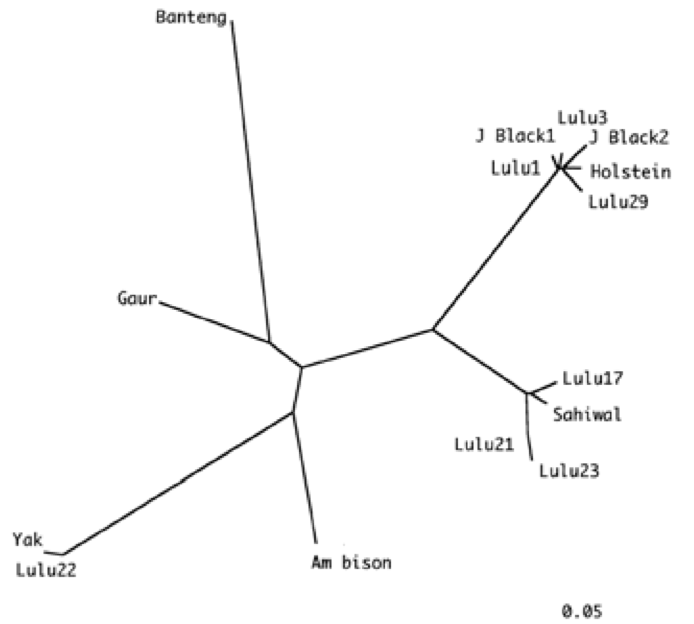

Figure 3.2 Unrooted neighbor-joining tree constructed from Dloop polymorphic sequences. A scale bar (divergence of 0.05) for branch length is shown.

Most of the Lulu showed the same mtDNA genotype as *B. taurus* cattle, namely, the A-A-A type (HindIII-Bg/II-HpaI). A few were found as mtDNA genotypes of the *B indicus* cattle (B-B-A type) and a few showed a A-A-B type that is different from the humpless and the humped cattle (Figure 3.3; Table 3.3).

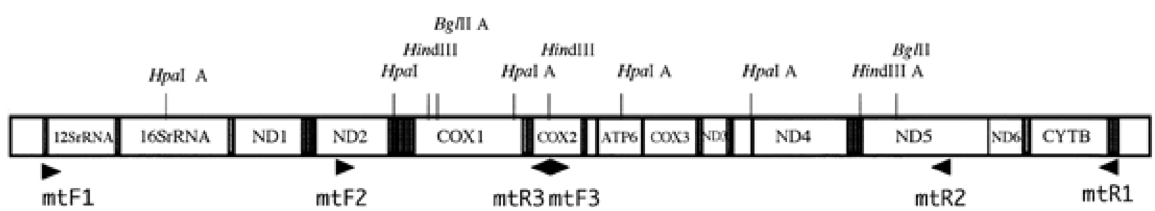

Figure 3.3 The locations of PCR primers (mtF1~F3, and mtR1~R3) and restriction sites (HindIII Bgl2, and HpaI) in mtDNA.

Source: Takeda et al., 2004

Table 3.3 Mitochondrial DNA haplotypes of Lulu cattle analyzed

Place	Individual no.	RFLP			SSCP	
		*Hind*III	*Bgl*II	*Hpa*I	S	L
Jharkot	1, 6, 8, 10	A	A	A	A	A
	2, 7	A	A	A	B	B
	3	A	A	A	B	F
	4	A	A	A	C	C
	5	A	A	A	D	D
	9	B	A	B	E	G
Kagbeni	11	A	A	A	D	D
	12, 14, 15, 18, 19	A	A	A	A	A
	13	A	A	A	B	B
	16, 20	A	A	A	C	C
	17	B	B	A	E	H
	21	B	B	A	E	E
Chhairo	27, 28	A	A	A	B	B
	29, 31	A	A	A	D	A
	30	A	A	A	A	A
Tukuche	22	B	A	B	E	I
	23, 24, 25, 26	B	B	A	E	E

RFLP, restriction fragment length polymorphism; SSCP, single strand conformation polymorphism; S, SF-SR fragments; L, LF-LR fragments; A–I, DNA haplotypes.

Source: Takeda et al., 2004

Gorkhali et al 2021 claims that the possible ancestral origin of *Bos taurus* and *Bos indicus* mtDNA lineage in the Nepalese cattle population is majorly influenced by China and India, respectively. The sampled population of Lulu, Siri and Achhami suggests that Nepalese cattle can be divided into two major groups: *Bos taurus* and *Bos indicus,* where most of the cattle population was of *Bos indicus* origin and can be classified into three significant haplogroups: T3 (25%), I1 (48%), and I2 (27%) revealing a higher genetic diversity among the Nepalese cattle population (Table 3.6).

Table 3.4: Percentage of Bos taurus and Bos indicus clades in the sampled population

Breeds	***Bos taurus* clades**				***Bos indicus* clades**	
	T1	**T2**	**T3**	**T4**	**I1**	**I2**
Achammi	0	0	3 (4%)	0	22(29%)	12(16%)
Lulu	0	0	12 (16%)	0	1(1%)	3(4%)
Siri	0	0	4 (5%)	0	13(18%)	5(7%)

Gorkhali et al., 2021

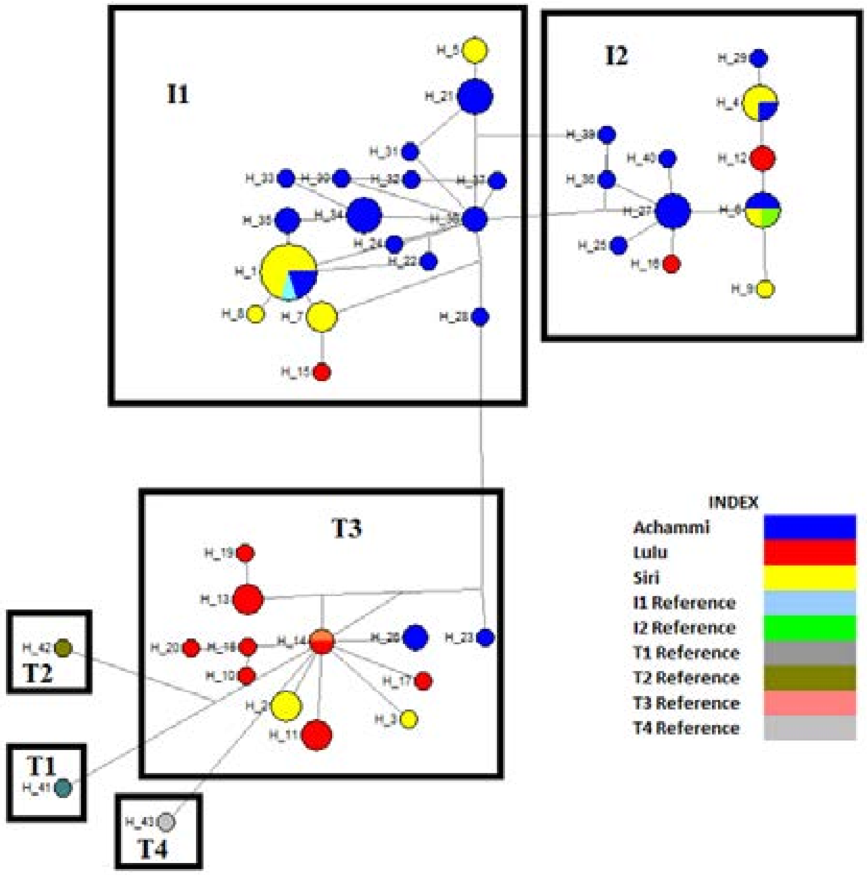

Figure 3.4 NETWORK analysis showing major I1, I2, and T3 haplogroup shared by three distinct Nepalese cattle breeds.

Source: Gorkhali et al., 2021

Uniquely, only T3 taurine haplogroup was found in the taurine population of Nepal (Figure 3.4). It was consistent with the fact that the absence of T1 haplogroup in North-East Asian cattle. In terms of *Bos indicus*, the I1 haplogroup was dominant over I2. Higher genetic diversity can be appropriate reasoning for Nepalese cattle's survival in a harsh environment and low food conditions.

3.5 Production performance of indigenous cattle

3.5.1 Milk production performance of indigenous cattle

Lulu cattle: Lulu cattle are small-sized cattle having low milk yielding ability. They produce on an average of 1.6 kg milk with 0.3 kg of standard errors in a lactation length of 195 days. The range of milk production lies between 0.5 to 3.57 litres. The highest milk production was found in the 7th lactation. In the recent research, Lulu cattle exhibited higher genetic potential under optimum management condition with the highest record of 6.7 litres of milk per day (Gorkhali et al 2017).

Achhami cattle: Achhami cattle have low milking ability and produce on an average of 1.5 kg milk with standard errors of 0.22 kg in a lactation length of 225 days. Although the average daily milk yield is less than 2 litres but it has wide variation ranging from 1 to 4 litres indicating the scope of improvement in milk production in Achhami cattle.

Siri cattle: Siri cattle are medium-sized cattle having good milk yielding ability. They produced on an average of 4.5 kg with 0.22 kg of standard errors in a lactation length of 268 days. In the recent study, maximum of 8.7 litres milk production was recorded under optimum management system (NABGRC Annual Report, 2020)

Khaila cattle: Khaila cattle are large-sized cattle having low milk yielding ability but good draught characters. They produce on an average of 2.5 kg milk per day in a lactation length of 10 months (305 days).

Terai cattle: Terai cattle are medium-sized animal having low milk yielding ability. They produce on an average of 2.1 kg milk errors in a lactation length of 246 days.

Pahadi cattle: Pahadi cattle are small-sized cattle having low milk yielding ability. They produce on an average of 1.1 kg milk daily in a lactation length of 240 days.

Yak: Yak is medium-sized mountain cattle having low milk yielding ability with high fat percentage in the milk (6.6%). They produce on an average of 0.8 kg milk in a lactation length of 5 months (160 days).

Table 3.5 Productive and reproductive performances of native cattle (Values are means ± standard errors)

Breeds	Age at 1st service (months)	Age at 1st calving (months)	Gestation length (days)	Calving intervals (months)	Average daily milk yield (litres)	Lactation length (days)
Lulu	42 (36-56)	52 (46-58)	280±1.7	18 (12-24)	1.6±0.31 (0.5-3.57)	195 (180-210)
Achhami	48 (36-60)	60 (48-72)	285±1.8	17 (12-24)	1.5±0.22 (1-4)	225 (180-270)
Siri	40 (36-48)	50 (42-70)	295.2±2.2	19.6±0.9	4.5 ±0.22 (2-6)	268.6±2.0
Khaila	45 (40-60)	55 (50-65)	288±1.85	18.0	2.5 (2-3)	305.0
Yak	45.3±0.65	56.6±0.75	252.2±1.5	21.3±0.76	0.8 (0.5-2.0)	160 (180-210)
Terai	39.4±0.50	49.9±0.46	296.1±0.25	16.3±0.23	2.1 (2-3)	246.0
Pahadi	48 (40-55)	50.1±1.1	275±1.65	17.6±1.98	1.1 (1-1.5)	240±2.1

Source: Annual report, ABD (1997); Shrestha and Shrestha (1998); Kunwar et al. (1998); Neopane et al. (2002); Shrestha (1996); Shrestha et al. (1996a); Shrestha et al. (1996b); Rana et al. (1996)

Reproductive production performance of indigenous cattle

Lulu cattle: They attain sexual maturity at about 3.5 years and produce the first progeny at an age of 4 to 4.5 years (Table 3.5). This figure is quite high when compared with European cattle (Jersey and Holstein-Friesian) which attain sexual maturity at about 1.5 to 2 years. Gestation length is about 9 months (280 days) which is similar with several literature reports. This is well within the range of cattle breeds.

Achhami cattle: They attain sexual maturity at about 4 years of age and produce the first calves at 5 years of age. Gestation length is 285 days close to Lulu and other several exotic breeds (Table 3.5).

Khaila cattle: They attain sexual maturity at about 4 years and produce the first progeny at an age of 5 years (Table 3.5). This figure is quite high when compared with European cattle (Jersey and Holstein-Friesian) which attain sexual maturity at about 1.5 to 2 years. Gestation length is about 9 months (288 days) which is well within the range of cattle breeds. Male calves are castrated for use as draught animals from 2.5 to 15 years of age.

Siri cattle: They attain sexual maturity at about 3.5 years and produce the first progeny at an age of 4 to 4.25 years (Table 3.5). This figure is quite high when compared with European cattle (Jersey and Holstein-Friesian) which attain sexual maturity at about 1.5 to 2 years (Table 3.8). Gestation length is about 295 days.

Pahadi cattle: They attain sexual maturity at about 4 years and produce the first progeny at an age of 5 years (Table 3.5). This figure is quite high when compared with European cattle (Jersey and Holstein-Friesian) which attain sexual maturity at about 1.5 to 2 years (Table 3.8). Gestation length is about 9 months (275 days).

Terai cattle: They attain sexual maturity at about 3.5 years and produce the first progeny at an age of 4 to 4.5 years (Table 3.5). This figure is quite high when compared with European cattle (Jersey and Holstein-Friesian) which attain sexual maturity at about 1.5 to 2 years. Gestation length is 296 days.

Yak: They attain sexual maturity at about 4 years and produce the first progeny at an age of 4.5 to 5 years (Table 3.5). This figure is quite high when compared with European cattle (Jersey and Holstein-Friesian) which attain sexual maturity at about 1.5 to 2 years. Gestation length is about 9 months (252 days) which is similar with several literature reports (Neopane et al., 1998). Generally, Nak (female yak) is not milked for the first two months after calving in order to make her calf healthy. Average milk production is 220 kg in the lactation of 167 days with 6.6 % fat as reported by Sherchand and Karki (1997).

2.6 Future prospects

The identified indigenous cattle breeds are considered to be low productive. This may be true when we compare them with developed countries standard and consider only limited traits rather single trait. For example, cattle are kept in the developed countries only for milk or meat. In developing countries like ours, cattle are kept for milk, manure, draught and many others. The indigenous breeds although produce low milk but they have several other positive attributes such hardiness, good for low input system, multipurpose uses and others. Even for milk production, there exists wide variation within a breed. For example, the indigenous cattle breeds produce milk less than 2 kg in a day in an average, but it ranges from 1 to 4 kg. This revealed that there is an ample scope for increasing milk yield in the indigenous cattle. This can be done through selection within a breed. Using a simple selection programme, the productivity of indigenous cattle can be increased to a great extent.

Indigenous cattle exhibited high genetic potential even when they are kept under optimum management condition. In order words, when provided proper nutrition, health care and husbandry practices, indigenous cattle also give competitive performance with crossbreds. Siri cattle which was reported as the highest milk yielders among the indigenous cattle gave maximum of around nine litres per day; similarly Lulu cattle yielded maximum of around six litres per day in research farm. The package of practices for indigenous cattle need to developed and disseminate in their home-tract.

Indigenous breeds have demonstrated their capacity to produce in low external input system where the exotics can't cope with. For example, Yak, Nak and Chauries utilise alpine pasture and play an important role for rural livelihood in the mountains of Nepal. They can easily move in mountainous terraces and pasture lands where exotic cannot. Religious, cultural and aesthetic values of indigenous cattle are additional attributes for their preservation and national heritage. There should be certain special programmes for comprehensive identification of indigenous breeds/strains through standard formats and community breed registration.

The role of native cattle breeds to the draught power has been significant. Draught animals are the major source of power for agricultural operations. Cattle are the major draught animals that are used extensively for agricultural operations. Yak, Nak and Chauries are used as pack animals but these are also used for draught in high hills and mountains. Yak, Nak and Chauries are important sources of transportation at high altitudes where alternative source of transportation is lacking. Yak and Nak can survive at high altitudes and remain important sources of transportation. Chauries which is a cross between yak and native cattle or Nak and native cattle bull can go down to mid-hills and play important role for transportation.

Yak cheese is a source of foreign exchange in the country. Nepalese Yak cheese is famous all over the world for its taste, flavour and hardiness. Yak cheese appears to be an important commodity that has comparative advantages for the country. Yak and Nak also are reputed for their Churpi/Dhurka production. Besides that, these animals are providing a substantial amount of manure that is being used for increasing/maintaining soil fertility. Use of chemical fertilizers is not very common in hills and mountains. Animals' manure has an important contribution to this aspect. Apart from these, the cattle is an important source of providing animal protein in the diet of hilly and mountain people.

Indigenous cattle, Achhami bull is used for cryopreservation. The Division has its own gene bank where the semen of Achhami and some exotic breeds; Jersey and Holstein-Friesian breeds are cryo-preserved both for enhancing the productivity of indigenous animals, and for the conservation. It has developed a programme of producing semen of other existing endangered and rare indigenous cattle of the country and its conservation. In long run the Division should develop its own semen production technology justifiable to the nation's need.

A plan for establishment of Eco-farm Park for the conservation and improvement of indigenous rare and endangered livestock species was made in the F/Y 2000/01. Proposed location for eco-farm park was Regional Agricultural Research Station (RARS), Lumle. Collaborators were Rare Breed International (RBI), Department of Livestock Services (DLS), Nepal Agricultural Research Council (NARC) and Institute of Agriculture and Animal Sciences (IAAS). The programme could not be continued as policy for conservation is not in the priority thus faced financial constraints. However, a concept of Eco-Farm Park is sensible and strongly justifiable for the conservation and utilisation of native animal genetic resources (AnGR).

Achhami cattle, which are the smallest cattle breed in the world having less than one meter height at girth are very suitable for low input system. They can be developed as a suitable and standard breed for low input system not only for Nepal but also for entire world where low input system prevails. Similarly, Lulu cattle, which are cool, dry tolerant and hardy breed, are excellent breed for the hills of Nepal, particularly for Mustang areas. They can be established as a good breed for cool and dry climate with improving their milk production through selection.

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4. INDIGENOUS SHEEP BREEDS OF NEPAL

Bhyanglung sheep

Baruwal sheep

Kage sheep

Lampuchhre sheep

Lampuchhre sheep flock in Kapilvastu district

Bhyanglung sheep flock in Mustang district

Baruwal sheep flock at DoAR, Lumle

Baruwal sheep flock at SGRP, Jumla

4. INDIGENOUS SHEEP BREEDS OF NEPAL

4.1 Zoological Classification of sheep

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Artiodactyla
Family	Bovidae
Sub-family	Caprinae
Genus	*Ovis*
Species	*aries*

4.2 Overview of sheep

Nepal, lying between India and China, can be broadly divided into three geographic regions, the Himalayan region, the lower mountain or hill region and the terai region (Joshi and Khatiwada 1986). Sheep are an important livestock commodity in the country, particularly for the hills and mountains. Sheep are an important livestock commodity in the country, particularly for the hills and mountains. There are 806,079 heads sheep in the country (MOAD, 2020). Around five to ten percent of this is exotic (pure or crossbred) and rest is indigenous suggesting more contributions comes from indigenous breeds (Neopane and Gorkhali 2008). They are mainly kept for wool, meat, manure and draught (particularly in the hills and mountains). Apart from these they have several other uses such as hides, bones and hairs. They have cultural and social values as well in the country. About 3 % of the household (3.4 %) keep sheep in the country. The primary function of keeping sheep is wool production. Their wool are used for making *radi/pakhi*. To make wool finer, several exotic breeds (Polwarth, Merino, Border Leicester, Rambouillet, Coop-worth and Romney Marsh were introduced in the country and used for crossbreeding with indigenous breeds. Most of the crossbreeding took place between exotic with Baruwal breed. Crossbreeding was successful in increasing wool production for crossbreds; however, there was problem of using crossbred wool (carding and spinning). Hence crossbreeding could not sustain for longer.

4.3 Origin of Nepalese sheep

Identifying the wild progenitors of domesticates is important to understand its domestication process. It was once believed that Urial (*O. vignei*) was domesticated first, since Urial remains have been found around the area where domestication appeared to have begun (Ryder 1984). Urial (*O. vignei*) is thought to have arrived in Europe first, followed by Mouflon (*O. musimon*) with which it has been mixed (Ryder 1983). It is also believed that Urial (*O. vignei*) gave rise to the “wool” sheep and the “hair” sheep originated from Mouflon (*O. musimon*) (Zeuner 1963). However, chromosomal (Ryder 1984) and mitochondrial phylogenetic studies (Heindleler et al., 2002) demonstrate no evidence of Urial ancestry. The most generally accepted hypothesis states that *O. aries* is descended sub-species of mouflons such as Asiatic and European mouflons which are an ancient breed of domestic sheep that turned feral rather than to be an ancestor. The exact line of descent between domestic sheep and their wild ancestors is still unclear (Heindleder et al., 2002). Based on chromosome counts and blood protein analysis, some researchers believe that only a single wild species could have contributed to the gene pool of present day domestic sheep (Schmidtt and Ulbright 1968; Ryder 1984). This hypothesis, however, could not be realistic as further molecular studies comparing European and Asian breeds of sheep showed significant genetic differences. Two explanations for this phenomenon have been posited. The first explanation is that a currently unknown species or subspecies of wild sheep contributed to the formation of these breed of domestic sheep (Heindleder et al., 2007). The second explanation is that this variation is the result of multiple waves of capture from wild mouflon, similar to the known development of other livestock. Thus both theories points to multiple ancestral contributions for the origin of the modern Asian sheep (Meadows et al., 2007). There are some examples or possibilities where the wild progenitor for the modern Asian sheep is either largely or entirely extinct. Various genetic markers have been applied to reconstruct animal phylogenies which has been key to charting the ancestry of domesticates.

There are still six species of wild sheep (Fig. 1) in existence, which could have given origin to our domestic breeds (Ryder 1983, 1984). The most important of these are Argali (*O. ammon*), Urial (*O. vignei*), Mouflon (*O. musimon*) and Bighorn (*O. canadensis*). All domestic breeds of sheep are thought to have descended from the Mouflon (*O. musimon*), although the Urial (*O. vignei*) might have contributed to European breeds.

Figure 4.1 (a) Mouflon, (b) Urial, (c) Argali, (d) Bighorn, (e) Dall/ Stone sheep, and (f) Snow sheep

4.4 Indigenous sheep breeds of Nepal

Four indigenous breeds of sheep in the country have been identified and characterized so far. They are Lampuchhre, Kage, Baruwal and Bhyanglung (Shrestha, 1995; Shrestha, 1996).

4.4.1 Demographic distribution of indigenous sheep breed

Out of the total estimated sheep population, 4% are Bhyanglung, 63% are Baruwal, 21% Kage and 12% Lampuchhre. About 84% of the sheep are concentrated in the hills and the remainder in the Terai (Shrestha et al., 2000).

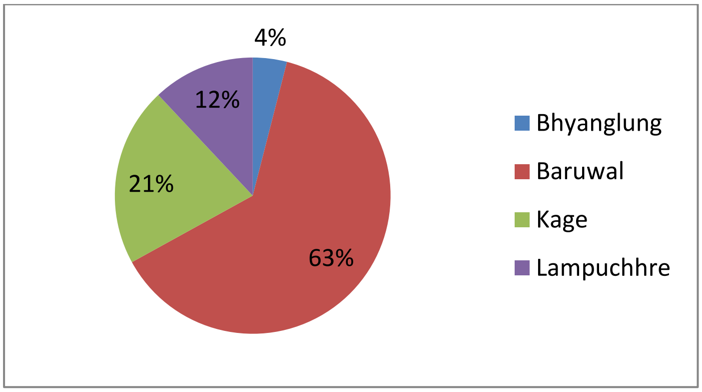

Figure 4.2 Population of different sheep breeds of Nepal (%)

Lampuchhre sheep (*Capra ovis*)

Lampuchhre sheep are found in terai region (tropical and subtropical climate) of the country and good for meat and fighting. They represent 12% of the total sheep population (Shrestha et al., 2000). Their population is declining and hence need attention. They are found in nomadic condition. They have been characterized at phenotypic level (Annual Report, ABD, 2003).

Kage sheep (*Capra ovis*)

Kage that is located in low hills and valleys represents 21% of the total sheep population (Shrestha et al., 2000). They are the smallest sheep breed in the country. They are suitable for coarse wool and are found in low to mid hills (subtropical) and are mainly used for wool. They produce coarse wool, which is suitable for making *radi/pakhi* (blankets). Their population is declining and hence the breed needs attention for conservation. They have been characterized at phenotypic and chromosomal level.

Baruwal sheep (*Capra ovis*)

Baruwal sheep are the principal sheep breed in the country and are located in hilly region of the country. They represent 63% of the total sheep population in the country and are mainly concentrated in the mountains (41%) and hills (22%) (Upreti and Pradhan, 1998). Their wool is suitable for making *radi/pakhi* (blankets), pullovers and shawls. They are normal and are not at risk for conservation. They have good grazing instinct and suitable for migratory system. They have been characterized at phenotypic and chromosomal level.

Bhyanglung sheep (*Capra ovis*)

Bhyanglung sheep are located in high mountains and Trans-himalayan region above 2500 meter above sea level. They are located in high hills and mountains under transhumance system. They represent 4% of the total sheep population in the country (Shrestha et al., 2000). They are the only indigenous sheep breed that can produce wool suitable for carpet. They have been reared in situ condition by farmers themselves. Their population is declining and needs attention for conservation. They have been characterized at phenotypic and chromosomal level.

4.4.2 Status of the breed

Sheep are an important livestock commodity in the country, particularly for the hills and mountains. About 3.4 % of the households keep sheep and there were 809536 sheep in the country (http://faostat.fao.org 2014) with the annual growth of -0.25 percent per annum since last two decades. Fig. 4.3 illustrates clearly the drop of the population of sheep steeply after 1994; it might be because of the youths are more attracted to more lucrative occupation and are not wanting to spend the gruesome life of shepherd. Lampuchhre sheep is at risk and need attention for their conservation and utilization. Baruwal is normal and other two breed's population is declining.

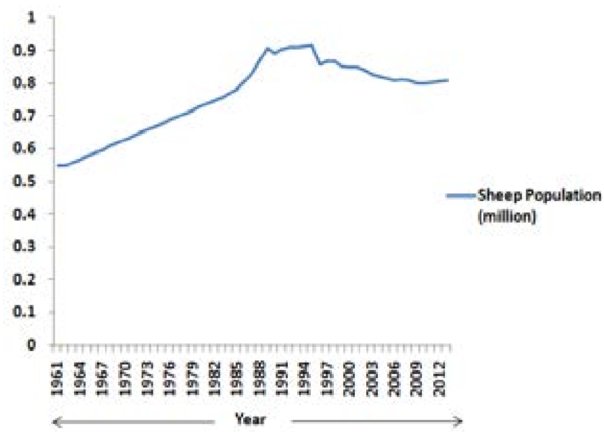

Figure 4.3 Trend of sheep population of Nepal in last 52 years (1961-2013)

4.4.3 Positive Attributes

In general, indigenous breeds are low producing than the exotics in terms of meat and wool production. However, they have several other positive attributes such as hardiness, adaptability to local harsh conditions and can produce in low input system. It is observed that these positive attributes are not duly recognized rather exotics breeds are unnecessarily given preference over them.

4.4.4 Socio-cultural significance

These indigenous sheep are high valued for meat, wool, manure and draught (particularly in the hills and mountains). Apart from these, they have several other uses such as hides, bones and hair. They also have cultural and social values in the country.

2.4.5 Characterization of indigenous sheep breeds

All these breeds are characterized in phenotypic and production level. Some work has been done on genetic diversity on the basis of blood protein polymorphism and non-protein typing (Tsunoda et al., 1989) and chromosomal study (Dohge et al., 1989). All four breeds have been characterized in molecular level (Gorkhali et al 2014; 2015; 2016).

4.4.5.1 Phenotypic characterization of indigenous sheep

4.4.5.1.1 Physical Characteristics of indigenous sheep

Lampuchhre sheep

- Ewes are polled while the ram possesses curved horn of 31 cm.
- The breed has 12 cm short ear.
- Lampuchhre is a hardy long-tailed breed. Tail length is 34 cm.

- Its body colour is mostly white with the variation in head colour from white, brown and black. They were mostly black and white in fleece colour (45%) followed by pure white (30%) and other mixed colour (25%) (Shrestha *et al.*, 1998).
- Its average body weight is 30 kg.

Kage sheep

- Kage is a short-tailed sheep.
- Kage is the smallest among the indigenous sheep breeds with better prolificacy (18% twinning).
- Males had sickle shaped horns while females were mostly polled.
- Its coat colour is white in the body except on head region. Head is mostly brown.
- Average body weight of ewes is 22 kg. Male weighs around 32 kg.

Baruwal Sheep

- Baruwal has the smallest ear among the Nepalese breeds. It has vestigial ears of 7cm length (3 to 5 cm, Wilson 1997).
- Its body colour is mostly white with variation in head colour from white or black. The fleece colour of Baruwal sheep were mostly white (82%) followed by brown (10%), black and white (5%) and pure black (3%).
- Ewes are mostly polled but rams have 51 cm curved horns.
- Tail length is 13 cm on average.
- The fleece also covering the head and upper part of legs, has much kemp, lacks crimp, grease and luster, and is somewhat shaggy.
- The average body weights is 35 kg (Males 30 to 35 kg, occasionally 45kg and females 25 to 30 kg).

Bhyanglung Sheep

- Both sexes carry wide-spreading spiral horns and some males have multiple horns (Wilson 1997). Bhyanglung has significantly varied horn length depending on the location ranging from 19 cm in Solukhumbu to 35 cm in Mustang district.
- Its body colour is mostly white with variable head colour from white, brown and black.
- Its average ear length is 11 cm.
- Average tail length is 13 cm.
- Average body weight is 26 kg.

4.4.5.1.2 Morphological measurement of indigenous sheep

Lampuchhre Its average body weight is around 30 kg having the body length of 63 cm and heart girth of 71 cm. Wither height averages 61 cm.

Kage Average body weight of ewes is 22 kg. Male weighs around 32 kg. Body length measures 62 cm and the heart girth is 65 cm. Wither height averages 60 cm.

Baruwal Average body weight ranges from 30-45 kg. Body length measures 70±0.54 cm and the heart girth is 76±0.56 cm. Wither height averages 65±0.55 cm.

Bhyanglung Average body weight of 26 (25-30) kg. Body length measures 65±0.54 cm and the heart girth is 76±0.46 cm. Wither height averages 60±0.54 cm.

Table 4.1 Body parts measurements of indigenous sheep (means ± standard errors in cms)

Parameters	Lampuchhre	Kage	Baruwal	Bhyanglung
Body length	63±0.45	62±0.52	70±0.54	65±0.54
Heart girth	71±0.45	65±0.52	76±0.56	76±0.46
Height at wither	61±0.35	60±0.52	65±0.55	60±0.54
Height at hip bone	62-66	55-56	66-68	66-69
Head length	20	16.5±2.67	19.5±1.5	18.1±2.01
Tail length	34±0.65	11.8±1.8	12.9±1.3	12.7±1.26
Horn length	M: 31.8±2.8 F: Polled	M: 25-35 F: Polled	Ewe generally polled M:51.0±1.7 F:17.0±0.9	M: 38.5±1.9 F: 33.5±1.0
Ear length	12±0.60	10.1±1.13	7.2±1.14	10.9±1.15
Neck length	24	18-20	22	24-27
Loin girth	*67*	76.8±7.08	78.8±4.91	76.4±4.2
Barrel girth	34	21	32	34
Fore legs above knee	29.3±1.2	27.2±5.0	25.7±2.4	22.7±2.2
Fore legs below knee	28.7±1.3	26.0±3.5	24.7±2.2	21.8±2.0
Rear legs above knee	25.0±1.8	19.4±4.02	27.1±2.9	23.4±1.9
Rear legs below knee	23.0±1.3	22.0±2.11	24.4±2.09	24.1±0.8
Adult body weight(kg)	30.3 (20-40)	F:22; M:32	35 (30-45)	26 (25-30)

Sources: Annual Report, ABD (1997); Upreti and Pradhan (1998); Shrestha et al. (2000); Neopane (2006)

4.4.5.2 Characterization on chromosomal level

Except of Lampuchhre breed, the karyotype was examined in identified sheep (Kage, Baruwal and Bhyaglung) of Nepal (Dohge et al., 1989). The karyotypes of all three breeds are the same (Fig. 4.4). The number of chromosomes was 2n = 54, with 3 metacentric pairs and 23 acrocentric pairs. The X chromosome was acrocentric (maximum) and the Y chromosome was metacentric (minimum). The number of fundamentals (NF) is 58.

Table 4.2 Karyotype and number of chromosomes in the Nepalese indigenous sheep

Breeds	No. of chromosomes	No. of fundamentals (NF)	Karyotype composition			
			Autosomes		Sex chromosomes	
			M	A	X	Y
Bhyanglung	54	58	6	46	LA	mM
Baruwal	54	58	6	46	LA	mM
Kage	54	58	6	46	LA	mM

M: metacentric, A: acrocentric, LA: large acrocentric, mM: metacentric

Figure 4.4 Karyotype of male Kage sheep (Dohge et al., 1989)

4.4.5.3 Molecular Characterization

The origin, genetic diversity, relationship and differentiation of the Nepalese sheep populations were unraveled by comparing with sheep from Asia using mtDNA control region and SRY 5' promoter region and SRYM18 microsatellite marker of Y-chromosome.

Analyses of mitochondrial DNA (mtDNA) and nuclear genome revealed high diversity among these breeds. The mtDNA analyses showed that all haplotypes in these breeds belonged to three haplogroups (A to C). Among the four breeds, three residing in mid to high hills, had all three haplogroups while Lampuchhre sheep from lowlands carried only haplogroups A and B. This study revealed southwestern route of gene flow in sheep probably originating from China to India via Nepal. In addition, we provide evidences that the genetic diversity and structure in mtDNA genome among Nepalese sheep were shaped not only by the extensive gene flow to the high-altitude sheep (specifically Bhyanglung) from China but also by the continuous exchanges between sheep found in mid hills and lowlands in Nepal and India. This phenomenon can be explained by considering occurrence of gene flow through ancient trading route as well as the current movement of sheep from/to the geographic vicinities in India and China.

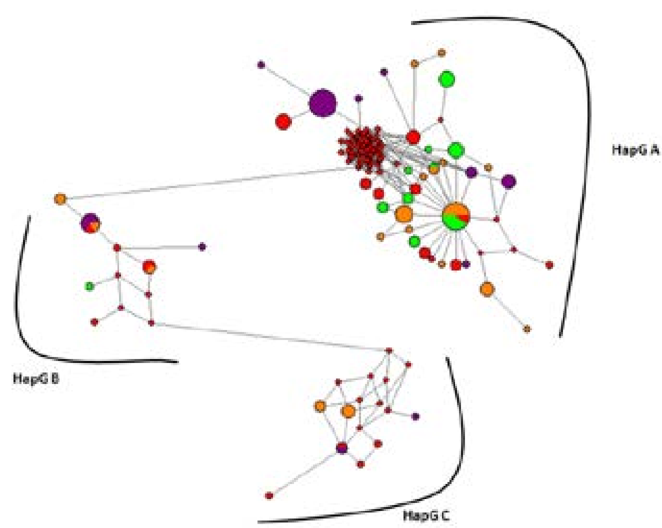

Figure 4.5 The median-joining network of 50 haplotypes in Nepalese sheep

Very few studies have been done to separate out the male-specific contribution specifically during breed development in domestic animals, specifically in the Asian region. The ancestral origin and genetic diversity was investigated in four Nepalese sheep populations along with wild sheep, Argali (*O. ammon byth*) sampled in the northwestern China using Y-chromosome microsatellites and SNPs variation in SRY 5' promoter gene. In the study, most of the Nepalese sheep breeds exhibited paternally monomorphic except Kage breed which exhibits three allelic variants (141 bp, 143 bp and 147 bp) in SRYM18 microsatellite region. The novel haplotype HY-20 (A-*oY1*/147-SRYM18) was identified in Nepalese sheep for the first time in domestic sheep (Table 4.3). More than 90% of Nepalese sheep shared the haplotype which corresponds with defined haplotype HY-6. This haplotype includes mouflons and high percentage of domestic sheep. Argali, wild species found in northwestern China and also in Nepal, showed the paternal monomorphism. Nepalese sheep and Argali (speculated ancestor population) clustered separately revealed that there is no introgression from any of the extant wild populations to today's sheep population. Low polymorphism in Y-chromosome in Nepalese male sheep might be due to an exaggerated reduction in male effective population size; however, the reason for monomorphism in case of Argali is not clear. In order to draw any rigid conclusion, further research including more sample size in domestic and wild sheep with inclusion of different Y-chromosome markers is warranted.

Table 4.3 Haplotypes generated through the combination of a compound microsatellite and six SNPs in Nepalese sheep

Haplotype	SRYM18				SRY SNPs						Species
	[TTTTG]m	Indel(G/-)	[TG]n	Allele (bp)	***oY1*** 88 nt	***oY5*** 157 nt	***oY6*** 393 nt	***oY7*** 397 nt	***oY8*** 399 nt	***oY9*** 460 nt	
HY_1	4	–	14	145	A	T	A	G	T		*Ovis dalli*
HY_2	4	–	13	143	A	T	A	G	T		*Ovis dalli/Ovis canadensis*
HY_3	4	–	11	139	A	T	A	G	T		*Ovis dalli/Ovis canadensis*
H Y_4	3	G	16	145	A	C	G	G	A	G	*Ovis aries*
H Y_5	3	G	16	145	G	C	G	G	A	G	*Ovis aries*
*H Y_6	3	G	15	143	A	C	G	G	A	G	*Ovis aries/ Ovis musimon/* Nepalese sheep
H Y_7	3	G	15	143	G	C	G	G	A	G	*Ovis aries*
*H Y_8	3	G	14	141	A	C	G	G	A	G	*Ovis aries/* Nepalese sheep (*Kage*)
H Y_9	3	G	9	131	A	C	G	G	A		*Ovis aries*
H Y_10	NA	NA	NA	110	A	C	G	G	A		*Ovis aries*
H Y_11	NA	NA	NA	106	A	T	A	G	A		*Ammontragus lervia*
H Y_12	3	G	13	139	A	C	G	G	A	G	*Ovis aries*
H Y_13	3	G	14	149	A	C	A	T	G		*Ovis vignei*
H Y_14	3	G	17	147	A	C	A	T	G		*Ovis vignei*
H Y_15	3	G	20	153	A	C	G	G	G		*Ovis ammon*
H Y_16	3	G	17	147	A	C	G	G	G		*Ovis ammon*
H Y_17	3	G	15	143	A	C	G	G	G		*Ovis ammon*
**H Y_18				135	A					G	*Ovis aries*
H Y_19	3	G	15	143	A	C	G	G	A	T	*Ovis aries*
*HY_20‡	3	G	17	147	A	C	G	G	A	G	Nepalese sheep (*Kage*)
‡‡Ha	3	G	12	137	A						*Ovis aries*
‡‡Hb	3	G	14	141	G						*Ovis aries*

*The haplotypes are composed of Y-specific microsatellite and SNP markers within the ovine sex-determining gene SRY (‡haplotypes identified in this study and * are Nepalese sheep) ‡‡Wang et al., 2015 **Ferencakovic et al., 2012; Source: (Meadows and Kijas 2009)*

In addition, we extended our objectives by using genome-wide SNPs markers (Illumina SNP50K *ovine* Beadchip) to: (*i*) investigate the phylogenic relationship between these four Nepalese sheep and previously studied sheep to estimate the origin of the Nepalese sheep; (*ii*) compare the population genomic structure of the high-altitude sheep with those of lowland sheep to identify molecular mechanism underlying the high-altitude adaptation in these breeds; and (*iii*) identify if high-altitude adaptation-related genes occurred among different sheep breeds and to determine if adaptation had a single or multiple origins.

Population structure analyses from our study also revealed that one highland breed (Bhyanglung) has similar genetic background as the Tibetan sheep, while another highland breed (Baruwal) shows a distinctly different population structure. The two lowland breeds (Kage and Lampuchhre) were found to be mixe with the highland sheep and Indian lowland breeds (Figure 4.6).

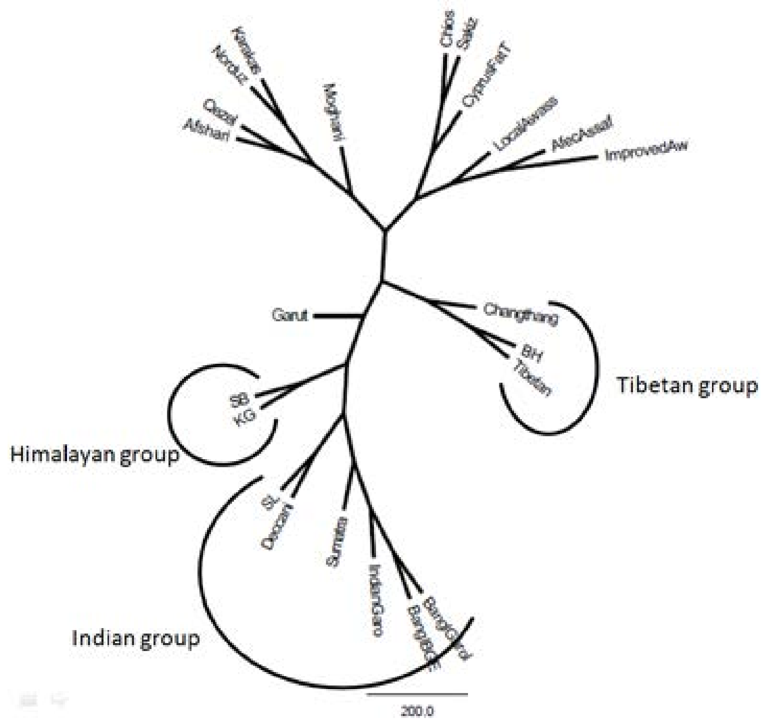

Figure 4.6 Phylogenetic neighbor-joining tree showing the effect of SNP ascertainments on breed relationship using Nei's distance (D)

(Source: Gorkhali et al., 2016)

To understand the genetic basis of adaptation to high altitude in farm animals, by comparing the breeds from different altitudes, strong signals of population differentiation at the four loci of hypoxia-related genes was revealed. Out of these, *FGF-7* is the most promising one with epithelium specific expression and an important role in early lung organogenesis and the morphogenesis of epithelium. Furthermore, one novel upstream regulatory novel mutation specific to the high-altitude sheep was identified. The genome-wide distribution of *di* value for the four highland breeds are shown in Figure 4.7. The genome-wide distribution of *di* of 45,267 SNPs revealed that the highest selection signal was detected on chromosome 7 (Fig. 4.7).

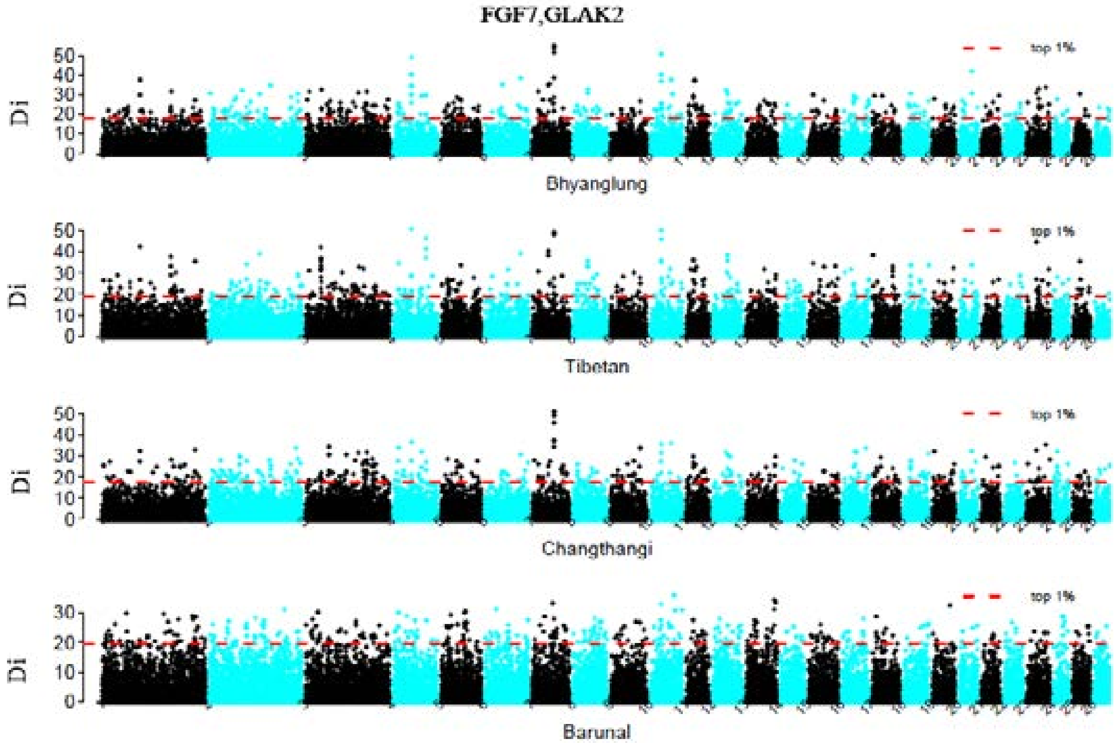

Figure 4.7 Distribution of di values in different breed comparisons (positive selection analysis on high altitude adaptation) (Source: Gorkhali et al., 2016)

When compared the allele frequencies at the four interesting SNPs in the high-altitude sheep breeds with those from different continents across the species range (Fig. 4.8), the SNP OAR7_63692612.1 and OAR7_63745942.1 showed clear allelic imbalance between high-altitude and other sheep breeds, providing further evidence that the two SNPs were targeted by high-altitude.

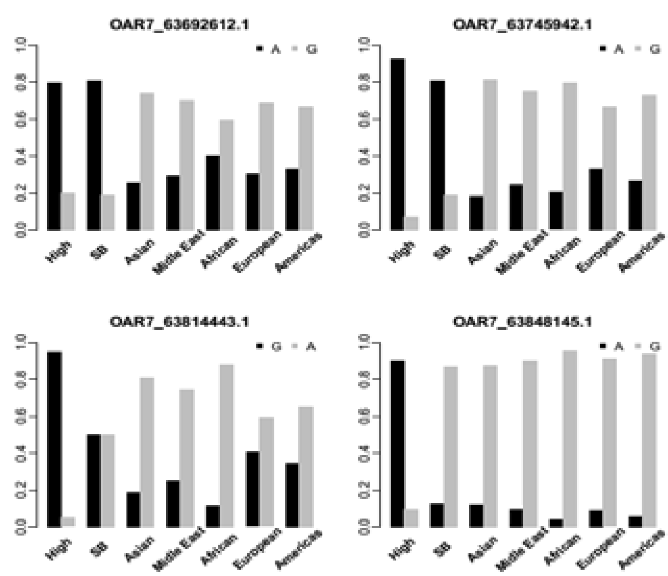

Figure 4.8 Comparison of the allele frequencies at the four interesting SNPs in the high-altitude sheep breeds with the sheep of different continents (Source: Gorkhali et al., 2016)

4.4.5.4 Biochemical studies

The polymorphic analysis of sheep populations from East and South east Asian regions showed Baruwal and Kage, which were speculated to be the native for Nepal clustered together with Bangladesh which again was hypothesized to be originally from Indian sheep (Figure 4.9) (Tsunoda et al., 2004) whereas Bhyanglung which is originally from Tibet (Tsunoda et al., 1989) and Lampuchhre (Lohia) assumed to be derived from the Lohi of the Punjab in Pakistan (Epstein 1977; Ryder 1983). In addition, Sun et al. (2010) has demonstrated two definite groups as South-South East Asia sheep and Mongolia-Tibetan sheep group. Nepalese sheep breeds inhabited in the Mid-Southern Nepal (Lampuchhre and Kage) lie in South-South East Asia sheep whereas sheep from Northern region (Baruwal and Bhyanglung) is grouped with Yunnan sheep. As the blood line of Yunnan sheep was influenced by Tibetan sheep and also share the same pasture land, Baruwal and Bhyanglung could be influenced by Tibetan sheep. Among the Nepalese breeds, Baruwal is the probable native breed that has high purity as it showed lower heterozygosity values (Fig. 4.10) (Tsunoda et al., 1989).

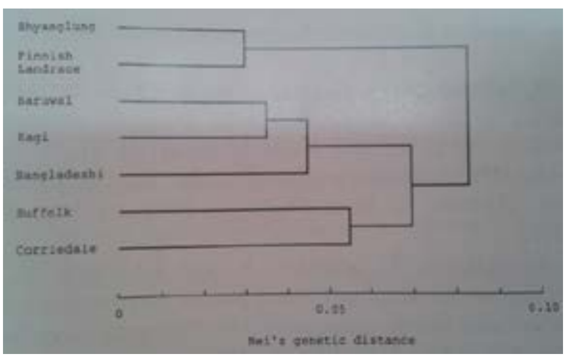

Figure 4.9 Dendogram drawn from the Nei's genetic distance matrix in native Nepalese sheep, Bangladesh and European sheep

Breed	P_{poly}±S.E.	$\bar{H}$±S.E.
Baruwal	10/20=0.5000±0.1118	0.0961±0.0333
Kagi	11/20=0.5500±0.1112	0.1676±0.0420
Bhyanglung	11/20=0.5500±0.1112	0.1752±0.0494
Bangladeshi	15/20=0.7500±0.0968	0.2168±0.0446
Suffolk	13/20=0.6500±0.1067	0.1786±0.0488
Corriedale	11/20=0.5500±0.1112	0.1289±0.0453
Finnish Landrace	11/20=0.5500±0.1112	0.1630±0.0444

Figure 4.10 Genetic variability of native Nepalese sheep and other sheep breeds

Source: Tsunoda et al., 1989

4.5 Production performance of indigenous sheep

Lampuchhre sheep

The average body weight is 30 kg. The average body length is 63 cm and average heart girth is 71 cm. These are leggy animals, males being 60-70 cm and females' 55-60 cm at the withers. Wither height averages 61 cm (Table 4.1). They produce coarse wool ranging from 0.25 to 0.5 kg in a year. Their wool is used for making *radi*, rough mats. Three times a year shearing is carried out. Fibre diameter is 25 to 50µm with a staple length of 7 to 10 cm. They attain sexual maturity at the age of one year and produce the first progeny at the age of 1.5 years. Lambing interval ranges from 8 to 12 months. Since having a free border with India, much interchange can be observed with similar sheep of India (Wilson 1997).

Kage sheep

Kage is kept by its traditional owners mainly for meat as it only has demand during festivals. The average body weight for ram and ewes are 32 kg and 22 kg, respectively. They produce wool that can be used to produce medium quality covers and shawls. Twice shearing a year, they produce 300 to 500 g of an annual fleece yield with fibre diameter of 25-50µm (Shrestha et al., 2000) with average staple length of 6-8 cm (Wilson, 1997). They attain sexual maturity at the age of one year and produce the first progeny at the age of 1.5 years. Lambing interval ranges from 8 to 14 months. This breed has better prolificacy (18% twinning) in comparison to others. Breeding takes place all year round but most lambing is in October-January, with few in the summer and rainy seasons. The average lambing interval on government farm (Lampatan Livestock Farm, Pokhara) where breeding is allowed all year is about 10 months. Very few ewes produce twins.

Table 4.4 Body weights of indigenous breeds of sheep at different ages (kg)

Parameters	**Lampuchhre**	**Kage**	**Baruwal**	**Bhyanglung**
Birth wt	1.8	1.5	2.4	2.2
Weaning wt (4 month)	7.5	6.9	8.1	7.4
6 month wt	9.5	8.8	10.1	9.0
9 month wt	13.1	12.2	13.7	12.2
12 month wt	16.7	15.6	17.3	15.4
2 year wt	32 (30-35)	25 (20-30)	35 (30-40)	30

Source: Annual Report, ABD (1997); Shrestha et al. (2000); Shrestha (2006)

Baruwal sheep

The average body weights is 35 kg (Males 30 to 35 kg, occasionally 45kg and females 25 to 30 kg), with average body length, heart girth and wither height of 70 cm,76 cm and 65 cm, respectively. They have coarse wool suitable for making *Radi/Pakhi*. They are generally sheared twice a year, once in spring and once in autumn, with an average wool yield of 900 to 1200 g annually and 46.3 µm fibre diameter (Shrestha et al., 2000) with a staple length of about 6 cm. They attain sexual maturity at the age of 1.5 years and produce the first progeny at the age of 2 years. Lambing interval ranges from 6 to 12 months. Baruwal sheep breeds throughout the year but most conceptions take place in April to October and fertility is generally high. Ewes that give twins are generally culled as survival of both labs is jeopardized. Ewes whose lambs die are milked but provide only very small amounts which is consumed or converted to ghee. Males are castrated and used as pack animal. Normally large flocks of 200 to 500 heads are night-herded on crop land to provide manure.

Table 4.5 Production characteristics of indigenous breeds of sheep

Parameters	**Lampuchre**	**Kage**	**Baruwal**	**Bhyaglung**
Lambing (%)	115.0	119.0	68.9	61.5
Lambing frequency (per annum)	1-2	1-2	1	1
Adult mortality (%)	15.0-20.0	15.0-20.0	25.6	35.5
Lamb mortality (%).	20.0-30.0	20.0-30.0	25.0-40.0	30.0-50.0
Wool production (kg)	0.3-0.5	0.32	0.9-1.2	0.8-1.0
Staple length (cm)	8.5	8-9	8.5-11	11-16
Fiber diameter (µm)	36-77.2	28-47	30	25-28
Kemp fiber	52.3-67.9	20-81	68	12-13
Wool use	Rough mats.	Medium quality covers and shawls	Radi (felt), Rough covers	Carpets Rough garments

Source: Annual Report, ABD (1997); Upreti and Pradhan (1998); Shrestha et al. (2000)

Bhyanglung sheep

Bhyanglung are sheared once a year and wool yield varies from 0.8 to 1.1 kg with a fibre diameter of 26.65µm. Heterotype hairs are medullated during the summer and non-medullated in winter (Epstein 1977). Average body weight is 26 kg with average body length of 65 cm, heart girth of 76 cm and withers height of 60 cm. They attain sexual maturity at the age of 1.5 years and produce the first progeny at the age of 2 years. Lambing interval is around a year. Bhyanglung only breeds in September/ October. The twinning percentage is extremely low. In addition to producing wool and meat, the breed is used as a pack animal in its home tract.

Table 4.6 Reproductive performances of indigenous breeds of sheep

Parameters	Lampuchhre	Kage	Baruwal	Bhyanglung
Age at 1st service (months)	12-16	12-16	18-30	18-30
Age at 1st lambing (months)	18	18	24	24
Lambing intervals (days	240-400	240-450	180-.365	210-300
Litter size at birth (no)	1.0	1.0	1.0	1.0
Litter wt at birth (kg)	1.6-2.0	1.4-1.8	1.8-2.6	1.7-2.5
Gestation length (days)	145-150	145-150	145-150	145-150

Source: Annual Report, ABD (1997); Neopane (2004)

4.6 Future prospects

Sheep serve as important genetic resources for sustainable development of animal production and preservation of biological diversity. Recently, the population of sheep is declining steadily due to various causes such as the alternate opportunities to the young people, blocking of free movement for livestock across the borders by the neighboring countries. Since population is getting smaller, the inbreeding rate has obviously been intensified. Moreover, a high level of inbreeding together with a reduced gene flow may lead to genetic fragility of population that is unfit to environmental changes (Bijlsma et al., 1997). Very limited work has been done in these breeds to measure the current status of genetic diversity and inbreeding in the breeding populations. This lack of information could be a barrier for future sustainable sheep industry development in Nepal, since further improvements rely on significant and sustained yield increments which depend on additive genetic merit of selected breeding stock. Moreover, losses of genetic diversity endanger the genetic selection potential of maintaining and improving yield traits. To minimize potential risk of genetic diversity losses, it is necessary to know the current genetic variability and its distribution among breeds, and to identify low frequency alleles which are indicative of unique genetic variants (Aranguren-Méndez et al., 2001).

Nepal Government has shown the immense concern on the abrupt reduction of nation's important asset of sheep genetic resources. The Government has given directives to emphasize the research and development activities in conservation and multiplication of the population of these breeds. Inadequate attempts, however, is being undertaken by the Government of Nepal by supporting local famers to conserve and to avoid further losses of genetic diversity and also developed some breeding schemes to maximize gene purity. Nonetheless, with an objective to attracting the local youths with better income generation opportunities, many research have been done to improve the wool quality of the most predominant indigenous sheep breeds: Baruwal and Kage through crossing with wool breeds of sheep such as Romney Marsh, Border Leicester, Merino, Polworth, Rambouillet and several investigations has been conducted on adaptation of these crossbreds under migratory system (Karki 1985; Karki and Dhaubhadel 1991; Rasali 1995; Amatya et al., 2006). However, these attempts were mere failure due to various reasons such as the strategies were developed were not client-driven and also without having depth knowledge or understanding the genetic makeover of the indigenous breeds which were well-adapted in the existing environment from generations. A deeper knowledge on genetic diversity is prerequisite for conservation decisions on maintenance and/or improvement. Thus the recent study has documented the information on phylogeny and population diversity within and between Nepalese indigenous breeds taking into account three different directions, viz. mtDNA, Y-chromosome DNA and nuclear DNA, and further undergone meta-analysis with GenBank dataset of different sheep of the region. It has shown the genetic structure and high levels of biodiversity within and among sheep populations. Importantly, it provides the genetic basis for the highland sheep for adapting to the hypoxic environment. Further the study has also provided important information on the genetic diversity of the Nepalese sheep and potential mechanisms for the adaptation to hypoxia caused by high-altitude. These are useful baseline scientific information on which any policy on holistic conservation decision related to sheep in the regions should be based. This study further opens a new avenue to study on the identified genes for the functional mechanism in the adaptive processes.

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5. INDIGENOUS GOAT BREEDS OF NEPAL

Chyangra goat

Sinhal goat

Khari goat male

Khari goat female

Terai goat

Terai goat flock in Bardiya district

Khari goat flock in Makawanpur district

Chyangra goat flock in Mustang district

5. INDIGENOUS GOAT BREEDS OF NEPAL

5.1 Zoological classification of goat

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Artiodactyla
Family	Bovidae
Sub-family	Bovinae
Genus	*Capra*
Species	*C. aegagrus*
Sub-species	*C. a. hircus*
Trinomial name	*Capra aegagrus hircus*
Synonym	*Capra hircus; Capra depressa; Capra mambrica, Capra reversa*

5.2 Overview of goat

Goats being one of the most economic livestock species in Nepal have a very important role to play in the national economy. There are 12.81 million goats in the country (MOALD, 2020). Five to ten percent of this is exotic (pure or crossbred) and rest is indigenous (Anon, 2004). This suggests that among goat species, most of the contribution comes from the indigenous breeds. The goats in the country are kept for multiple utilities including meat, manure and draught (particularly in the hills and mountains). Apart from these they have several other uses such as hides, bones and hairs. In some parts of the country, they are also used as pack animals (Upreti, 1991). They have cultural and social values as well in the country. About 50 % of the household keep goats in the country (Joshi et al., 2020). This figure is much higher for the case of hills. Literatures suggested that the proportion of goat keeping households in Nepal are being declined to 49.82% (Joshi et al., 2020) from 85% (Oli and Gatenby, 1990) of the farming households. Goats rank next to buffalo for income generation from livestock. Goat meat, which is being called as mutton but should have been called Chevon, is the most expensive meat in the country and is at high demand. This is very popular meat and is consumed by most of the caste and communities in the country. The price of meat has increased tremendously by almost 65% over last 20 years and the trend of increment has been quite high in goat as compared to other species such as chicken (70%), and buff and pork (125%) suggesting high demand of goat meat in the country.

There are four indigenous breeds of goat in the country that has been identified and characterized so far. They are *Terai*, *Khari*, *Sinhal* and *Chyangra* (Pradhan and Gurung, 1985; Shrestha, 1995; Kharel, 1997; Neopane, 1997) contributing about 27, 56, 16 and 1 percent to total population indigenous goat breeds, respectively. Besides this, presence of some subtypes/strains is also found in Khari goats of the country. Kunwar et al. (2000) studied Khari goat across the hills in the country and reported that three distinct strains (small, medium and large) existed among Khari population. Small types based on body size are found located in the eastern region while that of large type was found located in the western region. Chyangra is a mountain goat originating from Tibet and is mainly reared in the northern borders of the country at 2400 m asl. These goats are highly valued since time immemorial for their extremely fine quality wool/fiber. They are small and hardy, with a long hair coat and a fine inner coat of

Cashmere or *Pashmina*. Sinhal is a high hill goat, kept with Baruwal sheep, generally at elevation of 15002 to 3000 m asl (Keshary and Shrestha, 1980). They are generally black but white and brown patches are also common. Terai goats are found in the terai (plain areas) under tropical conditions. Hill goat (Khari) is one of the principal breeds of goats in the country and is recognized for its prolificacy and adaptability. They are commonly called Khari goat in the western hills and Hill goats in the eastern hills (Neopane, 1997). The chapter includes introduction, characterization on phenotypic and chromosomal levels, production performances, and status of the breeds, positive attributes and future prospects of the goat farming in the country.

Table 5.1 Contribution of goats in Nepalese economy

Provinces	**Population**	**Meat production**	**Contribution in national meat production (%)**
Province 1	2,501,263	12,247	41.5
Madhesh	1,677,368	2,158	7.3
Bagmati	2,351,217	3,343	11.3
Gandaki	1,533,629	3,148	10.7
Lumbini	2,329,047	6,894	23.4
Karnali	1,435,690	842	2.9
Sudur paschim	983,739	859	2.9
TOTAL	**12,811,953**	**29,493**	**100**

Source: MoALD, 2021

5.3 Origin of Nepalese goats

Goat belongs to the Bovidae family of hollow horned ruminants in the sub-order Ruminantia of the mammalian order of Artiodactyla. It is closely related to sheep (Ovina) and together constitute the tribe of Caprini. In this regard, goat finally belongs to the genus Capra and species hircus (Belanger, 1981). It is believed that the domestication of goats was started during 7000 to 9000 BC in Western Asia. According to Herre (1958) and Devendra and Mc Leroy (1988) the wild Bezoar of Western Asia is considered as the main ancestor of the most domestic goats. Logic revealed that the Markhor, raised in the areas East to the earliest domestication centers was an ancestor of domesticated goat (Epstein, 1971; Bokonyo, 1976). Whatever may be the truth, it is widely believed that Markhor of Northwest India together with Bezoar has contributed to the genetic background of Indian and Central Asian goat breeds. Mason (1988) reported that the ancestor of current day breeds of goats is Capra (hircus) aegagrus, Bezoar goat distributed to the Indian sub-continent and later migrated to Southeast Asia in the fourteenth century. Diversification took place in the area of domestication and is represented by coat color, size and shape ear and horn. Obviously, goat is the earliest ruminant domesticated by human being as reported by Jindal (1984) and Banerjee (2000) and has been serving humankind for a long-long period than any other class of livestock species. It is considered that domestication of goats occurred prior to taming of sheep, cattle and pig. In early years, after the initial domestication of wild goats, the availability of feed must have extended a critical and determinative influence on the evolution of domesticated goats (French, 1970). Kharel (1997) reported that Chapper and Damini of Pakistan, Barbari, Deccani and Surti of India, Black Bengal of West Bengal, Kambing Katjang of Southeast Asia and South China goat of China, have very close resemblance to Hill goats of Nepal in terms of physical features and reproductive behavior.

More similarity is observed within several goat breeds, which are found in Indian subcontinent including Nepal. Kharel and Neopane (1998) has described that Kasmiri and Changrya goats of Nepal are considered as the descents of the wild Markhor goat in term of appearance.

These results of genetic diversity study in goats indicated that there was no correspondence between the geographic regions of origin and relationships among goat breeds. Results also 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.

5.4 Indigenous goat breeds of Nepal

5.4.1 Demographic distribution of indigenous goat breeds of Nepal

Indigenous goat breeds of Nepal are distributed all over the country including all geo-ecological domains ranging from lower plain of Terai region to very high altitudes of hills and mountains.

Terai goat *(Capra hircus)*

Terai goats are light coloured (mostly white) animals located in the terai region of the country (Table 5.1). They are good meat type animals. They are also used for manure. Form the conservation point of view they are at risk as it is difficult to find them in pure form because they have been heavily crossed with Indian large size goats breeds (Jamunapari, Beetal and Barbari). They have been characterized at phenotypic and chromosomal level (Annual Report, ABD, 2003).

Khari goat (*Capra hircus*)

Khari goat is the principal breed of goat located across the hills in the country (Table 5.1). The Khari goat in the western hills and Hill goat in the eastern hills is the same breed (Neopane, 2000a). They represent 56% of the total goat population in the country (Kharel and Neopane, 1998). They are productive breed having twinning very common and shorter kidding intervals. They are normal from the conservation point of view. They have been characterized at phenotypic and chromosomal level (Rasali et al*.,* 1997)

Sinhal goat *(Capra hircus)*

Sinhal goats are found south of high mountain region (Table 5.1) and north of southern most hills of the country. They are the heaviest native goat breed and represent 16% of the total goat population. They are characterized at phenotypic level. The farmers are conserving them in situ but they need empowerment. They are at risk from conservation point of view. This can be a suitable breed for meat and draught under transhumance system with low input (in the high hills).

Chyangra goat *(Capra hircus)*

Chyangra goats are found in the high altitudes of the country (Table 5.1) and are raised under transhumance systems for multiple utilities including meat, fiber and draught as well. They represent only 1% of the total goat population in the country. They are also used for meat and *pashmina* production but they are not fully utilised for their *pashmina* production. This is an important area to be addressed/focused. It has been revealed that chyangra farming and pashmina production shares about 6.2 percent of total investment on livestock enterprises in the high Himalayan regions of Nepal (Khadka and Thapa, 2020).

5.4.2 Status of the Nepalese goat breeds

Except Khari other three breeds are critical from conservation point of view. Terai goats are difficult to find in pure form due to intensive crossbreeding with Indian breeds. The population of Sinhal and Chyangra goat is declining in numbers and needs conservation attention.

5.4.3 Positive attributes

In general indigenous breeds are low producing than the exotics in terms of meat production. However, they have several other positive attributes such as hardiness, adaptability to local harsh conditions and can produce in low input system. All identified breeds are well adopted in traditional grazing management system and spend more than 6-8 hours in pasture. They can easily convert farm and kitchen wastes; agriculture by-products, and low quality pastures into valuable meat, milk and wool. Goat meat is the most expensive item in the market in compare to any other available and preferred by almost all ethnic communities. It is also a source of hard currencies. It is observed that these positive attributes are not duly recognized rather exotics breeds are unnecessarily exaggerated over them.

Sinhal goat can thrive in high Himalayan mountain region between the elevations of 1500 to 3000 masl. This is the heaviest goat breed among the indigenous goats. Similarly, Khari are more prolific among the four indigenous breeds and can adopt in different agro-climatic zones from river basin to mid-hills (1100 masl). They generally produce first kid by the age of 12-14 months with the kidding interval of 9 months. The breed demonstrates higher twinning frequency with triplet and even quadruplet is fairly common. The breed is widely used by Government and non-government organizations for poverty reduction programme in rural areas of the country as they seldom compete with human beings in cereal consumption.

Terai goat is hardy in the southern hot plains of the country. They display a wide range of variation within the breed. They are well adopted in high rain fall to dry climatic condition of the Terai region. The first kidding occurs at the age of 15-16 months and kidding interval is 9-10 months. In terms of prolificacy the breed demonstrates similar ability as Khari goat. Chyangra goats are found in the trans Himalayan region of Nepal above 2400 masl and are raised under migratory system. They have coarse but silky long hair reaching up to the knees, beneath which a fine under coat is present. They are well-known for the quality cashmere (*pashmina*) production. It produces about 300-1130 g wool annually whereas and *pashmina* production is about 115-170g. The *pashmina* shawl is soft, warm and comfortable and priced as above from $3,000 to $15,000 (WP, 2007). They are equally recognized as means of transportation in higher Himalayan terraces where road facility rarely exists.

5.4.4 Socio-cultural significance

Goat production fits in very well in the context of rural poor due to their ability to consume low quality forage and other browsing materials normally not utilized by other large ruminants. These special features of goats provide significant economic, managerial and biological advantages. Goat meat is usually low in fat and accepted by almost all section of society. Also, goat meat is very popular and is preferred over other meat throughout the country (Dhakal *et al.,* 1985). In many countries, goat milk is used extensively for infant feeding. It has the distinct nutritional value of in human nutrition being more digestible and having lower curd tension as compared to cow milk (Macy *et al.,* 1953) so they are also known as the "Foster mother of man" as well as "Poor man's cow". In Nepal the small farmers can raise the goats and generate income within a short period of time with least input.

5.4.5 Characterization of indigenous goat breeds

Almost four breeds of indigenous goat genetic resources have been characterized phenotypically. Among four breeds, few breeds have been characterized at chromosomal level.

5.4.5.1 Phenotypic characterization of indigenous goats

5.4.5.1.1 Physical characteristics of indigenous goats

Terai goat

- Terai goat is a medium sized animal
- Popular for meat production and taste
- Produce on an average of 1.4 kids at the birth
- Hardy and suitable for hot climate
- Attain sexual maturity at about 8 to 10 months and produce the first progeny at an age of 13 to 15 months (Table 5.4).
- Kidding interval is shorter than one year (336 days), which is good character.
- Medium type goats having 20 kg weight at one year of age (Table 5.5).

Khari goat

- Khari goats are the principal goat breed in the country.
- Quite prolific breed having twinning commonly.
- Litter size at birth is 1.6 and kidding interval is substantially shorter than one year.
- Attain sexually maturity at an age of 7 to 10 months and produce the first progeny at an age of 12 to 17 years (Table 5.4).
- Medium type meat goats having 16 kg body weight at one year of age (Table 5.5).

Sinhal goat

- Sinhal goats are good breed for high hills and are suitable for pack animals.
- Largest goat breed in the country used for meat and draught purpose.
- Not prolific breed with single progeny at a time.
- Very hardy and suitable for adverse climate.
- Attain sexual maturity at about 10 to 15 months and produce the first progeny at an age of 15 to 20 months (Table 5.4).
- Kidding interval is less than one year (325 days).
- Large goat among the indigenous ones (22 kg at one year of age) (Table 5.5).

Chyangra goat

- Chyangra goats are good breed for high hills and mountains and are suitable for meat and pack animals.
- They are not prolific breed (single kid) .
- Very hardy and suitable for adverse climate.

- Attain sexual maturity at about 15 to 19 months and produce the first progeny at an age of 20 to 24 months (Table 5.4).
- Kidding interval is about one year (300-400 days).
- Medium type goats (20 kg in a year) (Table 5.5).

Table 5.2 Body parts measurements of indigenous breeds of goat (Values are means in cms ± standard errors)

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: Annual report, ABD (1997); Kharel and Neopane (1998); Upreti and Pradhan (1998); Tiwari et al. (2002); Primary source: ARS, Bandipur (2007)

5.4.5.1.2 Morphological measurement of indigenous goat

Terai goat

Terai goats are smaller in size among four genetic resources of goats. The average body length, height at withers, and heart girth are recorded as 60.6±0.87, 57.9±0.32 and 65.2±0.44 cm, respectively. Similarly, average height at hip bone, horn length and ear length have been observed 60.8±0.73, 8.37±0.2, and 18.7±0.30 cm, respectively. Average adult body weight of Khari goats are recored 23.3±0.1 kg for female and 30-35 kg for male. Additional morphological measurement of Terai goats are presented in Table 5.2.

***Khari* goat**

Khari goats are the major contributor of goat population and meat production in Nepal. The average body length, height at withers, and heart girth of Khari goats are recorded as 63.1±0.39, 55.9±0.28 and 65.5±0.37cm, respectively. Similarly, average height at hip bone, horn length and ear length have been observed 51.5±1.76, 11.5±1.3, and 16.2±0.4cm, respectively. Average adult body weight of *Khari* goats is recored 24.1±0.34 kg for female and 28-40 kg for male. Detail information on morphological measurements of *Khari* goats is presented in Table 5.2.

Sinhal goats

Sinhal goats are the largest breed among four Nepalese indigenous goats. The average body length, height at withers, and heart girth of Khari goats are recorded as 68.7±0.44, 59.2±1.06 and 77.8±0.44 cm, respectively. Similarly, average head length, horn length and ear length have been observed 16±0.4, 15.3±0.84, and 14.5±0.5 cm, respectively. Average adult body weight of Sinhal goats is recored 34.8±0.12 kg for female and 28-40 kg for male. Detail information on morphological measurements of Sinhal goats is presented in Table 5.2.

Chyangra goats

Chyangra is one of the most valuable indigenous goat breeds among four breeds in Nepal which is popular for meat and pashmina fiber. The average body length, height at withers, and heart girth of Chyangra goats are recorded as 62.3±0.36, 62.4±0.23 and 71.3±0.37 cm, respectively. Similarly, average head length, horn length and ear length have been observed 15.1±0.6, 15.1±0.6, and 10.5±0.4 cm, respectively. Average adult body weight of Chyangra goats is recored 29.1±0.69 kg for female and 25-40 kg for male. Detail information on morphological measurements of Chyangra goats are presented in Table 5.2.

5.4.5.2 Characterization on chromosomal level

Karyotyping study of goats revealed that Khari goat has 60 chromosomes comprising 58 acrocentric autosomes and one pair of sex chromosomes. The X chromosome was a large acrocentric chromosome, whereas the Y chromosome was a very small metacentric chromosome (Rasali *et al*., 1997).

5.4.5.3 Molecular Characterization

Mitochondrial DNA study

Nepal has a sizeable indigenous goat population with four identified breeds (Chyangra, Sinhal, Khari and Terai) and many non-descript goats. The study on genetic diversity and phylogeography of these identified breeds mitochondrial DNA (mtDNA) hyper-variable (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 5.1 and Table 5.3). mtDNA haplogroup A was observed in most of the Nepalese goat populations whereas only one breed (Chyangra) contained all four haplogroups (Gorkhali et al., 2014). Chyangra has 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.

Table 5.3 Distribution of mtDNAhaplogroups in Nepalese goat breeds/populations

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: Gorkhali et al., 2014

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.

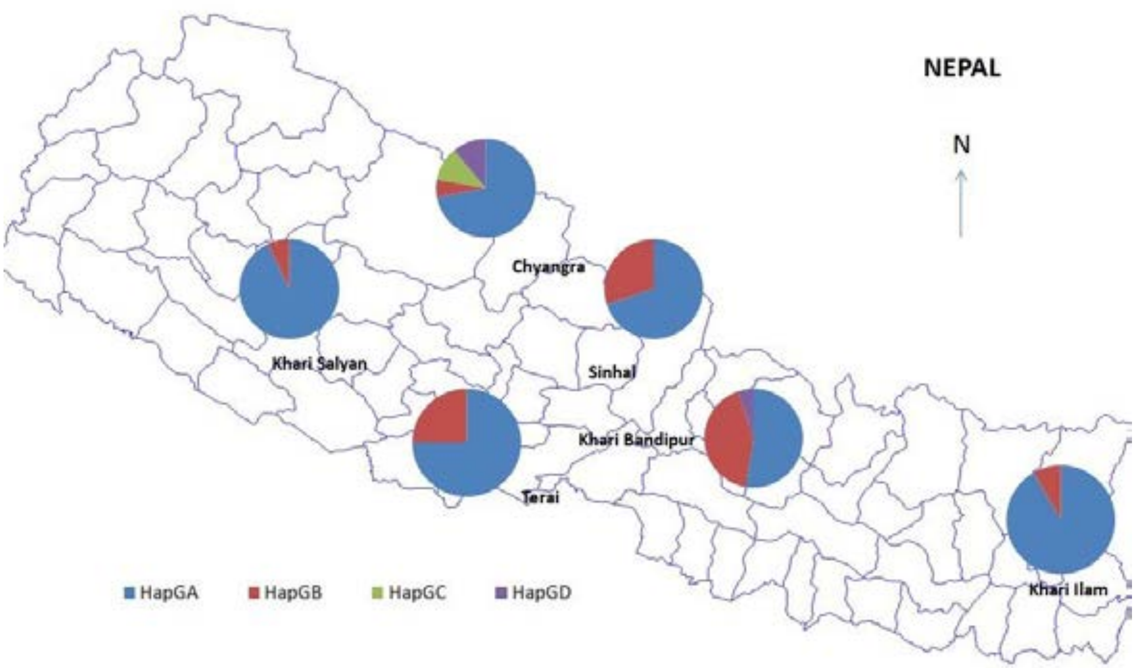

Figure 5.1 Haplogroups of Nepalese goats (haplogroups A-D)

Source: Gorkhali et al., 2014

5.4.5.4 Biochemical characterization

Kuwar et al (2000) working with Khari/Hill goats across the hills from east to west of the country reported three distinct types with respect to genetic distance. The goats of the eastern region are smaller in size and the goats from mid-western region are bigger in size. A protein analysis indicated that haemoglobin was polymorphic in Hill goats. Two genotypes of haemoglobin, HbAA and HbAB were found in the sampled population. The gene frequency of HbA was higher than HbB, which was more in the goats sampled from east Nepal. Four genotypes of transferrin, TfAA, TfAB, TfBB and TfAC were found in the Hill goats with decreasing trend of genotypes 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 east Nepal than west Nepal. Polymorphism of these two principal blood protein including differences in gene frequencies between the populations of Hill goats found in different locations indicated the genetic variation in Hill goats (Kunwar et al 2000).

5.5 Production performance of indigenous buffalo

Terai goat

Terai goat is a medium sized animal reputed for meat production. They produce on an average of 1.4 kids at the birth. They are hardy and suitable for hot climate. They attain sexual maturity at about 8 to 10 months and produce the first progeny at an age of 13 to 15 months (Table 5.4). Kidding interval is shorter than one year (336 days), which is good character. They are medium type goats having 20 kg weight at one year of age (Table 5.5).

Khari goat

Khari goats are the principal goat breed in the country. They are quite prolific breed having twinning quite common. The litter size at birth is 1.6 and kidding interval is substantially shorter than one year. They attain sexually maturity at an age of 7 to 10 months and produce the first progeny at an age of 12 to 17 years (Table 5.4). They are medium type meat goats having 16 kg body weight at one year of age (Table 5.5).

Table 5.4 Production performances of indigenous breeds of goats (Valuesare means ± standard errors)

Parameters	Terai	Khari	Sinhal	Chyangra
Age at 1st service (days)	348±10.7	311±5.6	363±12.4	405±9.9
Wt at 1st service (kg)	17.3±0.49	15.4±0.22	17.0±0.35	18.5±0.40
Age at 1st kidding (days)	491±5.1	453 ±6.2	576±9.8	555±9.6
Wt at 1st kidding (kg)	19.5±0.56	17.8±0.23	20.5±0.42	18.8±0.35
Kidding intervals (days)	336±4.2	302±3.7	287±5.4	354±8.7
Litter size at birth (no)	1.4±0.21	1.6±0.02	1.1	1.0
Litter wt at birth (kg)	2.5±0.33	3.38±0.06	2.0	1.9
Litter size at weaning (no)	1.3±0.26	1.42±0.03	0.8	0.7
Litter wt at weaning (kg)	11.1±1.0	11.9±0.36	10.0	9-11
Gestation length (days)	149.9±0.30	144.8±0.15	145-150	145-150

Source: Tamrakar and Chapagain (2000); Chapagain et al. (2002); Tiwari et al. (2002); Pokharel and Khanal (2006); Tamrakar and Sah (2007)

Sinhal goat

Sinhal goats are good breed for high hills and are suitable for pack animals. They are the largest goat breed in the country used for meat and draught purpose. They are not prolific breed. They are very hardy and suitable for adverse climate. They attain sexual maturity at about 10 to 15 months and produce the first progeny at an age of 15 to 20 months (Table 5.4). Kidding interval is less than one year (325 days). They are large goat among the indigenous ones. They have 22 kg weight at one year of age (Table 5.5).

Chyangra goat

Chyangra goats are good breed for high hills and mountains and are suitable for meat and pack animals. They are not prolific breed. They are very hardy and suitable for adverse climate. They attain sexual maturity at about 15 to 19 months and produce the first progeny at an age of 20 to 24 months (Table 5.4). Kidding interval is about one year (300-400 days). They are medium type goats having similar weight with Terai goat at one year of age (20 kg) (Table 5.5).

Table 5.5 Body weights of indigenous breeds of goats at different ages (kg) (Values are means ± standard errors)

Parameters	Terai	Khari	Sinhal	Chyangra
Birth wt	1.58±0.5	1.65±0.02	2.0	1.6
Weaning wt (4 months)	10.7±0.34	7.5±0.12	10.3	9.5
6 months wt	11.9±0.08	8.8±0.19	11.3	11.0
9 months wt	16.2±0.88	12.4±0.17	15.1	13.8
12 months wt	20.1±0.97	16.3±0.33	22.4	20

Source: Neopane (1999); Annual Report, ARS, Bandipur (2000); Neopane (2000c); Shresthta et al. (2000); Neopane and Upreti (2001); Shrestha (2004)

On the other hand, estimation of genetic parameters of weight traits of Khari goat revealed that these traits have moderate to high heritability estimates ranging from 0.37 at birth to 0.46 at post-weaning (six months) age (Bhattarai et al., 2017) and declined gradually from nine to fifteen months age (Table 5.6).

Table 5.6 Heritability estimates of weight traits of Khari goat kids at different stage of growth in Nawalparasi, Nepal.

Traits	Heritability estimates
Birth weight	0.37±0.12
Pre-weaning	0.42±0.13
Weaning	0.42±0.13
Six months	0.46±0.14
Nine months	0.44±0.13
Twelve months	0.40±0.12
Fifteen months	0.39±0.12

Source: Bhattarai et al., 2017

5.6 Future prospects

Analyzing the current situation and use of goat in the country it could be assumed that the future prospects of the species is quite promising. As a versatile animal in terms of uses and adaptability in diversified climatic condition right from hot to extreme chill and an output in low management condition, the species due receive high priority in government programme planning. In spite of its positive features the breed has limitations in terms of body weight gain and market weight. Lower body weight gain and market weight make the species comparatively economically less marginable in intensive or semi-intensive management system.

Agriculture Research Station, Pakhribas, NARC has initiated a selective breeding programme for improvement of body weight gain in Hill goat. Both on-station and on-farm results showed that a substantial genetic gain could be achieved by applying simple selection index (Pokharel and Neopane, 2006). The index is based on 4 and 6 month body weight of kids from multiple born cases. The developed selection index should be applied in all Khari population from the eastern part of the country to the western. It is interesting to note that similar breeding programme had been implemented in India for the development of meat type goat breed (NCA, 1976). Similarly, systematic breeding plan in remaining 3 breeds (Chyangra, Sinhal and Terai) of goats with emphasis on selection needs to be initiated. Such scheme has been even documented in government's plan however; their implementation part is virtually poor.

The importation of exotic breeds for crossbreeding particularly in the hill and mountain regions should not be recommended unless provision for feed with increased nutrient requirements and disease control measures are readily available. 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 stressed. Furthermore, the importance of indigenous breed populations and the role in adding value to animal products should be explained to the community.

In indigenous breeds there exists different types and sub-types based on their morphological features and blood protein (Kunwar, 2000). The study clearly indicated existence of three different lines within the Khari population of the country. Similar study has to be initiated for other breeds of indigenous goats. Such study certainly will have greater impact in the breed improvement programme as well as in productivity enhancement of the local population.

Characterization of the indigenous breeds of goat at molecular level is an important avenue of the future programme. Indigenous breeds are not studied and understood so far at DNA level. Initiation of such programme in coming days provides greater opportunity to understand them and which further undoubtedly accelerates the production and productivity. Further, this kind of study will assist to utilize the positive attributes of indigenous goats like disease resistance, hardiness and adaptability in different harsh climatic and management conditions. The quality could be beneficial for other indigenous and exotic breeds of goat in the country and elsewhere.

Biotechnological advances particularly 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 programme. Lack of goat breeding centres for quality seed and ever-increasing demand on breeding stocks as well as on chevon strongly justify the massive use of AI and ET in goat. Animal Breeding Division, NARC has stepped up in the direction however; there needs to do a lot.

An attempt to establish elite nucleus herd of different strains of Khari goat started in 2053/54 BS (1997/98) in the initiation of Animal Breeding Division (ABD) currently upgraded to National Animal Breeding and Genetics Research Center (NABGRC), Khumaltar. The project location was ARS-Bandipur. Goats from Salyan, Dhading, Tanahu and Dhankuta were included in the programme *(Annual report, ABD, 1997)*. But unfortunately, outbreak of PPR restricted the achieving the purpose. Such project undoubtedly has great significance as nucleus breeding centre of goat breeds in the country is virtually very few or even none. So, revitalization of such project and establishing nucleus breeding centres of goat so as farmers could get certified breeding stock is immensely important.

Owing to the remoteness, harsh climatic condition and transhumance system of management Chyangra goat is not getting due consideration from public and private institutions as result of which 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). Beside 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 was available on morphological characteristics and growth traits. Systematic study to understand the situation and potential for improvement was not evaluated for this region. Neopane (2006) stated that the breed is not fully utilized for its Chyangra cashmere production and this is an area of importance where focus is required. Oli (1986) also reported that production performance of high-altitude species including Chyangra is relatively poor.

Some other vital aspects of goat husbandry like indigenous traditional knowledge (ITK) in goat keeping, predator losses in the mountains and hills, poor health and nutrition management leading to infertility, higher pre and postnatal mortality, problem of internal and external parasites, feed shortage especially during dry winter, pasture problem in high hills, under development marketing channels and post-harvest works where focus should be provided for the improved goat farming in the country.

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6. INDIGENOUS PIG BREEDS OF NEPAL

Chwanche pig

Hurrah pig

Bampudke pig

Bampudke sow feeding her piglets

Wild Boar

Wild Boar cross piglets

Hurrah pig flock

Hurrah pig flock

6. INDIGENOUS PIG BREEDS OF NEPAL

6.1 Zoological classification of pig

Kingdom	Animalia
Phylum	Chordata
Sub-phylum	Craniata (Vertibrata)
Class	Mammalia
Sub-class	Theria (Viviparous)
Order	Ungulata (Hoofed mammals)
Sub-order	Artiodactyles (Even-toed)
Family	Suidae
Genus	*Sus*
Species	*domesticus*
	scrofa (wild pigs)
	Porcula salvania (Bampudke)

6.2 Overview of pig

Nepal has a population of about 1.5 million pigs and annual pork production in the country is 29493 MT contributing about 5.34% of total national meat production (MOALD, 2021). As per capita meat consumption currently stands at 18.1 kg, of which buffalo meat takes the number one position with 58% of all the meat consumed, pork currently comes on the fourth position contributing barely 1 kg per capita (5.5% of the total meat consumption). The highest number of pigs (0.63 million pigs and 12247 MT pork) are found in Province I (MOALD, 2021) (Figure 6.1, Table 6.1). About 10 % of the household (9.9 %) keep pigs in the country (Singh and Chapagain, 1998). This figure is higher in eastern hilly region where ethnic people and socially disadvantaged are populated. Since pig is the rapid converter of feed to meat protein, pig is considered as an important commodity for achieving food security for the rapidly growing human population (ADS, 2015). Pigs are primarily maintained for pork and provide animal protein to human beings and their role in progressive agriculture is by providing manure for maintaining soil fertility and to meet socio-cultural beliefs (Shakya, 2008).

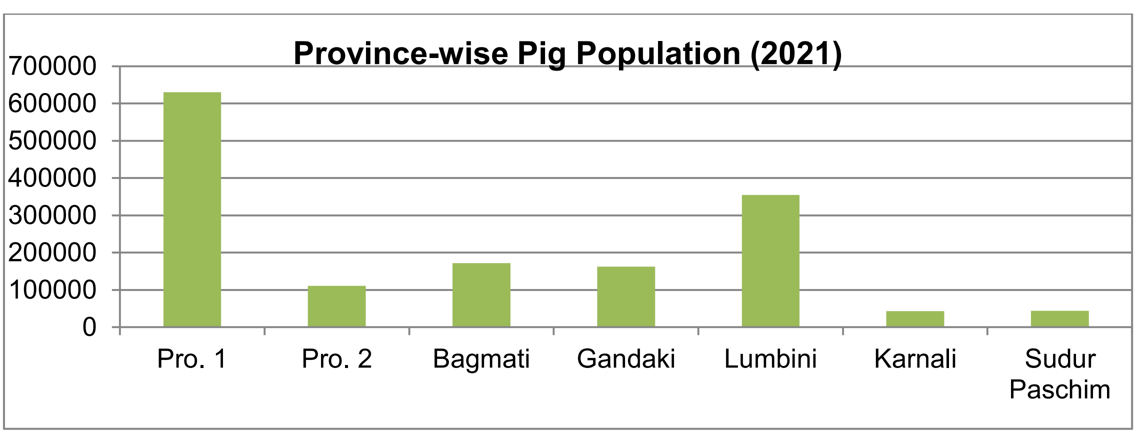

Figure 6.1 Province-wise pig population

Source: MOALD, 2021

Table 6.1 Province-wise pig population and pork production

Province	Pig Population (number)	Pork Production (MT)
Pro. 1	630318	12247
Pro. 2 (Madesh)	111322	2158
Bagmati	172277	3343
Gandaki	162153	3148
Lumbini	355246	6894
Karnali	43469	842
Sudur Paschim	44308	859
Total	**1519593**	**29493**

Source: MOALD, 2021

Pigs are small-sized livestock contributing to poor and subsistence farmers who can't afford to rear large-sized livestock which demand high price per head and cost of maintenance. The subsistence farmers rear mainly the indigenous pigs in their backyard using mainly the kitchen leftovers. The indigenous pig breeds in the country cover around 81% (Chwanche 53%, Hurrah 23%. Bampudke <1%) and the exotic origin represents about 19% of total pig population (Rasali *et al*., 1998) suggesting the more contribution comes from indigenous breeds. Many countries consider their indigenous adapted species of farm livestock to be of low productivity and genetic potential. Traditional production system association with indigenous breeds is replaced by the rapid spread of intensive livestock production using narrow range of breeds (exotic breeds) is used in larger scale. More recent data revealed that indigenous pigs constitute 58% of the total pig population while the remaining 42% are exotic or improved breeds (Kayastha 2006). With the technology intervention and the change in attitude towards pig, the production of pig meat is increased drastically. Production of pig meat of Nepal increased from 4,300 thousand MT in 1970 to 29,493 thousand MT in 2020 which is growing each year (Figure 6.2). The demand of pork meat production is rising annually by 10% in Nepal exhibiting high scope in pork industry (SAMARTH and CEAPRED report, 2016). One of the main reasons for the rise in pork demand is removal of cultural barriers that prevented people from consuming the meat.

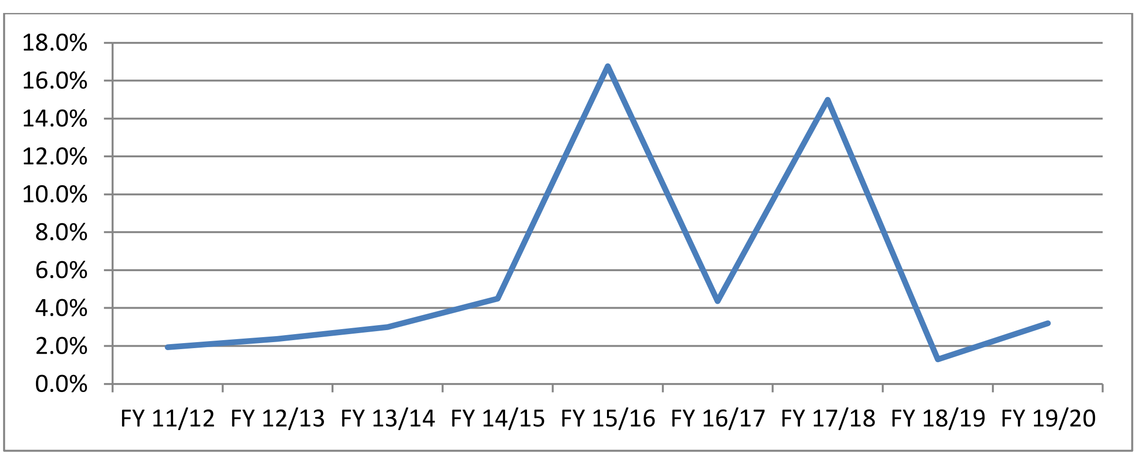

Figure 6.2 Trend of meat production

6.3 Origin of Nepalese pigs

The domestic pig originates from the Eurasian wild boar (*Sus scrofa*). Clear evidence was obtained for domestication to have occurred independently from wild boar sub-species in Europe and Asia. The time since divergence of the ancestral forms was estimated at about 500,000 years, well before domestication about 9,000 years ago. Historical records indicate that Asian pigs were introduced into Europe during the 18th and early 19th centuries. The study is an advance in pig genetics and has important implications for the maintenance and utilization of genetic diversity in this livestock species (Giuffra *et al* 2000).

The wild boar is widespread in Eurasia and occurs in Northwest Africa; the existence of at least 16 different sub-species has been proposed (Ruvinsky and Tothschild 1998). Domestication of the pig may have occurred repeatedly from local populations of wild boars (Bokonyi 1974). However, it is not yet established whether modern domestic pigs showing marked morphological differences compared with their wild ancestor have a single or multiple origin. Darwin (1868) recognized two major forms of domestic pigs, a European (*Sus scrofa*) and an Asian form (*Sus indicus*). The former was assumed to originate from the European wild boar, while the wild ancestor of the latter was unknown. Darwin considered the two forms as distinct species on the basis of profound phenotypic differences. It is well-documented that Asian pigs were used to improve European pig breeds during the 18th and early 19th centuries (Darwin 1896; Jones 1998) but to what extent Asian pigs have contributed genetically to different European pig breeds is unknown. Nepal is blessed with the presence of wild population of pig having grey to brown body color, rough hairs and horizontal brown color stripes on the body of piglets that disappear later. It is assumed that these are the ancestor of Nepalese domestic pigs. It is warranted to perform research to prepare scientific basis for proving the origin of Nepalese domestic pigs.

6.4 Indigenous pig breeds of Nepal

There are three indigenous breeds of pigs in the country that has been identified and characterized in different level. They are Chwanche, Hurrah and Bampudke (Shrestha, 1995; Neopane, 2004).

6.4.1 Demographic distribution of indigenous pig breeds of Nepal

Nepal has diverse agro-ecosystems in relation to its size of 147181 square kilometers. The climate varies from tropical in the Terai (plain), through subtropical, warm and cool temperate at medium altitudes, to alpine and frigid at the highest elevations. The highest population of pig is found in mid hills (53%) followed by Terai (36%) and high hills (11%) (MoALD, 2020). (Please refer to Appendix 1 for detailed information)

Chwanche pig *(Sus domesticus)*

Chwanche pigs are located in low to mid hills and are good scavenger animals. This breed is also called as “Pundi” in Eastern Hills (SARP, 1996). They are hardy, disease resistant and well suited to local environments (DLS, 2016). Chwanche is a poor man's pig raised by under privileged people of hilly region in scavenging situation.

Hurrah pig *(Sus domesticus)*

Hurrah pigs are located in terai region (tropical and subtropical) and are mainly used for meat. They are hardy and suitable for privileged people of Terai region in scavenging situation.

Bampudke pig *(Porcula salvania)*

Bampudke pigs, also known as Pigmy hog (Esptein 1977), are one of the smallest pig breeds in the world and are very hardy animals. The species was originally named *Porcula salvania* by Hodgson (1847). The species was formerly distributed along the narrow alluvial tract south of Himalayan foothills from south-eastern Uttarakhand in the west to central Assam in the east, along the international border of Nepal and Bhutan with Indian states of Uttar Pradesh (UP), Bihar, West Bengal, and Assam (Oliver 1980; Oliver & Deb Roy 1993). https://www.researchgate.net/publication/326070385_Pygmy_hog_Porcula_salvania_Hodgson_1847

6.4.2 Status of the Nepalese pig breeds

Amongst Indigenous breeds, Chwanche constitutes a major proportion of the population and are located in hills (Shrestha, 1996). Chwanche located in the hills represent 58% of the total pig population (Rasali *et al*., 1998; Funk et al 2007). Hurrah pigs are located in terai region and contributes 23% of the total pig population (Rasali *et al*., 1998; Funk et al 2007). Bampudke, also known as Sano Badel and Pigmy hog (Epstein 1977), which are found both in wild and domestic form are now in the stage of risk cateory of existence i.e. about to be extinct (Neopane, 2006). Government organization has taken replacement strategy to improve the productivity of national pig population, indigenous pigs population is reduced to 58% of the total pig population while the remaining 42% are exotic or improved breeds (Kayastha 2006).

6.4.3 Positive attributes

In general indigenous breeds are low producing than the exotics in terms of meat production. However, they have several other positive attributes such as hardiness, adaptability to local harsh conditions and can produce in low input system (Chapter 1 Table 1.1). It is observed that these positive attributes are not duly recognized rather exotics breeds are unnecessarily given preference over them.

6.4.4 Socio-cultural significance

The pig production system prevalent in the country can be broadly divided into subsistence (traditional) production in scavenging management and recently emerging commercial piggeries. Under the traditional subsistence production system, mostly indigenous pigs are found to be reared under scavenging management near the villages. Hurrah, Chwanche and Bampudke are the native pig breeds (Neopane and Kadel, 2008). Certain ethnic communities are found to be involved in the production of pigs under this system. Both input and output under this system are low, but have significant contribution in the household level food and nutrition security as well as for the fulfillment of the religious requirement. In some communities, pigs are even used as gift particularly during the marriage ceremony. Pig's meat (pork) used to be consumed by certain communities in the country in the past. The recently emerging and fast growing is the commercial pig production system, under which mostly exotic breeds and their various crosses are reared in the confinement with commercial feed supplementation. Yorkshire, Landrace, Duroc and Hampshire are the common exotic breeds introduced for commercial production. The tribes and religion are not important in this production system, even the Brahmins youths are found to be involved in commercial piggery. Under this system, farmers are found to be keeping from few breeding sows to as large as 200 breeding sows with more than 1000 fatteners with the concept of factory farm production. Beside these systems, pig production has also been found to be integrated with fish farming in the country (Shrestha *et al.*, 2014).

On the negative side, pigs are generally blamed for environmental pollution, particularly those reared under scavenging management system. These animals contaminate water sources and waste dropped here and there in the village is a real problem for the community. Likewise, it can disturb social harmony due to noise and off odor created by pig farming in the human settlement. The most important point is these animals can help in spreading of various zoonotic diseases. However, if properly managed the risk of disease spreading and dispute due to noise and off odor can be minimized (Shrestha *et al.*, 2014).

6.4.5 Characterization of indigenous pig breeds

All identified indigenous pig breeds have been characterized phenotypically. Besides, Hurrah and Chwanche breeds have also been characterized on chromosomal level.

6.4.5.1 Phenotypic characterization of indigenous pig

6.4.5.1.1 Physical characteristics of indigenous pig

Chwanche pig

- They are black in color
- Long and straight snout
- Small erect ears
- Its barrel is dropping type
- Female has 8 to 12 teats
- Average adult weight is 35 kg ranging from 25 to 40 kg
- Long and straight tail
- Small body size and short height.
- The top length (from head point to the base of tail) is 76 cm and heart girth is 86 cm
- They are semi-wild in nature

Hurrah pig

- Its body color is completely grayish black or rust brown with rough skin
- Small and erect ears
- Straight snout
- Hair is straight
- Straight brown bristles in neck and back
- Its barrel is dropping type
- Long and strong legs
- Straight and long tail
- Female has 8 to 12 teats
- The average adult weight is 45 kg ranging from 40 to 55 kg
- The top length (from head point to the base of tail) is 79 cm and heart girth is 88 cm
- They are semi-wild and are active in nature

Bampudke pig

- They are normally red and brown color and sometime found in black color
- Top length (from head point to the base of tail) is 45 cm
- Heart girth is 52 cm
- Female has 8 to 12 teats
- Their average adult body weight is 20 kg (ranges from 18 to 25 kg)
- The indigenous pig breeds are high fertility and have good reproductive characters such as litter size and farrowing intervals
- Bampudke pigs are found in both domestic and wild form

6.4.5.1.2 Morphological measurement of indigenous pigs

Chwanche pig

The average body length, height at withers, height at hipbone and heart girth of this breed is 75.9±2.1 cm, 55.9±1.84 cm, 54.6±1.51 cm and 86.3±3.37 cm respectively. The average adult weight of this pig is 35 (25-40) kg.

Hurrah pig

The average body length, height at withers, height at hipbone and heart girth of this breed is 79.5±1.75 cm, 61.1±1.2 cm, 62.1±1.07 cm and 87.7±2.18cm respectively. The average adult weight of this pig is 45 (40-55) kg.

Bampudke pig

The average body length, height at withers, height at hipbone and heart girth of this breed is 45.7±3.30 cm, 39.6±2.71 cm, 34.5±2.94 cm and 51.8±2.42 cm respectively. The average adult weight of this pig is 20 (18-25) kg.

Table 6.2 Morphological body parts measurements of indigenous pigs (means ± standard errors)

Traits	Hurrah pigs	Chwanche pigs	Bampudke pigs
Body length (cm)	79.5±1.75	75.9±2.1	45.7±3.30
Heart girth (cm)	87.7±2.18	86.3±3.37	51.8±2.42
Wither height (cm)	61.1±1.2	55.9±1.84	39.6±2.71
Height at hip bone (cm)	62.1±1.07	54.6±1.51	34.5±2.94
Head length (cm)	29.2±0.54	26.5± 0.7	25.8±1.25
Neck length (cm)	9.78±0.37	7.6± 0.43	7.6±0.43
Ear length (cm)	13.2±0.43	11.1± 0.46	14.5± 0.67
Tail length (cm)	26.8±0.8	25.3±0.9	19.5±0.63
Adult weight (kg)	45 (40-55)	35 (25-40)	20 (18-25)
Fore feet above knee (cm)	19.7±0.72	15.9±0.84	-
Fore feet below knee (cm)	18.0±0.71	14±0.7	-
Rear feet above hock (cm)	23.0±0.81	21.6±0.68	-
Rear feet below hock (cm)	23.4±0.75	18.7±1.0	-

Source: Annual report, ABD (1997); Rasali et al. (1998) and Neopane (2006)

Characterization of wild pig

Bandel (*Sus scrofa*) (Shrestha, 2014)

- Grey to brown body color
- Rough hairs
- Horizontal brown color stripes on the body of piglets that disappear later
- Straight drooping tail
- Long straight snout
- Strong legs

Characterization of synthetic breeds

Pakhribas Black Pig (Shrestha, 2014)

The most popular synthetic breed of pig named as 'Pakhribas Black', developed by crossing five different breeds, British Shaddleback (63%), Chinese Fayeun (18%), Tamworth (9%), Large White (5%) and Hampshire (5%) as reported by Wilson (1997). They are very popular in the eastern hills of Nepal as well as in India and Bhutan as some of the ethnic people of these countries because of their black body color which has significance in their culture (Aryal, 1992; Shrestha, 2000; Neopane, 2005).

- Black in color
- Adult body weight ranges from 150 to 180 kg
- Snout straight with medium length
- Smooth face without wrinkled skin
- Moderate drooping ears
- Shining black hairs
- Short Legs with moderate to long body
- Resistant to parasites and diseases
- Long and curved tail

Dharane Kalo Bangur (Shrestha, 2014)

- Putatively a mixture of indigenous Chwanche and the synthetic Pakhribas black pig (Nidup 2010).
- Black in color
- Medium body size, adult body weight ranges 80-120 kg
- Smooth Face (No wrinkles on face)
- Moderate to drooping ears
- Medium to short length and straight snout

Introduced exotic pigs

- Large White Yorkshire
- Middle White Yorkshire
- Landrace
- Hampshire (Saddleback)
- Duroc
- Fayuen
- Tamworth
- Meishan
- Berkshire (semen)

Among these, Yorkshire, Landrace, Hampshire and Duroc are widely used.

6.4.5.2 Characterization on Chromosomal level

The karyotype organization of two identified pigs of Nepal (Hurrah and Chwanche) was found to be the same (Dohge *et al*., 1989; Tsunoda, 1989). The number of chromosomes was 2n = 38, with 10 metacentric, 10 sub-metacentric, 12 acrocentric and 4 telocentric. The X chromosome was metacentric (maximum) and the Y chromosome was metacentric (minimum) (Table 6.3). Cytogenetic studies of Bampudke breed is yet to be done. Similar metaphases spread was reported in the exotic breeds (Yorkshire, Landrace and Hampshire) found in Nepal (Dohge *et al*., 1989).

Table 6.3 Chromosomal characterization of indigenous pigs

Breeds	Sex chromosome	Autosome chromosomes				Total
		Acrocentric	Metacentric	Sub-metacentric	Telocentric	
Hurrah	X: metacentric; Y:minute metacenter	12	10	10	4	38
Chwanche	X: metacentric; Y:minute metacenter	12	10	10	4	38

Source: Dohge et al. (1989); Tsunoda (1989)

6.4.5.3 Molecular Characterization

Molecular studies are done in Hurrah, Chwanche and Kalo Dharane bangur/ sungur using different molecular markers such as microsatellite markers and mitochondrial DNA marker.

Microsatellite markers

To investigate their genetic structure and diversity, Hurrah (NKH), Kalo Dharane Sunggur (NKD), and Chwanche breeds from Nepal was genotyped using 21 microsatellite markers. The number of alleles, heterozygosities, genetic distances, and genetic variations within and among populations were estimated. The analysis confirmed genetic distinctness of the Hurrah (NKH), Kalo Dharane Sunggur (NKD), and Chwanche breeds in Nepal as they have unique phenotypic characteristics (Figure 6.3). The sampled pig populations did not contain admixed individuals. Similarly, the Nepalese pigs, NKH and NKD also showed a high level of genetic diversity with mean of 0.74 ± 0.03 and 0.75 ± 0.02 respectively which has shown that there is very less selection within the population.

NKD were expected to display a higher level of genetic diversity than NKH since they are putatively a mixture of indigenous Chwanche and the synthetic Pakhribas Black Pig, which is a blend of British Saddleback, Chinese Fayeum, Tamworth, Large White and Hampshire (Neopane & Kadel 2008). However, the difference is trivial. Further, NKD showed no tendency to cluster with AC, perhaps suggesting that the exotic contribution to this breed has been substantially diluted out by crosses to indigenous Chwanche. NKH are unique indigenous pigs raised for meat by the poor communities of Terai region of Nepal (Nidup et al. 2010). Despite sampling from only one district, the high genetic diversity observed in NKH is possibly due to free-range and scavenging system of rearing which allows unselected mating. Although its population is declining (Joshi 2006), there is potential for conservation of Hurrah (NKH) pigs.

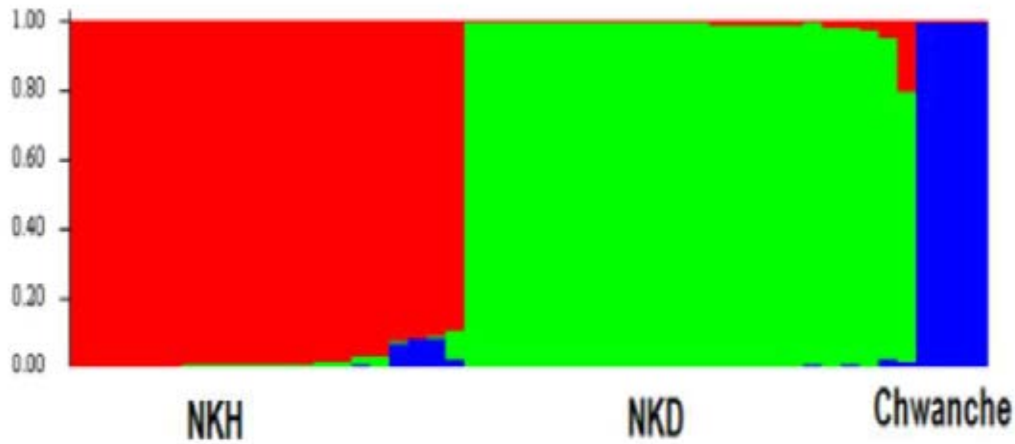

***Figure 6.3 Inference of Nepalese pig populations shown distinct genetic background of three populations of pigs (Nidup K, 2011.** Genetic Structure and Biodiversity of Pigs (Sus scrofa) in South Asia and Papua New Guinea, PhD Dissertation, https://ses.library.usyd.edu.au/handle/2123/10488)*

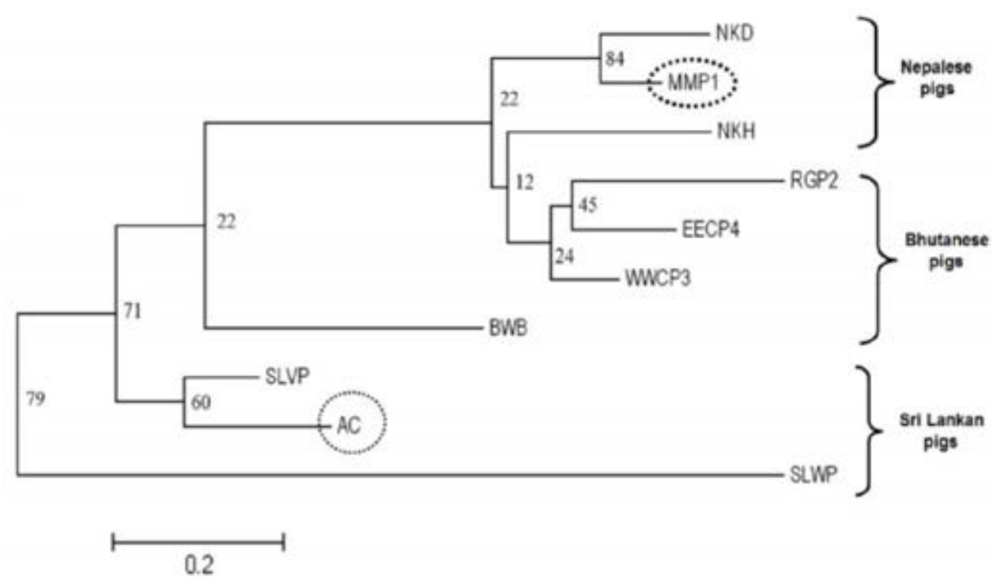

Figure 6.4 The NJ dendogram shows genetic relationships amongst South Asian pigs.

Source: Nidup K, 2011

Mitochondrial phylogeography

When analyzing the time of pig farming in Nepal using mitochondrial DNA marker, ancient sequence from Nepalese domestic pigs suggests that Nepalese were farming pigs at least 1,500 years ago. This scientific evidence is also supported by the culture of some castes within the ethnic Nepali in Nepal still sacrifice black pigs to implore local deities (deota) for bountiful crop yields, and good health and safety of the whole family (Nidup *et al.,* 2010).

Mitochondrial DNA diversity study also provides support for an independent cryptic domestication centre in the foothills of Himalayas and Indian sub-continent as domestic pigs of Nepal, Bhutan and Northeast India shared haplotypes (Nidup et al 2010). In the absence of corroborated archaeological or fossil evidence, this could also be explained by introgression of maternal genes from wild boar to domestic pigs (mediated by human migration). Furthermore, some Nepalese pigs cluster together with wild boar indicating close association and integration between two species. Since the government is promoting European pigs to cross with domestic pigs, which is clear evident by introgression of European genes into the domestic pigs of South Asia, including Nepalese pigs (Hurrah).

6.5 Production performance of indigenous pigs

6.5.1 Growth performance of indigenous pig

Chwanche pig

Chwanche produces the first progeny at an age of 10.7 months with an average birth weight of 0.7±0.06 kg. They attain about 33.2±0.08 kg body weight at one year of age. The Chwanche pigs are the medium sized pigs amongst the indigenous breeds (Table 6.4).

Hurrah pig

Hurrah produces the first progeny at an age of 14 months with an average birth weight of 0.8±1.2 kg. They attain about 41.6± 0.09 kg body weight at one year of age. The Hurrah pigs are the largest sized pigs amongst the indigenous breeds (Table 6.4).

Bampudke pig

Bampudke produce the first progeny at an age of 11.5 months with an average birth weight of 0.6±0.08 kg. Their average adult body weight is 20 kg (ranges from 18 to 25 kg). The Bampudke pigs are the smallest sized pigs amongst the indigenous breeds (Table 6.4).

Table 6.4 Body weights of indigenous pigs at different ages in Kg (means ± standard errors)

Traits	Hurrah	Chwanche	Bampudke
Birth wt	0.8±1.2	0.7±0.06	0.6±0.08
Weaning wt (6 wks.)	6.1± 0.09	5.7± 0.08	NA
6-month wt	22.7± 0.09	18.8± 0.07	NA
9-month wt	32.6± 0.08	26.2± 0.09	NA
12-month wt	41.6± 0.09	33.2±0.08	NA
Adult wt	45 [40-55]	35 [30-40]	20 [18-25]

Sources: Annual Report, ABD (1997) and Pradhan (1999)

6.5.2 Reproductive production performance of indigenous pig

Chwanche pig

Age at first service, age at first farrowing and farrowing interval of Chwanche pig were recorded to be 7.3±0.85, 10.7±0.80 and 7.4±0.6 months, respectively. The average litter size at birth of this breed is 7.33±1.28 (Table 6.5).

Hurrah pig

Age at first service, age at first farrowing and farrowing interval of Hurrah pig were recorded to be 10.8±0.99, 14.0±0.96 and 5.57±0.57 months, respectively. The average litter size at birth of this breed is 7.04±1.26 (Table 6.5).

Bampudke pig

Age at first service, age at first farrowing and farrowing interval of Bampudke pig were recorded to be 6.2±0.12, 11.5±0.23 and 4.6±0.28 months, respectively. The average litter size at birth of this breed is 4.7±0.27 (Table 6.5).

Table 6.5 Production parameters of indigenous pigs (Values are means ± standard errors)

Traits	Hurrah pigs	Chwanche pigs	Bampudke pigs
Age at 1st service/puberty (months)	10.8±0.99	7.3±0.85	6.2±0.12
Age at 1st farrowing (months)	14.0±0.96	10.7±0.80	11.5±0.23
Farrowing intervals (months)	5.57±0.57	7.4±0.6	4.6±0.28
Gestation length (days)	114.5±0.66	114.8± 0.52	-
Litter size at birth (no)	7.04±1.26	7.33±1.28	4.7±0.27
Litter size at weaning (no)	5.73±1.25	6.0±1.0	3.4±0.30
Birth weight (Kg)	0.8±0.08	0.7±0.06	0.6±0.08

Sources: Annual Report, ABD (1997); Pradhan (1999); Pandit et al. (2001) and Neopane (2004)

6.6 Future prospects

Average pork production of pigs in the country is increasing day by day. Despite of huge demand of pork, pig farming is neglected in most of the communities. Indigenous pig breeds represent 80% of the pig population. Indigenous breeds are popular due to their positive attributes. Indigenous pigs are successfully reared in low investment as well as well adopted in Nepalese clay in comparison to exotic breeds. Pork meat is very popular in different arena of the country. Despite low meat production than exotic breeds, local breeds are preferred to a great extent by consumers. Indigenous breeds have several other positive attributes such as hardiness and adaptability to local harsh conditions. Indigenous breeds have demonstrated their ability to produce in low external input system where the exotics can't cope with. For example, Indigenous pigs (Chwanche and Hurrah) are raised by under privileged people of hilly and Terai region in scavenging situation. They play an indispensable role for rural livelihood in the Terai and hilly region of Nepal. Religious, cultural and economic values in certain hill tribes are additional attributes for their preservation. There should be certain special programs and breeding policies to maintain indigenous breeds.

The native breeds of pig have given immense contribution in meat production. Today, most of the castes consume wild pig (*Badel*) rather than domestic pig (Chwanche and Hurrah). Badel meat is famous for its taste. Badel (wild pig) farming will be increased in the form of commercial industry due to its huge demand in star hotels and special ceremonies. Badel is also reputed for its sausage production. Besides that, these animals are providing manure that is being used for increasing/ maintaining soil fertility. Farmers have now kept pigs in large number to uplift the economic status and sustaining livelihood. Despite of rapid growth of pig farming, farmers have compelled to bear inbreeding problems in native pigs and mating problem in Badel.

The National Animal Breeding and Genetics Research Centre have initiated Artificial insemination programs in some exotic pigs. The Centre has proposed collection, evaluation and production of semen of native and exotic pig's projects since fiscal year 2065/66. The Centre has its own gene bank where semen of some exotic breeds; Landrace and Yorkshire are cryo-preserved for enhancing the productivity. In near future the Division should produce semen of endangered and rare indigenous pig of the country.

Bampudke pigs are the smallest breed and are about to be extinct in Nepal. There is an urgent need to develop and implement plan and programs at local level for in-situ conservation of different indigenous pigs. Our indigenous population of pig has low productivity and is necessary to upgrade these by crossing with some exotic breeds. Artificial insemination is the most efficient tool to conserve indigenous breed as well as to increase the productivity by crossing them with exotic breeds. Pakhribas pig was accepted by the farmers in eastern Nepal because of prolific and good mothering ability. Oli (1986) reported that the introduction of the Pakhribas pig increased the earning capacity of a farmer by 87% compared to raising indigenous pigs. Now a day, they have been highly inbred and productivity is declining. Therefore, development of its second generation is required. They can be established as a good breed for the farmers in eastern Nepal.

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7. INDIGENOUS CHICKEN BREEDS OF NEPAL

Sakini chicken male

Ghanti Khuile chicken male

Pwankh Ulte chicken male

Pwankh Ulte chicken female

Indigenous chicken in the market

Indigenous chicken in scavenging

Luinche (wild chicken in Nepal)

Sakini chicken flock at NABGRC, Khumaltar

7. INDIGENOUS CHICKEN BREEDS OF NEPAL

7.1 Zoological Classification of chicken

Kingdom	Animalia
Phylum	Chordata
Class	Aves (Birds)
Order	Galliformes
Family	Phasianidae
Genus	*Gallus*
Species	*gallus domesticus*

7.2 Overview of chicken in Nepalese context

The chicken is one of the most ubiquitous domesticated animals which is bred for both egg and meat. Backyard chicken farming has played a significant role in rural households of Nepal and meeting their social, economic, cultural and nutritional needs (Dube et al., 2010; Yusuf, 2014; FAO, 2014; Wong et al., 2017). Production of backyard chickens requires less investment, limited land and minimal knowledge of handling. Indigenous poultry production constitutes about 70 percent of poultry products in developing countries (Daikwo et al., 2011 and Mekonnen et al., 2010), whereas in Nepal it occupies about 55 percent share of total poultry production (MOAD, 2014; MOAD, 2015) and contributes 17.6 percent of total meat production (MoALD, 2019) of the country. However, they are least prioritised as expected mainly because of their low productive performance. There are 82.6 million chicken in the country (MoALD, 2019). Chickens from exotic origin is higher in number in urban areas where commercial level of production exists including both layers and broilers. This suggests that despite of being highly established sector among livestock commodities, still indigenous chicken population is high and contributes a lot to the national economy. This figure is much higher for urban areas like Kathmandu, Pokhara, Nepalgunj, Biratnagar and Chitwan. Chicken is highly preferred over other meat in the country. Most indigenous chickens are raised under semi-intensive and extensive management system with different breeds having intriguing features (Simainga et al., 2011) and are well known for their tropical adaptability and disease resistance, with their plumage colour serving as a protective means against predators (Abdelqader et al., 2007 and Melesse, 2014).

Chickens are primarily kept for meat and eggs and provide animal protein to human beings and manure for maintaining soil fertility. Along with, they have cultural and social values. For several ethnic communities such as Tharu, Derai, Magar, Tamang etc., chicken are used for sacrificing in different religious activities and festivals. It is distributed throughout the country from Terai plain land of southern border (64 masl) to high mountains of northern hills (3000 masl) across the country (Sapkota et al., 2020). The price of chicken meat has not increased tremendously over last 20 years and the trend of increment has been consistence as compare to other species suggesting chicken meat production has become efficient and accessible to every economic level of people. This efficient chicken production had become only possible due to larger involvement of private entrepreneurs supported by high producing dual purpose and synthetic broilers/layers breeds. Chicken is the cheapest meat and is highly preferred by most of the people of all age groups. There are about 75.71 millions of fowl in the country (MoALD,

2019) which contributes 9% of total AGDP. Distribution of fowl population, meat and egg production across the different provinces of Nepal are presented in Table 7.1.

Table 7.1 Province-wise distribution of chicken population, meat and egg production during FY 2019/20

Provinces	Population (No.)	Meat production(MT)	Laying hen (No.)	Egg production (No. in '000)
Province 1	8,621,288	8,529	1,671,533	241,432
Madhesh	4,497,818	5,740	811,793	106,646
Bagmati	41,564,880	28,085	6,794,498	802,562
Gandaki	5,989,704	5,572	895,574	106,848
Lumbini	10,271,826	9,624	1,675,763	187,324
Karnali	1,949,269	1,964	209,230	26,278
Sudurpashchim	2,814,545	3,386	468,588	63,590
TOTAL	**75,709,330**	**62,899**	**12,526,979**	**1,534,680**

Source: MoALD, 2020

7.3 Origin of domestic chicken

Various researchers agreed that chickens were first domesticated from a wild form called Red Jungle Fowl (*Gallus gallus*), a bird that are still found in wild form in most of southeast Asia, most likely hybridized with the grey jungle fowl (*G. sonneratii*), probably about 8,000 years ago (Hata et al., 2021). Recent research suggests, however, there may have been multiple other domestication events in distinct areas of Southeast Asia to Southwest China, Thailand, Burma, and India is thought to have originally been domesticated from the Red Jungle Fowl (*Gallus gallus*) native to multiple regions from Southeast Asia to Southwest China (Fumihito et al., 1994; Liu et al., 2006; and Miao et al., 2013). Study on genetic diversity of indigenous Nepalese Sakini chicken indicated that this breed was also originated from Red Jungle Fowl from Indian Sub-continent (Sapkota et al., 2021).

Chicken domestication was previously considered to have occurred in the Indus Valley at around 2000 BC (Zeuner, 1963). However, West and Zhou (1988) proposed an earlier origin in Southeast Asia, before the 6000 BC, based on archaeological evidence from China, Southeast Asia, and Europe, and palaeo-climatic evidence in China. Chickens were initially used for rituals, including the use of a crowing cock to proclaim the hour of dawn, and later, various cock-fighting and pet breeds were produced and raised around the globe. Commercial chicken breeds, including layers and broilers, have been bred over the last 100 years through selective mating of various indigenous breeds (Crawford, 1984; Rubin et al., 2010; and Elferink et al., 2012).

The process of chicken domestication through the breeding of indigenous chickens has an approximately 8000 year-long history. Consequently, over the years, indigenous chickens have acquired diverse genetic characteristics that have facilitated adaptation to different challenging conditions in diverse locations (Hall & Bradley, 1995), such as heat stress, humidity (Lawal et al., 2018; Walugembe et al. 2019) and disease (Bobbo et al. 2013). Recently, the crossbreeding of indigenous chickens with common commercial chickens has been actively performed to develop breeds that exhibit the aforementioned desirable traits. However, repeated crossing with commercial chickens decreases the genetic diversity of indigenous chickens, resulting in the loss of genetic resources in the latter populations (Ravindran, 2013). In addition, in Southeast Asia, genetic contamination of the ancestral species via crossing of red junglefowl with free-range indigenous chickens has become a major concern for conservation biologists. Consequently, genetic characterisation of red junglefowl and indigenous chickens is essential to reveal the potential genetic erosion in the former. In addition, the results of such activities could facilitate the adoption of appropriate strategies to recover and conserve the genetic diversity of the species, which represents an invaluable genetic resource (Hata et al., 2021).

7.4 Indigenous chicken breeds of Nepal

There are three indigenous breeds of chicken identified so far in the country and registered in FAO global assessment of animal genetic resources. They *are Sakini, Ghanti Khuile* and *Puwankh Ulte* (Neopane, 2006; Neopane & Gorkhali, 2008; Pokharel et al., 2012). *Sakini* is very common and are found throughout the country. *Ghanti Khuile* or naked feather is considered to be tastier in meat quality than *Sakini* or full feather type. These chickens have good brooding and mothering ability and resistance to diseases and hence are popular in rural areas (Bhurtel, 1998; Neopane & Gorkhali, 2008; Pokharel et al., 2012). *Puwank Ulte* is another indigenous hardy breed found throughout the country in a limited numbers. The details of each breeds with their characteristic features and breed related studies till date were presented in this chapter.

7.4.1 Demographic distribution of indigenous chicken breeds of Nepal

Sakini

Sakini chicken are located throughout the country. They have a wide range of adaptability from tropical to temperate region. They are mainly used for meat and eggs. They are hardy and suitable for scavenging conditions. They are found in different colour ranging from white to dark (black, brown, shiny red) with mixed colour as well. They have been characterized at phenotypic (Neopane & Gorkhali, 2008; Pokharel et al., 2012; Sapkota et al., 2020) and mtDNA level (Sapkota et al., 2021).

Ghanti Khuile

Ghanti Khuile chicken are located throughout the country in a limited number. They are good scavenger birds, hardy and well suited to local environments. They are found in different colour. They have been characterized at phenotypic level. They are at risk from conservation point of view.

Puwankh Ulte

Puwankh Ulte chicken *a*re located throughout the country in a limited numbers. They are hardy and dual purpose suitable for meat and eggs. They have ruffled feathers. They are rarely found and need immediate conservation attention. They are found in different colour. They have been characterized at phenotypic level. They are at risk from conservation point of view. Apart from these breeds there are number of introduced breeds both for meat and eggs. The common breeds are New Hampshire, Black Australorp and Giriraja as dual-purpose breeds. Among commercial synthetic broiler breeds the most commonly used are Hubbard, Cobb 100, Kegbro and Saver Star brow. For synthetic layers commonly used breeds are Hyline Brown, Isa Brown; Key Stone Brown and Lohman Brown.

There are some breeds of ducks available in the country but characterization work has not been done so far. Maskavi and White Peking ducks are commonly found in the country. Quails are found in wild forms in the country. However, during the last 10 years domestic quails were introduced. Three broilers lines and one layer line of domestic quails were introduced to the country for their study. The results indicated that they can be reared successfully (Karki, 2002). Pigeons are quite popular in the rural areas particularly in terai region of the country where they are eaten as meat. The information on breeds is not available as works on this species have not been initiated. Turkey has been recently introduced in the country and results obtained so far indicated that they can be successfully reared in the country (Karki and Sah, 2006).

7.4.2 Status of chicken breeds

Sakini chicken are considered to be found across the country and in all agro-ecological zones of Nepal (Sapkota et al. 2013; Gorkhali & Bhusal, 2015; and Sapkota et al. 2020); other two breeds are critical from conservation point of view. Both Ghanti Khuile and Puwankh Ulte are found in limited numbers and hence they need special attention for conservation (Neopane, 2004; and Neopane, 2006). It is reported by the farmers that they (Ghanti Khuile and Puwankh Ulte) are hardier and resistance against diseases than the Sakini. They also produce tastier meat than the Sakini. (Please refer to Chapter 1, Table 1.1 for detailed status of chicken in Nepal.)

7.4.3 Positive Attributes

In general indigenous breeds are low producing than the exotics in terms of meat and eggs production. However, they have several other positive attributes such as hardiness, adaptability to local harsh climatic as well as management conditions and can produce in low input system. It is observed that these positive attributes are not duly recognized rather exotics breeds are unnecessarily given preference over them. Unique organoleptic characteristics such as rich flavours and chewy texture of meat contribute to the higher popularity of indigenous chicken in many south Asian countries. Apart from these, chickens provide nutritious egg and meat for human consumption and manure for soil fertility.

Unemployed youth and women can also earn an income through chicken farming. The native breed chickens are the reservoir of genomes and major genes for improvement of high yielding exotic germplasm for wider adaptableness and disease resistance while their plumage colour helps in protecting themselves against predators. The low production performance of native breeds of chickens may be improved through improvement in husbandry practices, better healthcare, and supplementary feeds during lean season and also through selection and crossbreeding (Padhi, 2016). (Please refer to Chapter 1, Table 1.1 for detailed status of chicken in Nepal.)

7.4.4 Socio-cultural and economic significance

Indigenous chickens, in many rural households, are kept by poor families, providing them employment, family proteins and means of increasing family economic gains. Farmers have been traditionally raising different breeds of indigenous chickens for religious purpose, family consumption and for sale. Ethnic tribes across Nepal such as Tamang, Derai, Tharu and Magar sacrifice lots of indigenous chicken that are bigger, healthy, with bright colors during various ceremonies, festivals, and for guest hospitality. Chicken and eggs provide a readily available, high quality and inexpensive source of proteins, vitamins, and micronutrients accepted by all ethnic groups and important for children and nursing mother. Chickens are the source for pest control with minimum environmental impact (Kattel, 2016). Farmers preferred to raise indigenous chickens because of unsuitability of commercial chickens for religious ceremonies;

extra skill, space, labor and capital requirement for commercial chickens; preference for meat and eggs of the native chickens; and the income from indigenous chickens is higher. However, the productivity of indigenous chickens is not encouraging, so more education and support on chicken keeping is essential to enhance a positive economic impact on the local communities. Socially accepted technology with sustainable environment should be worked out by government and non-government organizations for rural poultry development (Bhurtel, 1995).

7.4.5 Characterization of Indigenous chicken breeds

Majorities of the indigenous chicken found in the country are full feathered and few are naked neck and frizzled feathers. In full feather chicken, all part of the body from head to the hock joints is fully covered by feather. In case of naked neck chicken some variation on the area of featherless skin are observed (Bhurtel, 1996), mainly at neck area. However, in some cases, tufts of feathers are found in the front portion of the neck. In addition, Pwankh Ulte chickens have feathers curved outwards all over the body, rather than lying flat giving chicken distinct breed characteristics. The plumage colour tends to vary according to agroecology. In plains of Nepal more grey, cream and brownish red colour are found, whereas brownish red and black colour are found in temperate region (Bhurtel, 1996), but overall brownish red is the most common dominant across the country.

This could be attributed to the Red Jungle Fowls from where the indigenous chickens are originated (Sapkota et al., 2021). Majority of them has single comb with white ear lobe and yellow shank, but few has pea or rose comb with red or pink ear lobe. Nishida *et al.* (1988) studied the external characters of indigenous chicken found in jungles of India and Nepal and reported that the indigenous chicken in Nepal are closer to those in from Asian sub-continent.

7.4.5.1 Phenotypic characterization of indigenous chicken

7.4.5.1.1 Physical characteristics of indigenous chicken

Sakini

- Sakini is an attractive breed among three indigenous breeds of chicken in Nepal.
- The feather color varies from black to red, spotted black and white, red and white, red and black.
- Skin color varies from white to yellow.
- Earlobe color of sakini chicken varies from pink to red.
- Shank is yellow to brown in color.
- This breed has single or rose type comb of red color.
- They have brown to black legs.

Ghanti khuile

- They have featherless neck i.e. naked neck.
- Ghanti khuile chickens have black to red or some times red and black feather color.
- They have white to yellow skin color.
- Ghanti khule chickens are characterized by pink to red ear lobe color.
- Their Shank is yellow to brown in color.
- Ghanti khuile chicken have red colored single or rose type comb.
- They are also characterized by brown to black legs.

Pwankh ulte

- They have ruffled feathers (like porcupine) curved outwards all over the body.
- They comprise with Sakini breed in their feather color.
- Skin color of Pwankh ulte chicken is white to yellow.
- Pwankh ulte chicken have pink to red earlobe color.
- Shank is yellow to brown in color.
- Pwankh ulte chicken have single or rose type comb of red color.
- They have brown to black legs as other indigenous breeds of chicken.

7.4.5.1.2 Morphological measurement of indigenous chicken

Table 7.2 Morphological body parts measurements of indigenous chicken (Values are means in cms ± standard errors).

Traits	**Sakini**	**Ghanti Khuile**	***Puwankh Ulte***
Body length	18.7±0.51	18.8±0.19	*16.2± 0.70*
Wither height	27.6±0.82	30.6±1.56	*27.2± 1.13*
Comb length	4.9±0.56	5.9±0.87	*2.9± 0.15*
Leg length	8.8±0.37	9.2±0.37	*7.75± 0.16*
Wattle length	2.45±0.38	4.4±0.57	*1.41±0.08*
Feather length	14.7±0.93	17.6±3.10	*13.2± 0.87*
Toes length	5.35±0.24	5.6±0.37	*4.45±0.09*
Neck length	11.1±0.37	12.4±0.90	*9.5±0.25*
Colour of skin	Yellow	Yellow	Yellow
Colour of shank	Yellow	Yellow	Yellow
Type of comb	Single and rose	Single and rose	Single and rose
Colour of earlobe	Red	Red	Red
Colour of egg	*Brown*	*Brown*	*Brown*

Source: Shrestha (1995); Bhurtel (1996); Annual report, ABD (1997); Bhurtel (1998); Primary source from Nawalparasi and Lalitpur districts

Sakini*:* Sakini is the principal chicken breed in the country. *Sakini* is a hardy poultry breed found throughout the country. They are hardy and dual purpose suitable for meat (reputed for delicious meat) and eggs. They are found in different colour ranging from white to dark colour (black, brown) with mixed colour as well. They have been characterized at phenotypic level. They are normal and are not at risk from conservation point of view. They have an average body length of 18.7 cm and wither height of 27.6 cm. Toes length is 5.4 cm (Table 7.2).

Ghanti Khuile: *Ghanti Khuile* is a hardy chicken breed found throughout the country but in limited pockets with few numbers. They are good scavenger birds, hardy and well suited to local environments. They are found in different colour. They have been characterized at phenotypic level. Their population is very low and need conservation attention. They are at risk from conservation point of view. They have an average body length of 18.8 cm and wither height of 30.6 cm. Toes length is 5.6 cm (Table 7.2). They are good for meat and eggs.

Puwankh Ulte: *Puwankh Ulte* is a hardy chicken breed throughout the country but in limited pockets with few numbers. They are good scavenger birds, hardy and well suited to local environments. They are found in different colour and have ruffled features. They have been characterized at phenotypic level.

They are at risk from conservation point of view. They have an average body length of 16.2 cm and wither height of 27.2 cm. Toes length is 4.5 cm (Table 7.2). They are good for meat and eggs.

7.4.5.3 Molecular Characterization

Diversity using RADP Markers

The cluster analysis based on UPGMA clustering with 59 loci generated by 10 Random primers separates 20 Sakini birds of three different ecological zones into six major clusters in 88% similarity level (Figure 7.1). Whereas Maeda (1988) present three types of local chicken in Nepal. Bootstrap of 1000 replication was done which suggest highest recovery from resampling by RT4 bird of Rautahat and K17 bird of Rasuwa. Five regional chicken populations in the central part of Nepal were clustered into three groups. Among the five regions two regions were from high hills (2500 m), two regions from mid hills and one region from Terai. According to Dorji *et al.* (2012), there are 13 strains of native chickens in Bhutan. However, the FAO Domestic Animal Diversity Information System lists only 10 strains.

Diversity using Mitochondrial DNA markers

The mtDNA diversity of Sakini chicken was explored. For this analysis, blood samples from Sakini chickens of three different agro-ecological zones were collected. The genomic DNA extraction was carried out followed by PCR. Subsequently, sequencing was done. 20 polymorphic sites were found within 33 sequences resulting 14 haplotypes. The haplotype and nucleotide diversity is 0.813 with SD 0.065 and nucleotide diversity (Pi) is 0.00525 with SD 0.00091 respectively. The neighbour joining tree revealed that Red Jungle Fowl (RJF) from India could be potential progenitor of the Nepalese Sakini chicken (Figure 7.2). The genetic difference between Nepalese Sakini chickens were more close to Gallus gallus gallus than Gallus gallus bankiva. These haplotypes were subjected for assessed. The NETWORK analysis gave information that there exist four types of haplogroups (A1, E1, E2 and E3) within sampled population. Majority of haplogroups (n=17) belonged to E1 haplogroup. Rest of the Sakini chickens (n=8) lied in E3 and (n=7) beloned to E2 haplogroup. Only one haplogroup shared A1 haplogroup types. The overall result indicates that there is a genetic diversity within the Sakini population (Figure 7.3).

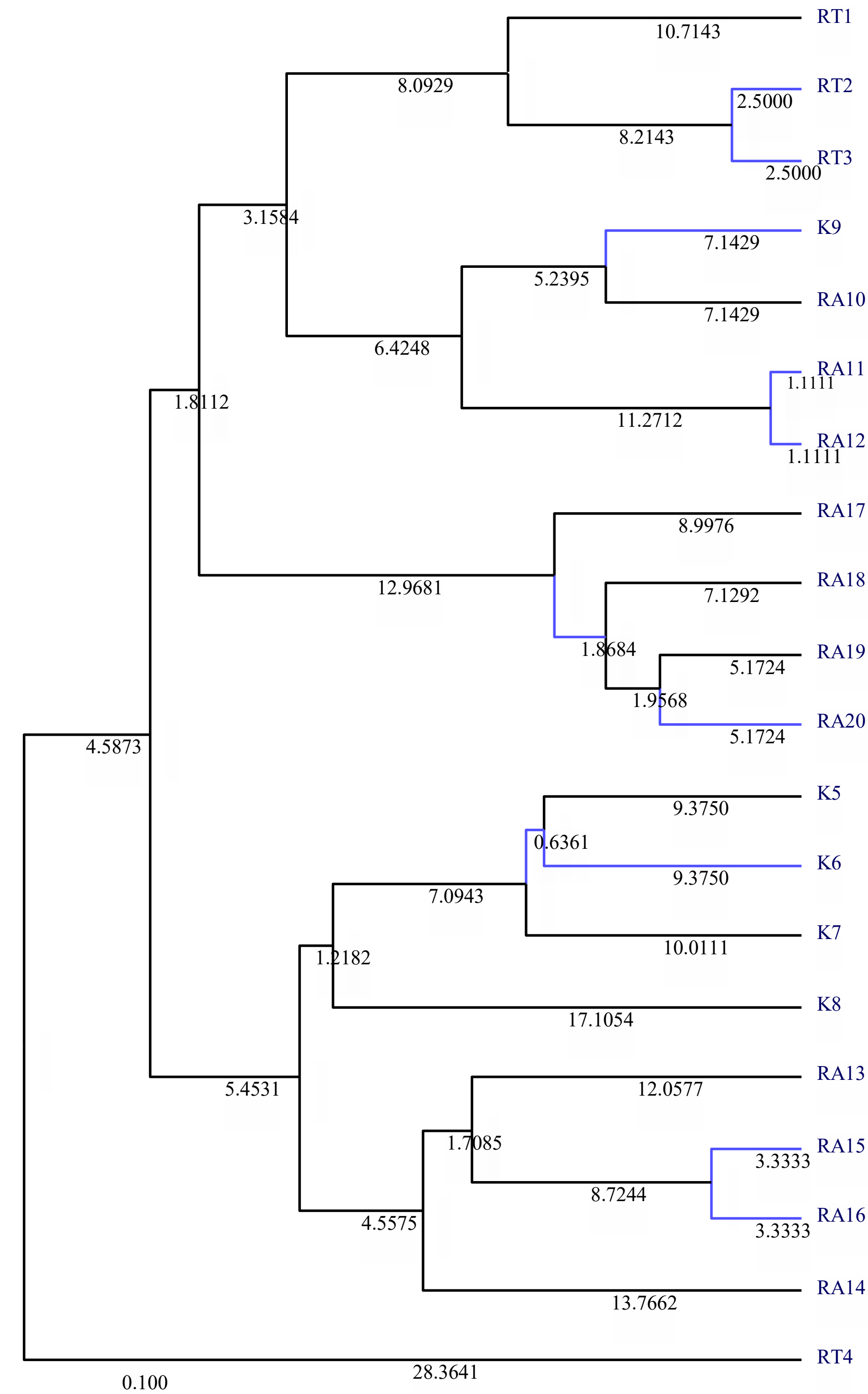

Figure 7.1 Dendrogram showing 20 Sakini breed based on Nei's Genetic Distance using UPGMA method with Bootstrap of 1000 replication

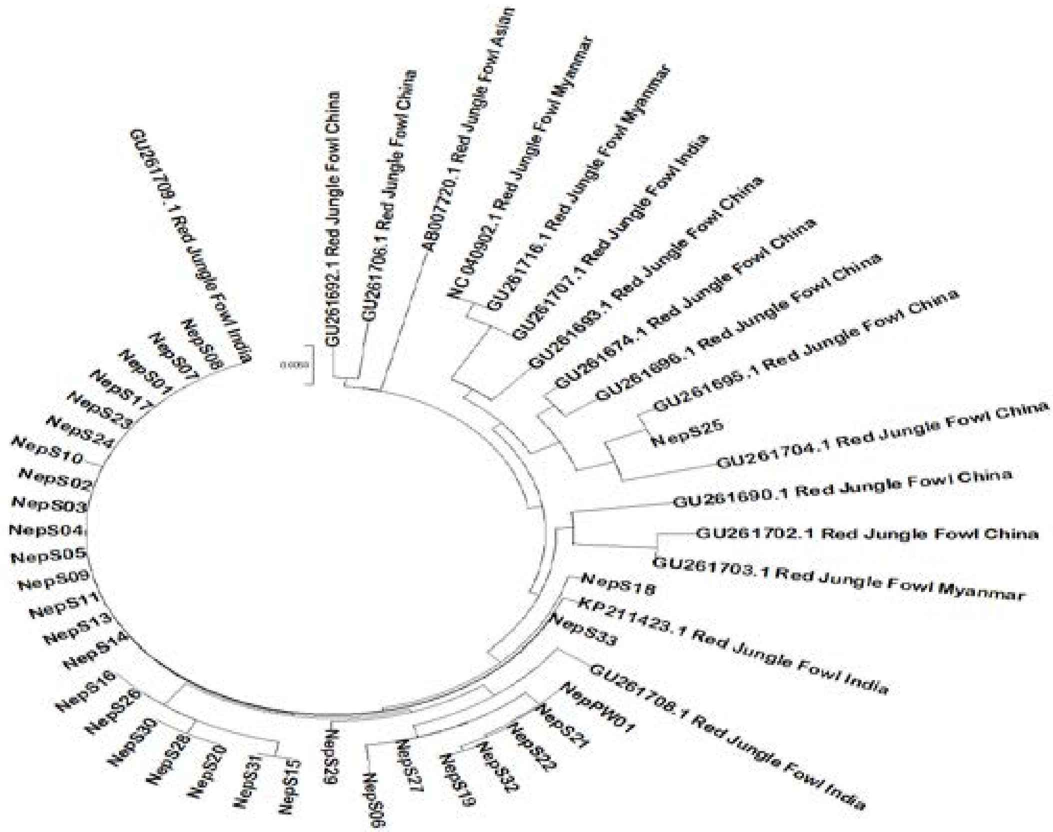

Figure 7.2 Unrooted neighbour joining tree of Sakini chickens against Red Jungle Fowls in the region

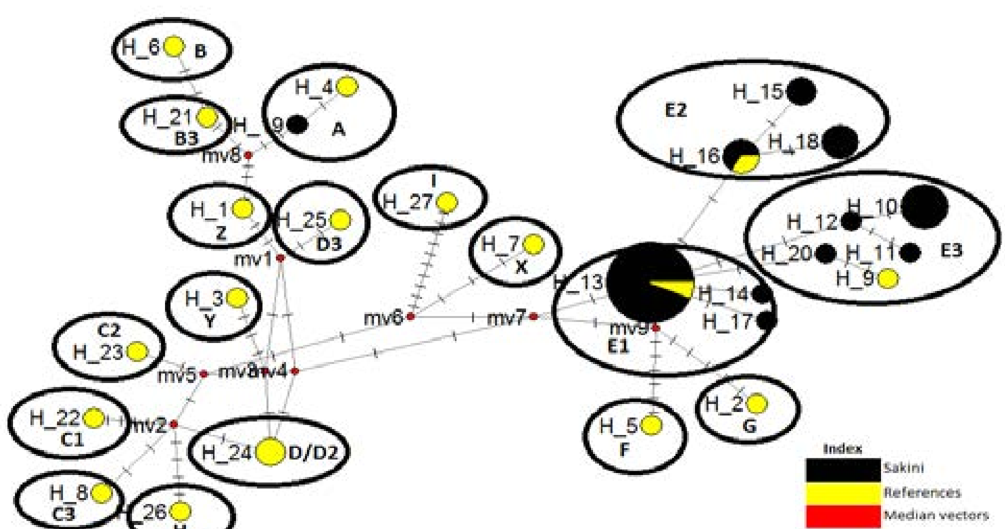

Figure 7.3 Network analysis of major haplogroups (A1, E1, E2, and E3) present in Nepalese Sakini chickens

Diversity using Microsatellite Markers

Microsatellite markers (20 MS markers) showed Nepalese Indigenous Sakini as a unique population in comparison to the other 22 Asian chicken indicates the importance of conversion of Sakini chicken.

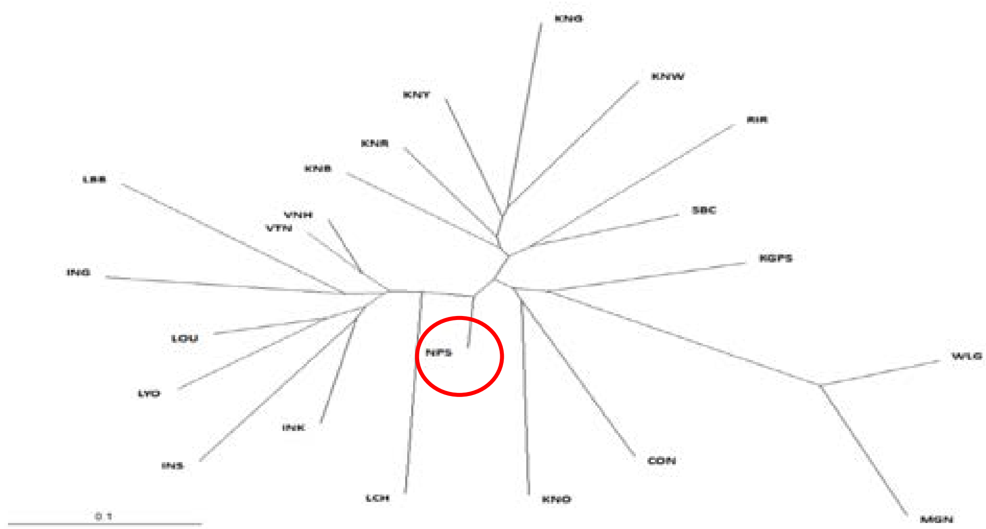

Figure 7.4 Neighbor-joining phylogenetic tree showing genetic relationships among 22 chicken breeds based on D_A genetic distance.

Above figure shows the genetic relationships among 22 chicken breeds. RIR, Rhode Island Red; WLG, White Leghorn; CON, Cornish; KNG, Korean Grayish-brown; KNB, Korean Black; KNR, Korean Reddish-brown; KNW, Korean White; KNY, Korean Yellowish-brown; KNO, Korean Ogye; MGN, Mongolian Nuthiin bor; INK, Indonesian KUB; INS, Indonesian Sensi; ING, Indonesian Gaok; KGPS, Kyrzyzstani GPS-H; LYO, Laotian York; LCH, Lotian Chae; LBB, Laotian Black Bone; LOU, Latotian Ou; NPS, Nepalese Sakini; SBC, Sri Lankan Junglefowl.

7.5 Production performance of indigenous chicken

Sakini

Sakini is a dual purpose chicken breed found throughout the country. They attain sexual maturity at 6 months and produce 60 to 80 eggs in a year. However, at intensive management, Sakini chicken can produce an average of 111 eggs/hen/year (Sapkota et al., 2020) with a range of 92 to 162 eggs per hen per year. Its adult body weight ranges from 1.5 to 2.4 kg in females and 1.8 to 3.0 kg in males (Table 7.3). They have good brooding characters having hatchability more than 90% under intensive management system.

Ghanti Khuile

Ghanti Khuile is a dual purpose chicken breed found through out the country but in limited pockets with few numbers. They attain sexual maturity at 5 to 6 months and produce 60 to 80 (average of 75) eggs in a year. Its adult body weight ranges from 1.5 to 2.2 kg in females and 1.8 to 2.8 in males (Table 7.3). They have good brooding characters having hatchability more than 85%.

Puwankh Ulte

Puwankh Ulte is a dual purpose chicken breed through out the country but in limited pockets with few numbers. They attain sexual maturity at 6 months and produce 60 to 80 (average of 55) eggs in a year. Its adult body weight ranges from 1.4 to 2.2 kg in females and 1.78 to 2.5 kg in males (Table 7.3). They have good brooding characters having hatchability more than 80%.

Table 7.3 Production performances of indigenous breeds of chicken (Values are means ± standard errors)

Traits	Sakini	Ghanti Khuile	Puwankh Ulte
Body weight at 8 weeks (days)	400-600	400-600	*400-600*
Age at 1st lay (days)	170±4.5	162±5.1	*176±3.9*
Body weight at 1st lay (kg)	1.04±0.02	1.14±0.06	*1.0± 0.04*
Egg production /hen/year (no.)	68±4.0	75±2.8	*52±2.9*
Egg weight (g)	40-45	40-45	*40-45*
Adult weight (kg)	Male: 2.4±0.05 (1.8-3.0) Female:1.8±0.05 (1.5-2.4)	Male:2.2±0.04 (1.8-2.8) Female:1.6±0.04 (1.5-2.2)	*Male:1.9±0.03 (1.7-2.5) Female:1.6±0.03 (1.4-2.2)*
Hatchability (%)	*85±3.5*	*86±4.0*	*80±4.1*

Source: Bhurtel (1996); Annual report, ABD (1997); Bhurtel (1998); Neopane (2004); Neopane (2006); Primary source from Nawalparasi and Lalitpur districts

7.6 Research on production performance of indigenous Sakini chicken and genetic improvement through selective breeding and crossbreeding

The productive and reproductive performances of chicken are the resultant of two major factors: one is genetic potential and the other is the environment such as feeding, health, care, shed and the ecological conditions. The genetic potential of an animal is inherited from its parents and is passed to off-springs. Through simple selection, animals with targeted characters are selected and thus the high genetic merit can be passed on the future generation. When selection is done over many generations, it results in improvement of targeted traits. The possibility of improvement in growth traits, production performance, hatchability, fertility and survivability of indigenous chickens through selective breeding over multiple generations has been widely reported (Gueye, 1998; Sahota et al., 2003; Anjum, et al., 2012; Islam et al., 2015; and Sapkota et al. 2020). Productivity of indigenous chicken breeds may be substantially doubled with selection, improved diets, management conditions and crossbreeding with other dual purpose available in the country (Somu, 2015; Sapkota et al., 2020; and Sapkota, 2021). Weekly body weight gain and production performance with respect to generations of selection of indigenous *Sakini* chicken is presented in Table 7.4 and Table 7.5.

Table 7.4 Least Square Means and Standard Error of Means (LSM±SEM) for weekly body weight gain with respect to generations of selection of indigenous Sakini chicken

Factors	LSM±SEM (g)				
	Hatch wt	12 weeks	16 weeks	20 weeks	24 weeks
Generations	$p<0.001$	$p<0.001$	$p<0.01$	$p<0.001$	$p<0.001$
Base population	-	759.5 ± 27.7^{c}	1070.9 ± 50.4^{b}	1370.3 ± 36.6^{c}	1570.9 ± 35.5^{d}
First Gen	33.2 ± 0.33^{b}	900.4 ± 24.2^{b}	1159.2 ± 53.5^{b}	1399.2 ± 32.4^{c}	1627.8 ± 40.1^{c}
Second Gen	34.9 ± 0.33^{a}	1180.2 ± 38.1^{a}	1444.3 ± 62.3^{a}	1641.6 ± 36.2^{b}	1874.4 ± 44.5^{b}
Third Gen	35.1 ± 0.24^{a}	1201.2 ± 24.3^{a}	1532.9 ± 56.1^{a}	1916.1 ± 49.6^{a}	2097.5 ± 52.9^{a}

Note: LSM- Least square mean, SEM- Standard error of means, N- Number of observation, Means having different superscript in the same column are significantly different (p<0.01 or p <0.001); G0- Base population; G1- First generation; G2- Second generation; G3- Third generation.

Table 7.5 Least Square Means for AFE, BWFE, EN90, EW90 and EHY of indigenous Sakini chicken in different generations of selective breeding

Factors	LSM±SEM				
	AFE (days)	BWFE (g)	EN90 (No.)	EW90 (g)	EHY (No.)
Overall Mean	162.7±1.1	1365.7±41.9	27.52±0.43	45.62±0.9	136.7±1.6
Generations	p<0.001	p<0.001	p<0.001	p<0.001	p<0.01
Base population	173.4±0.6[a]	1241.2±26.6[c]	23.43±0.32[b]	42.03±0.6[c]	111.9±1.6[b]
First Gen	164.7±0.8[b]	1292.2±31.7[c]	24.76±0.34[b]	45.62±0.7[b]	115.7±1.2[b]
Second Gen	157.9±0.9b[c]	1393.6±32.2[b]	31.28±0.40[a]	46.24±0.7[b]	162.3±1.2[a]
Third Gen	153.6±0.9[c]	1537.1±39.6[a]	31.73±0.41[a]	48.79±0.8[a]	157.5±1.1[a]

Note: LSM- Least square mean, SEM- Standard error of means, N- Number of observation; No.- Numbers; AFE- age at first egg laying, BWFE-body weight at first egg laying, EN90-egg number at first 90 days, EW90-Egg weight at first 90 days and EHY-egg production per hen per year; G0-Base population; G1-First generation;G2-Second generation;G3-Third generation; Means having different superscripts in the same column are significantly different (p<0.01 or p<0.001).

7.7 Future prospects

Indigenous farm animal genetic resources are vital to the development of sustainable agriculture in Nepal. In rural communities, the indigenous chicken are reared as an important source of protein and house hold income. Almost every farmer rears a few chicken near their homestead, and the birds are managed under a scavenging system. Although the native chicken in the country have lower productive performance than the exotic breeds, they have certain positive attributes which should not be overlooked such as their character of brooding is very important for farmers to breed the chick. The taste of indigenous poultry is commonly preferable and better paid.

Domestic animal population has changed significantly over the last century. Private initiative and Government programmes have resulted in the importation of exotic breeds of potential commercial interest and their subsequent propagation through crossbreeding with indigenous population. In case of poultry, importation of commercial hybrids and the development of successful commercial poultry enterprises have to a large extent replaced the scavenger chicken and backyard poultry raising.

Furthermore, a formal institution, such as Breed Association or Society, is absent to represent the Breeders' interest and the lack of promotion and publicity usually associated with the breed related activities have resulted in failure to characterize these populations. However, the fitness of the indigenous stock in their natural habitat through their production of meat and egg has been sufficiently recognized. Not only in poultry, but also in any of the identified indigenous animals have not been subjected to the scientific advances made in genetics, nutrition, reproduction, disease control and husbandry practices developed. Most of the work is undergoing in introduction of new breeds to improve the low productivity of the indigenous breeds and its adaptation in Nepalese climate and acceptance in Nepalese taste.

Dramatic increases in the size of commercial poultry farms, and tendency to use highly productive breeds has resulted in the loss of many indigenous animals at an alarming rate. Breeds like Pwankh Ulte and Ghanti Khuile are decreasing tremendously and need to be conserved. It is essential that in the marketing of specialty products, it is to be emphasized that value-added products are derived from the exploitation of indigenous livestock and birds raised without the use of chemical fertilizers, insecticides and growth stimulants. Furthermore, the technology and knowledge base to best exploit the indigenous animals' ability to adapt to their environment, to generate new revenue, need to be researched and developed. The advance in the field of molecular biology over the last two decades has been dramatic, increasing the understanding of the structure and function of genes, leading to identification, mapping and sequencing of the genome in livestock and poultry species. However, without further knowledge from molecular research, one cannot access on a strictly scientific bases.

Sakini, the principal breeds of chicken in the country are used for meat and egg production. Commercial breeds are dominating for supplying meat to urban people. The native chickens are tastier than commercial type for meat. They are resistant to many diseases and parasites. For better use of native breeds, their value in terms of meat taste (Native chicken meat is tastier than the broilers), hardiness and disease resistance should be valued in terms of economic, social and cultural terms. Native breeds have a potential for producing organic products that has high market value at the national, regional and international level. Examples are eggs produced from free range system and meat produced from native chicken. Similarly for better use of native breeds, conservation and improvement programme should be tied with and they should go simultaneously.

Good production performance of indigenous Sakini chicken in terms of growth and egg with continuation of selective breeding for successive generations until Sakini population with plateaued performance established for sustainability view point. Concerned institutions including government and private farms need to develop, maintain, and promote the improved nucleus flock of Sakini chicken for different agro ecological zones. Hence, this study has shown an opportunity to distribute such selected cockerels for the improvement of nationwide Sakini flock genetically.

Among the studied population, the results confirmed the probability of genetically superior germplasm of Sakini chicken available at high hills of cental Nepal. This germplasm could be an option to be considered for multilocational evaluation in other parts of the country. Based on the result of such multilocational experiments, concerned institution (extension) should dissiminate the developed technologies with complete package of practices.

The lines developed respectively for egg, meat and dual purpose traits have satisfactory production on-station and need a verification and performance evaluation trials under village condition through outreach research with separate husbandry practices which could be the gateway for the overall improvement of the productivity of backyard chicken of the country. Concerned institutions (NARC, Universities, extension and/or I/NGOs) should take over this research and work on stabilizing the lines, certify and release as three separate synthetic breeds.

The study showed the high level of genetic diversity within indigenous Sakini population. For sustainable development of indigenous chicken, apart from production performance, unique phenotypic traits signifying valuable local adaptations should also be given the utmost priority while considering for conservation and genetic improvement. With the advancement in the molecular studies, use of functional genomics aids to achieve the objectives in shorter period which could be the promising area to identify the specific genes concerned with economic important traits (growth and egg production).

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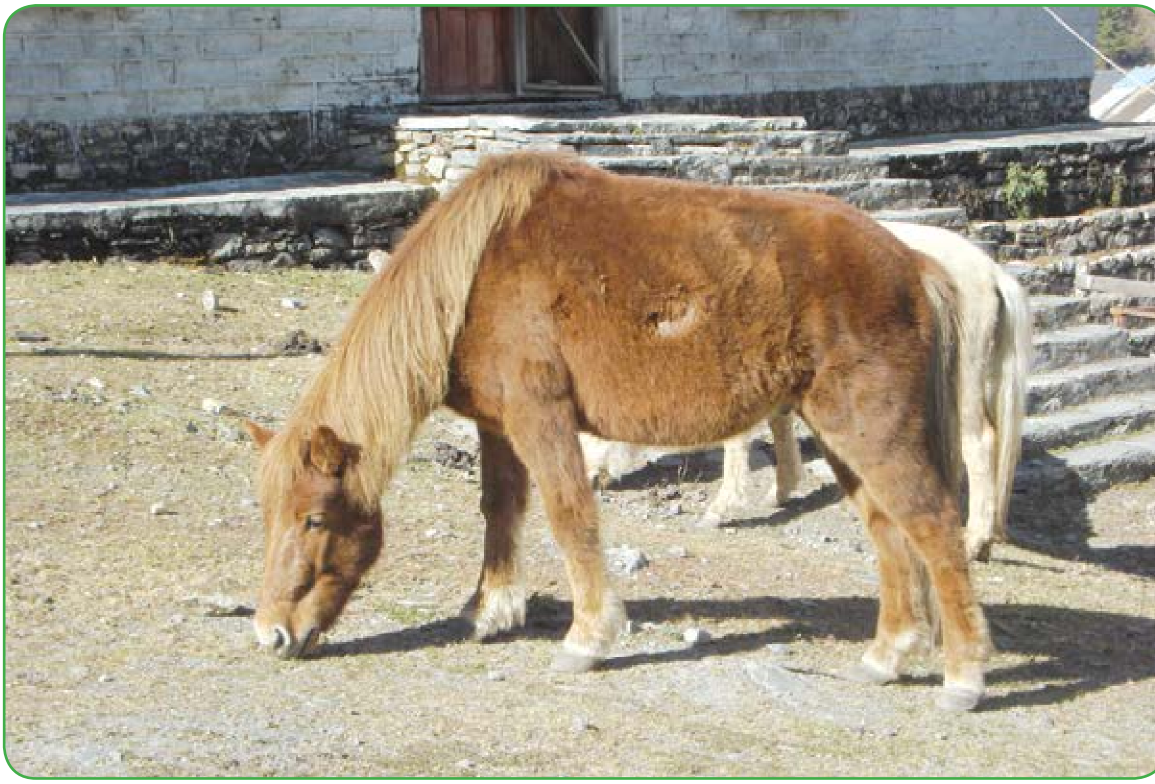
8. INDIGENOUS HORSE BREEDS OF NEPAL



Jumli horse

Jumli horse

Local horse in Mustang district

Local horse in Mustang district

Local horses in Jumla district

Local horses in Mustang district

Local horse in Gulmi district

Local horse in Jumla district

8. INDIGENOUS HORSE BREEDS OF NEPAL

8.1 Zoological classification of horse

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Perissodactyla
Family	Equidae
Sub-family	
Genus	*Equidae*
Species	*Caballus*

8.2 Overview of Equine (Horse) in Nepalese context

Nepal has a very diverse topography. In southern Nepal, plain (Terai) extends nearly 800 km from east to west and about 30-40 km from north to south with average elevation below 750 m. Terai covers only 17% of the area and remaining area is hills and mountain. Because of the challenging geography, horses played an important role in the movement of people and commodities. Because of improved road access to rural locations, the number of horses and asses is rapidly falling. According to the Economic Survey 2020/21, the entire horse population, including asses, is 59,762. Horses are now exclusively used by trekkers for riding, accompanying, horse racing, and transporting products in tourist regions, and they are also employed as pack animals in inaccessible areas. Despite the fact that the horse is a multipurpose animal in the agricultural sector, it has not been actively involved in agricultural areas. They are utilized indirectly, such as carrying things when transportation is scarce or non-existent. Similarly, in Brick Kiln, asses are used for carrying bricks and used for pulling carts. Although there are five types of horses in Nepal's rich biodiversity (Bhatta et al, 2020), only one indigenous breed of horse, the Jumli horse, is included in the country report submitted to the Food and Agricultural Organization (Ministry of Agriculture and Cooperatives 2004; 2014). Horses are mostly reared in hill and mountainous region of Nepal. These breeds are hardy in nature, having high disease resistance and are strong and sure-footed.

Table8.1 Population of horses and asses in Nepal

	Overall	Province I	Province II	Bagmati Province	Gandaki Province	Lumbini Province	Karnali Province	Sudurpashchim Province
2014	52577							
2015	52655							
2016	55808	7616	503	965	6530	7058	29325	3811
2017	68711	7414	305	1231	5056	4795	44842	5068
2018	58091	5567	305	1230	5071	4112	36703	5103
2019	59822	6012	306	1236	6680	4068	36375	5145
2020	59762	6264	579	1241	6689	4524	34754	5711

Source: Statistical information on Nepalese Agriculture, MoALD, 2020

8.3 Origin of Nepalese horses

Archaeological evidence suggests that horses were domesticated some 6,000 years ago in the steppe areas north of the Black Sea, from Ukraine to Kazakhstan. Horses were used for transportation, agricultural labor, and warfare across Eurasia. Domestic horses today are descended from feral ancestors that escaped from captivity. The Jumli horse is the most well-known indigenous breed of horse in Nepal, and it resembles the Bhotia horse breed (Rousseau E (2017), however this has yet to be validated with scientific data.

8.4 Indigenous horse breeds of Nepal

The Jumli horse is the only indigenous horse that has been identified, phenotypically characterized, and listed in the FAO database. Apart from the Jumli horse, Nepal has five phenotypically different populations of horses, namely the Chyanta, Tanghan, Terai, Tattu, and Bhotia, which display significant diversification (Bhatta et al, 2020).

Table 8.2 Phenotypic description of indigenous hourses

Horse breeds	Description	Remarks
Jumli horse	Jumli horses are medium sized with strong muscular body structure. They are found mainly on white, red and grey color. Generally, Jumli horses have the solid color but some have combination of two or more colors. Under the feet and tail are normally grey in colour. Grey colored horses are changed into white colour after some time with the increase in their age. Some Jumli horses are also found black in color and some are mixed white. (Detailed description is in subsequent sections)	Limited studies have been carried out.
Bhote horse	Also known as Bhotiya horse and are gray or bay, chestnut and roan in colour. Bhotia is similar but less broad than Tibetan pony. They are better known for intelligence, willing and quite in character and hardy nature. They are well adapted and suited in mountains and cold climate region of the country. In spite of small size, it is very sure-footed pack horse (Ryan A., n.d.).	Yet to be studied
Terai horse	Smaller body with an average height of 115 cm at withers and mostly found in southern Terai region of Nepal (Porter et al., 2016 and Heilman, 2011).	Yet to be studied
Chyante horse	Primarily bay in colour having short thick neck, compact body, strong back, strong legs with hooves and have long and heavy manes and tails (Chyante pony, n.d.).	Yet to be studied
Tattu horse	Tattu hourse is found in mountains rather than hills. It is the smallest breed with 110 cm height. This horse has ability to suffice in higher mountains with narrower trails (Sparks, n.d.).	Yet to be studied
Tanghan horse	It is the largest horse among Tattu, Chyante and Terai. They are strong, powerful and enduring in nature Hooker (2004).	Yet to be studied

8.4.1 Demographic distribution of of Jumli horse of Nepal

The bond between humans and horses has been observed in Nepal from ancient times. Horses were employed as a source of pride and prestige by kings and village leaders, and they are still utilized for transportation of products in Nepal's hills and mountains (Kadel, 2019). The Jumla district is one of the most isolated and challenging topography regions in the Nepal. Horses are an essential mode of transportation due to the tough terrain. So, horses were abundant and phenotypically distinct in those areas, which later named as Jumli horse. It is mostly concentrated in the Jumla district (high hills) of Nepal and also found in India (Ministry of Agriculture and Cooperatives 2004). Because the animal is suited to the hard climate, the Jumli horse is also popular in adjacent districts of Jumla such as Dolpa and in the high altitudes of the country's mid-western area. Seasonal migration is also frequent in Jumli raising. To protect the animals from the cold during the winter season, farmers move horses to terai locations such as Dang, Nepalgunj, Kailali, and Kanchanpur.

8.4.2 Status of Jumli horse

Prior to a few decades, the importance of horses was enormous due to the extremely challenging geography in Nepal's hills and mountains for transportation of people and commodities. With increased road connectivity in recent years, individuals increasingly prefer vehicles for the same reason, resulting in a dramatic fall in horse population. The scenario of Asian horse population has showed a steady drop from the year 2000 to a nearly constant number after 2008. Nepal has a similar scenario, with nearly steady population in the last three years, such as 58091, 59822, and 59762 in 2018, 2019, and 2020. The consistent later results may indicate the importance of horses in remote areas and tourism attractions in the higher altitude region. The importance of horse is clearly exhibited by the decline in trading of horses in the market. There are a few economic evidences that demonstrated the importance and higher number of Jumli horse in their home tract Jumla district (Gyawali, 2015). A decade ago, the yearly sale of horses in Darchula's Jaljibi Mela was over 600 heads, but that figure has now plummeted to less than 100 heads. The local businesses of Jumla district also traded around 6000 Jumli horses to the districts of Dolpa, Mugu, and Humla. Due to natural calamities in 2013 June 15 to 20, about 700 horses and mules were killed creating huge economic loss to the farmers and as a consequence, farmers showed less encouragement to rear horses in general. Rearing system of Jumli is very unique: leaving in wild in winter season and collect in spring and summer season again. Since these Jumli horses are semi-wild in nature, human encroachment of their natural habitat might be another reason for declining of the population of this horse. Jumli horse is classified as being “at risk”. For conservation and promotion of this breed, District Livestock Service Office of Jumla seldom organize the racing horse competition which is also the nomadic culture of Jumli people especially of the Mongolian tribes (Bhutiya caste).

8.4.3 Positive attributes

Jumli horses are hardy in nature, has fortitude and very well acclimatize to hilly and mountain region. They are amazingly sure-footed having greater ability to hike even in snow. They are very clever and can walk in very difficult roads. They can carry average weight of 60-70 kg for 6-7 hours regularly. The healthy and adult can carry up to 80-100 kg. Due to their hardy nature, Jumli possess good health and being undemanding in nature, are easy to raise. They are resistant against diseases and parasites. They are well-adapted to unique rearing system. They are sent to jungle/ rangeland in winter season without attendants and collect in spring and summer season again by luring with fresh grass and salt (authors’ personal experiences while collecting information on Jumli horses in Jumla, 2018).

8.4.4 History and socio-cultural significance of horses in Nepal

The relationship between humans and horses has been evident in Nepal from ancient times; horses were utilized for transportation by Kings and local leaders (Kadel, 2019). King Surendra

Bir Bikram Shah founded the cavalry in Nepal in 1849, and horses were utilized in battle during the 1855-56 war with Tibet. Horses fought alongside the Gurkhas in the First and Second World Wars. The Nepal Army cavalry now has the most horses in Nepal, with 107, and more are being bred at Bharatpur. The army cavalry also has its own riding school at its headquarters at the Narayanhiti Palace Museum. The former war horses today mostly have a ceremonial role in festivals, and during official ceremonies.

Every year in Nepal, horse racing is organized by the Nepal Army and police at Tundikhel, Kathmandu, as part of the Ghode Jatra or Horse Parade (Ashesh 2019). According to myth, the thunderous sound of horses' hooves repels child-eating demons. Similarly, the "Yartung Festival" is a three-day horse-racing festival conducted in Mustang (Yartung Festival Mustang Trek 2021 (The Ancient Wall City of Mustang)) (trekking-in-nepal.net). In Terai, a Ghodi, or feminine white horse, is used to transport the groom.

In Nepal, the number of horses has decreased due to mechanization, but still horses are still used for transportation in some Himalayan settlements because of their ability to navigate through difficult terrain. They have been used for tourism as company for trekkers. They are also used to produce excellent mules (Rousseau, 2017).

8.4.5 Characterization of Jumli horse

Jumli horse have been characterized only on phenotypic level.

8.4.5.1 Phenotypic characterization of Jumli horse

8.4.5.1.1 Physical characteristics of Jumli horse

- Jumli horses are medium sized with strong muscular body structure.
- Eyes are almond – shaped with wide forehead.
- Neck is horizontally set, exceedingly sloping croup, low set tail, straight back, and small hooves yet sure-footed and have thick and dense mane and tail.
- They are found mainly on white, red and grey color. Generally, Jumli horses have the solid color but some have combination of two or more colors. Under the feet and tail are normally grey in colour. Grey colored horses are changed into white colour after some time with the increase in their age. Some Jumli horses are also found black in color and some are mixed white.
- The average adult body weight is 196 kg.
- Its temperament is semi wild.

8.4.5.1.2 Morphological measurement of Jumli horse

Some of the phenotypic attributes of Jumli horses are presented in Table 8.3.

Table 8.3 Phenotypic Characterization of Jumli horse

Age	**Wither height (cm)**	**Body length (cm)**	**Head length (cm)**	**Tail length (cm)**	**Body weight (kg)**
Adult (about 3 years)	108.3	145.9	55	48.9	196
One year of age	69.6	92.5	36	31	61

Source: Gyawali, 2015

8.5 Production performance of Jumli horse

- Male horses became adult earlier in comparison to female.
- Generally female are ready for breeding in 3 years but male became mature within 2.5 to 3 years.
- Mares come on heat during summer season. But 15 to16 years aged mares come on heat within one month of parturition.
- The Gestation period is one year (365 days).

8.6 Future prospects for conservation and promotion of Jumli horse

The aspects of breed recording, identification, and characterization, updating the information at regular intervals, large equine industry, equestrian activities and a wide range of equine related education, training and researches are the main key factors to get large number of established horse breeds in developed countries. In case of developing countries including Nepal, there is still lack of reporting the correct data or lack of technical and human resources, missing population data or unreliable sources even to assess the very basic data such as risk status (population data). Without assessment of the real situation of status of horses, no development of proper equine industry and equine activities can be expected.

Recommendation of conservation strategies

- Initiating exploration and research on local horses through national research institute as well as processing for patenting these important animal genetic resources as national property.

- Developing capacity and creating awareness of community people about the importance of conservation and promotion of horse genetic resources.

- Promoting the conservation programs by government and the non-government organizations involving the local community people.

- Conserving *in situ* as well as promoting them *ex situ* as Demonstration farm and preserving their semen in national gene bank established in national research institute who has the mandate to conservation, utilization and promotion of indigenous animal genetic resources.

- Encouraging establishment of breeding centers by Government organization with the involvement of private sector for commercialization and marketing.

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Yartung Festival Mustang Trek 2021 (The Ancient Wall City Of (trekking-in-nepal.net)

APPENDIX

Appendix 1: Livestock Population for the last nine years *(Unit: Number)*

CATEGORY	PROVINCES	2015/16 72/73	2016/17 73/74	2017/18 74/75	2018/19 75/76	2019/20 76/77
CATTLE	PROVINCE 1	1970177		1,948,899	1,955,096	1,981,755
	MADHESH	1030922		1,100,900	1,111,055	1,247,124
	BAGMATI	1093311		1,051,263	1,045,119	1,064,349
	GANDAKI	525781		555,174	551,162	481,865
	LUMBINI	1055496		1,145,631	1,141,280	1,162,262
	KARNALI	616276		563,594	550,981	504,184
	SUDURPASHCHIM	1010845		1,010,845	1,030,344	1,017,346
	TOTAL	**7,302,808**	**7,347,487**	**7,376,306**	**7,385,035**	**7,458,885**
BUFFALO	PROVINCE 1	857085		859,686	861,251	850,013
	MADHESH	779525		780,047	794,555	826,851
	BAGMATI	910788		894,453	891,707	894,926
	GANDAKI	677545		718,675	699,095	677,490
	LUMBINI	1116926		1,170,298	1,191,317	1,185,676
	KARNALI	307341		335,061	344,482	302,893
	SUDURPASHCHIM	519599		519,599	526,257	519,742
	TOTAL	**5,168,809**	**5,177,998**	**5,277,819**	**5,308,664**	**5,257,591**
SHEEP	PROVINCE 1	76,841	76,255	76,011	73,661	62,783
	MADHESH	6,849	7,707	7,736	6,767	6,452
	BAGMATI	73,251	75,626	75,432	73,475	93,639
	GANDAKI	105,228	121,192	121,072	86,231	100,782
	LUMBINI	142,381	129,573	128,036	145,376	145,027
	KARNALI	293,537	289,133	290,189	309,360	306,790
	SUDURPASHCHIM	102,571	102,489	102,273	104,019	90,606
	TOTAL	**800,658**	**801,975**	**800,749**	**798,889**	**806,079**
GOAT	PROVINCE 1	2,285,180		2,026,769	2,355,046	2,501,263
	MADHESH	1,406,039		1,553,440	1,614,314	1,677,368
	BAGMATI	2,108,581		2,056,778	2,118,931	2,351,217
	GANDAKI	1,144,030		1,509,622	1,541,539	1,533,629
	LUMBINI	1,958,983		2,227,563	2,297,862	2,329,047
	KARNALI	1,005,011		1,359,890	1,400,696	1,435,690
	SUDURPASHCHIM	1,078,290		913,256	955,364	983,739
	TOTAL	**10,986,114**	**11,165,099**	**11,647,319**	**12,283,752**	**12,811,953**
PIGS	PROVINCE 1	578,472		650,209	660,038	630,818
	MADHESH	97,016		95,327	104,816	111,322
	BAGMATI	174,246		116,449	120,194	172,277
	GANDAKI	90,522		182,842	193,482	162,153
	LUMBINI	224,260		311,619	321,620	355,246
	KARNALI	66,504		44,335	49,750	43,469
	SUDURPASHCHIM	60,288		34,588	38,437	44,308
	TOTAL	**1,291,308**	**1,328,036**	**1,435,369**	**1,488,338**	**1,519,593**
FOWL	PROVINCE 1	7,917,589		9,105,408	8,621,288	9,523,433
	MADHESH	7,041,839		4,303,850	4,497,818	6,343,895
	BAGMATI	34,480,063		38,435,143	41,564,880	44,841,957
	GANDAKI	6,246,252		5,779,917	5,989,704	6,785,607
	LUMBINI	8,556,850		9,535,931	10,271,826	10,232,588
	KARNALI	1,400,617		2,098,046	1,949,269	1,917,888
	SUDURPASHCHIM	2,987,428		2,987,428	2,814,545	2,953,511
	TOTAL	**68,630,638**	**70,007,151**	**72,245,723**	**75,709,330**	**82,598,879**
DUCK	PROVINCE 1	105,477		87,792	92,499	104,058
	MADHESH	96,439		82,962	83,980	95,098

CATEGORY	PROVINCES	2015/16	2016/17	2017/18	2018/19	2019/20
	BAGMATI	49,679		49,908	49,467	85,110
	GANDAKI	54,521		111,491	116,460	42,712
	LUMBINI	62,112		50,897	52,407	75,900
	KARNALI	10,409		8,009	8,202	9,964
	SUDURPASHCHIM	13,618		13,611	13,385	14,384
	TOTAL	**392,255**	**394,775**	**404,670**	**416,400**	**427,226**
MILKING COW	PROVINCE 1	288,160	274972	271879	280,422	321,753
	MADHESH	146,119	153848	158523	162,084	187,071
	BAGMATI	161,833	150707	161934	158,610	168,930
	GANDAKI	83,926	68282	71065	78,712	76,656
	LUMBINI	145,887	152809	152307	161,583	183,796
	KARNALI	69,615	80856	80416	81,774	72,528
	SUDURPASHCHIM	130,595	148055	143414	155,590	155,422
	TOTAL	**1,026,135**	**1,029,529**	**1,039,538**	**1,078,775**	**1,166,156**
MILKING BUFFALOES	PROVINCE 1	226,783	231,280	232414	238,732	258,901
	MADHESH	204,560	279,919	289169	293,810	258,576
	BAGMATI	238,576	255,050	262171	266,494	282,167
	GANDAKI	176,525	187,899	196322	193,127	208,619
	LUMBINI	300,523	313,598	310754	321,691	374,396
	KARNALI	76,160	93,301	95594	96,654	93,253
	SUDURPASHCHIM	132,257	148,465	149524	150,076	159,580
	TOTAL	**1,355,384**	**1,509,512**	**1,535,948**	**1,560,584**	**1,635,492**
LAYING HEN	PROVINCE 1	1,425,167	1,636,579	1682363	1,671,533	1,260,665
	MADHESH	1,267,532	773,855	793088	811,793	807,736
	BAGMATI	6,206,412	6,652,868	6801953	6,794,498	7,588,682
	GANDAKI	1,124,326	1,006,555	942842	895,574	1,124,060
	LUMBINI	1,540,231	1,601,160	1604774	1,675,763	1,436,175
	KARNALI	252,111	207,743	215692	209,230	219,177
	SUDURPASHCHIM	537,736	510,129	476846	468,588	491,347
	TOTAL	**12,353,515**	**12,388,889**	**12,517,558**	**12,526,979**	**12,927,842**
LAYING DUCK	PROVINCE 1	43,495	45,341	47047	49,590	46,884
	MADHESH	43,424	43,834	44967	45,194	44,796
	BAGMATI	22,846	25,760	26420	26,225	38,949
	GANDAKI	25,047	27,389	27034	26,985	18,603
	LUMBINI	35,337	30,085	29198	30,612	31,099
	KARNALI	4,406	4,975	5335	5,385	4,618
	SUDURPASHCHIM	6,372	6,556	6911	6,756	6,752
	TOTAL	**180,927**	**183,940**	**186,912**	**190,747**	**191,701**
YAK/NAK/CHAURI	PROVINCE 1	22,797	21981	21985	21,377	21,293
	MADHESH					
	BAGMATI	12,484	11442	11653	11,527	11,935
	GANDAKI	14,823	15232	15472	15,766	13,997
	LUMBINI	31	62	14	15	16
	KARNALI	17,804	19450	19670	19,678	21,761
	SUDURPASHCHIM	892	1179	1184	1,226	1,003
	TOTAL	**68,831**	**69,346**	**69,978**	**69,588**	**70,005**
HORSES/ ASSES	PROVINCE 1	7616	7414	5,567	6,012	6,264
	MADHESH	503	305	305	306	579
	BAGMATI	965	1231	1,230	1,236	1,241
	GANDAKI	6530	5056	5,071	6,680	6,689
	LUMBINI	7058	4795	4,112	4,068	4,524
	KARNALI	29325	44842	36,703	36,375	34,754
	SUDURPASHCHIM	3811	5068	5,103	5,145	5,711
	TOTAL	**55808**	**68,711**	**58,091**	**59,822**	**59,762**

CATEGORY	PROVINCES	2015/16	2016/17	2017/18	2018/19	2019/20
		72/73	**73/74**	**74/75**	**75/76**	**76/77**
CATTLE MILK (Mt.)	PROVINCE 1	171,930	176065	195592	204,762	284,940
	MADHESH	95,516	99903	108946	117,793	147,391

	BAGMATI	107,078	107357	123797	128,380	135,800
	GANDAKI	60,363	61188	67878	75,444	61,247
	LUMBINI	86,808	92290	109753	117,239	146,450
	KARNALI	34,175	36420	44370	40,814	39,802
	SUDURPASHCHIM	87,936	92062	103790	111,098	104,769
	TOTAL	**643,806**	**665,285**	**754,126**	**795,530**	**920,400**
BUFFALO MILK (Mt.)	PROVINCE 1	212,347	208775	220745	225,426	193,745
	MADHESH	161,696	174205	185249	191,160	234,591
	BAGMATI	247,640	250581	267245	269,594	250,570
	GANDAKI	189,259	194633	206627	205,168	185,365
	LUMBINI	230,532	242756	258123	272,844	320,258
	KARNALI	56,529	58212	69004	74,530	65,499
	SUDURPASHCHIM	112,438	116792	131284	134,183	130,572
	TOTAL	**1,210,441**	**1,245,954**	**1,338,277**	**1,372,905**	**1,380,600**
TOTAL MILK (Mt.)	PROVINCE 1	384,277	384,840	416,337	430,188	478,685
	MADHESH	257,212	274,108	294,195	308,953	381,982
	BAGMATI	354,718	357,938	391,042	397,974	386,370
	GANDAKI	249,622	255,821	274,505	280,612	246,613
	LUMBINI	317,340	335,046	367,876	390,082	466,708
	KARNALI	90,704	94,632	113,374	115,345	105,301
	SUDURPASHCHIM	200,374	208,854	235,074	245,281	235,341
	TOTAL	**1,854,247**	**1,911,239**	**2,092,403**	**2,168,434**	**2,301,000**
BUFF (Mt.)	PROVINCE 1	34,132	33848	34,649	34,981	30,603
	MADHESH	23,991	27136	27,654	28,323	29,757
	BAGMATI	33,341	34175	34,997	35,604	32,247
	GANDAKI	22,109	21563	22,424	22,843	24,381
	LUMBINI	32,448	33660	34,828	34,775	42,746
	KARNALI	10,830	11093	11,599	12,680	10,994
	SUDURPASHCHIM	18,154	18605	19,029	19,369	18,788
	TOTAL	**175,005**	**180,080**	**185,180**	**188,574**	**189,517**
MUTTON (Mt.)	PROVINCE 1	259	261	278	273	213
	MADHESH	21	21	24	22	22
	BAGMATI	245	246	260	256	317
	GANDAKI	437	451	470	409	342
	LUMBINI	445	452	446	434	492
	KARNALI	942	947	938	1032	1,042
	SUDURPASHCHIM	335	336	338	337	307
	TOTAL	**2,684**	**2,714**	**2,754**	**2,763**	**2,735**
CHEVON (Mt.)	PROVINCE 1	12,243	12220	12,499	13,106	14,646
	MADHESH	10,012	10439	10,686	11,098	9,821
	BAGMATI	10,367	10945	11,553	11,996	13,768
	GANDAKI	6,416	6869	7,550	8,017	8,981
	LUMBINI	14,594	14986	15,516	15,786	13,637
	KARNALI	5,058	5229	5,673	6,062	8,409
	SUDURPASHCHIM	6,893	7018	7,325	7,849	5,761
	TOTAL	**65,583**	**67,706**	**70,802**	**73,914**	**75,023**
PORK (Mt.)	PROVINCE 1	9,527	10204	11,004	11,769	12,247
	MADHESH	1,813	1831	2,138	2,113	2,158
	BAGMATI	3,287	3483	4,112	2,812	3,343
	GANDAKI	2,976	2375	2,965	4,020	3,148
	LUMBINI	3,901	4565	5,238	5,773	6,894
	KARNALI	1,020	1053	1,497	1,131	842
	SUDURPASHCHIM	985	1024	1,260	961	859
	TOTAL	**23,509**	**24,535**	**28,214**	**28,579**	**29,493**
CHICKEN (Mt.)	PROVINCE 1	6,701	7449	8,076	8,529	29,994
	MADHESH	5,859	6130	6,389	5,740	20,063
	BAGMATI	24,979	26121	26,594	28,085	136,966
	GANDAKI	5,442	5336	5,730	5,572	20,789
	LUMBINI	7,666	7707	8,288	9,624	32,017
	KARNALI	1,660	1723	1,916	1,964	6,130
	SUDURPASHCHIM	2,734	2802	3,129	3,386	9,043

	TOTAL	**55,041**	**57,268**	**60,122**	**62,899**	**255,001**
DUCK (Mt.)	PROVINCE 1	70	72	77	81	96
	MADHESH	52	53	51	62	86
	BAGMATI	34	36	36	39	77
	GANDAKI	42	39	56	105	38
	LUMBINI	30	30	42	46	69
	KARNALI	3	4	8	6	9
	SUDURPASHCHIM	6	7	10	13	13
	TOTAL	**237**	**241**	**280**	**353**	**387**
TOTAL MEAT (Mt.)	PROVINCE 1	62,932	64,054	66,583	68,738	87,798
	MADHESH	41,748	45,610	46,942	47,358	61,907
	BAGMATI	72,253	75,006	77,552	78,792	186,719
	GANDAKI	37,422	36,633	39,195	40,966	57,679
	LUMBINI	59,082	61,400	63,185	66,437	95,855
	KARNALI	19,515	20,049	21,631	22,876	27,427
	SUDURPASHCHIM	29,107	29,792	31,091	31,914	34,772
	TOTAL	**322,059**	**332,544**	**346,179**	**357,082**	**552,156**
HEN EGG ('000 NUMBER)	PROVINCE 1	178,928	191617	285341	241,432	142,036
	MADHESH	87,298	80914	99743	106,646	77,811
	BAGMATI	704,798	720071	742691	802,562	1,016,168
	GANDAKI	107,738	107983	111913	106,848	136,478
	LUMBINI	147,403	171600	168304	187,324	171,852
	KARNALI	27,258	18214	25938	26,278	17,618
	SUDURPASHCHIM	40,743	47913	64094	63,590	42,563
	TOTAL	**1,294,166**	**1,338,312**	**1,498,024**	**1,534,680**	**1,604,526**
DUCK EGG ('000 NUMBER)	PROVINCE 1	3,404	3579	3618	3,879	4,116
	MADHESH	3,338	3385	3408	3,515	3,504
	BAGMATI	1,877	1960	1977	1,981	2,991
	GANDAKI	1,735	2045	2028	2,165	1,480
	LUMBINI	2,708	2188	2296	2,484	2,476
	KARNALI	340	324	339	404	361
	SUDURPASHCHIM	504	503	575	582	544
	TOTAL	**13,906**	**13,984**	**14,241**	**15,009**	**15,474**
TOTAL EGG ('000 NUMBER)	PROVINCE 1	182,332	195,196	288,959	245,311	146,153
	MADHESH	90,636	84,299	103,151	110,160	81,315
	BAGMATI	706,675	722,031	744,668	804,543	1,019,160
	GANDAKI	109,473	110,028	113,941	109,013	137,958
	LUMBINI	150,111	173,788	170,600	189,808	174,328
	KARNALI	27,598	18,538	26,277	26,682	17,979
	SUDURPASHCHIM	41,247	48,416	64,669	64,172	43,107
	TOTAL	**1,308,072**	**1,352,296**	**1,512,265**	**1,549,689**	**1,620,000**
WOOL (KG)	PROVINCE 1	55,745	55102	55181	56,074	43,730
	MADHESH	5,132	5333	5357	4,831	2,713
	BAGMATI	54,420	54386	54610	51,834	66,596
	GANDAKI	76,883	90641	91273	64,252	73,927
	LUMBINI	101,761	97238	97002	107,889	82,126
	KARNALI	218,093	215326	214967	229,625	255,619
	SUDURPASHCHIM	76,314	76286	76249	75,231	67,976
	TOTAL	**588,348**	**594,312**	**594,639**	**589,738**	**592,687**

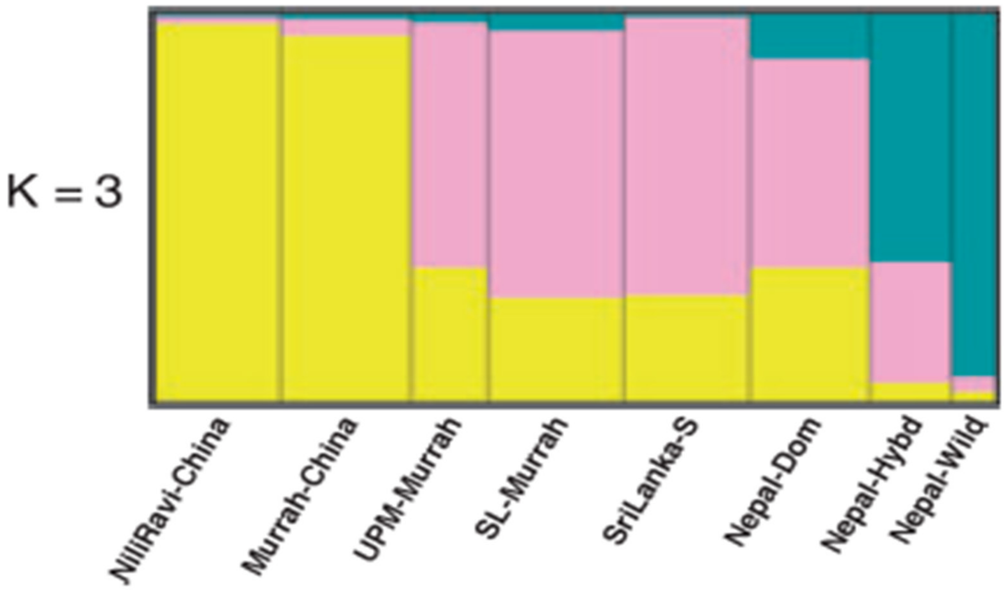

Figure 2.2 River population assuming K=3

Source: Zhang et al., 2011

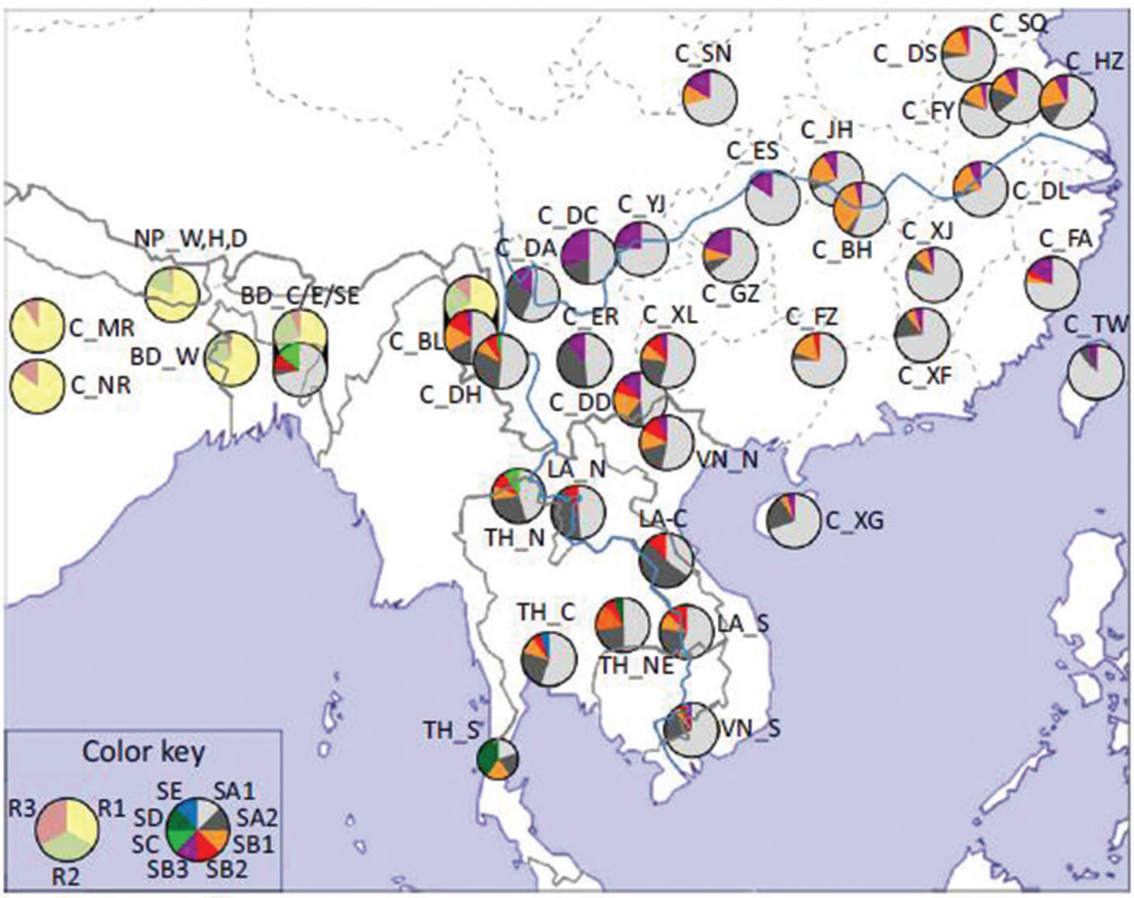

Figure 2.3 mtDNA haplogroup distributions of river and swamp buffalo. In the colour keys, SA1 to SE indicate swamp haplogroups, and R1 to R3 indicate river haplotypes

Source: Zhang et al., 2016

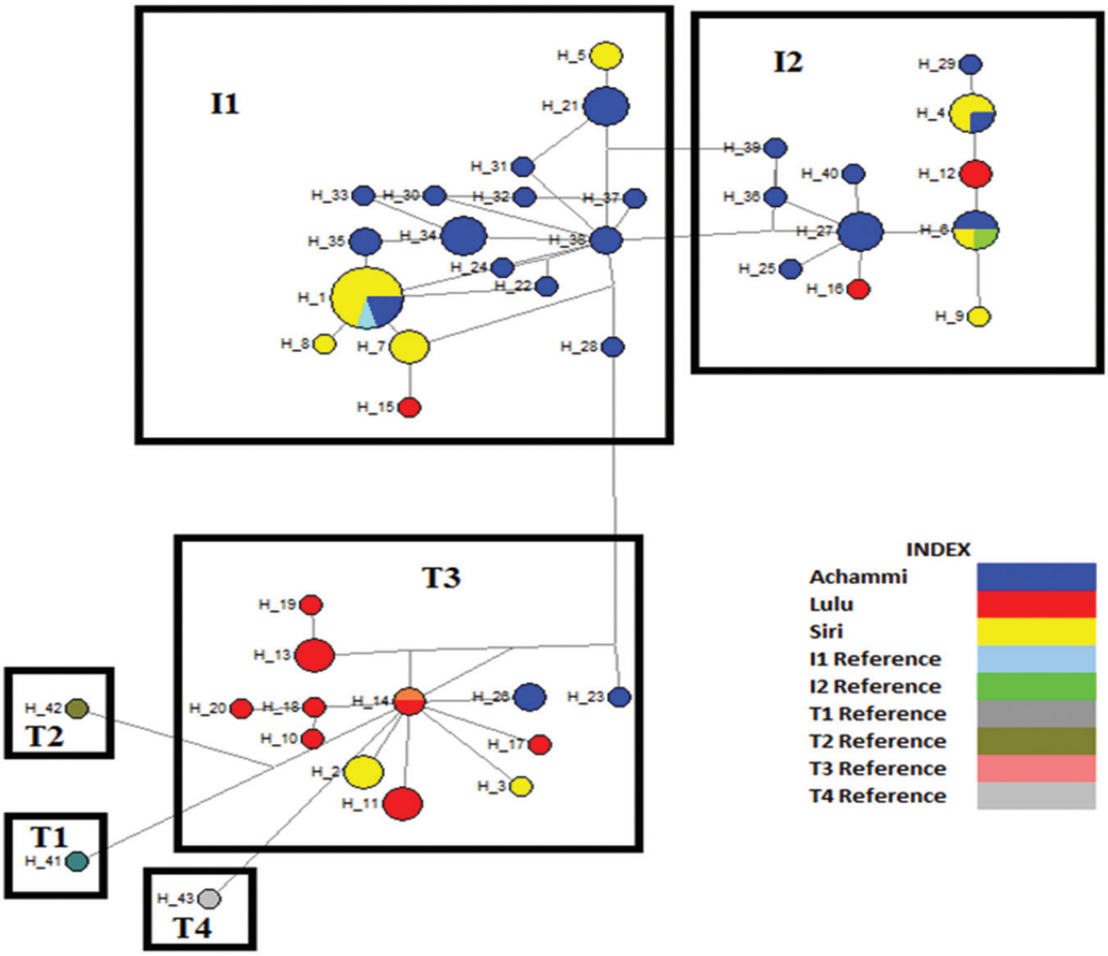

Figure 3.4 NETWORK analysis showing major I1, I2, and T3 haplogroup shared by three distinct Nepalese cattle breeds.

Source: Gorkhali et al., 2021

Figure 4.1 (a) Mouflon, (b) Urial, (c) Argali, (d) Bighorn, (e) Dall/ Stone sheep, and (f) Snow sheep

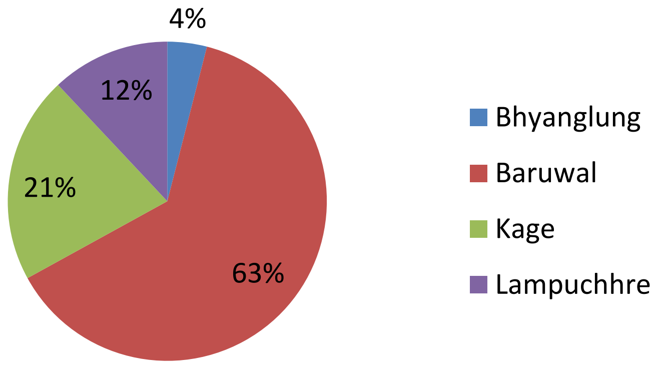

Figure 4.2 Population of different sheep breeds of Nepal (%)

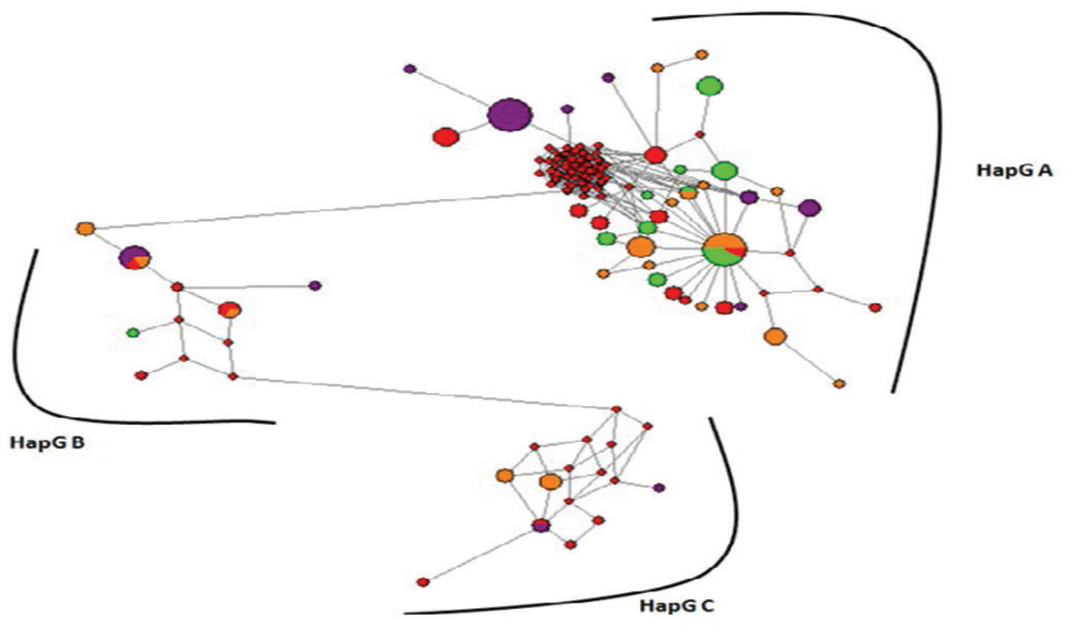

Figure 4.5 The median-joining network of 50 haplotypes in Nepalese sheep

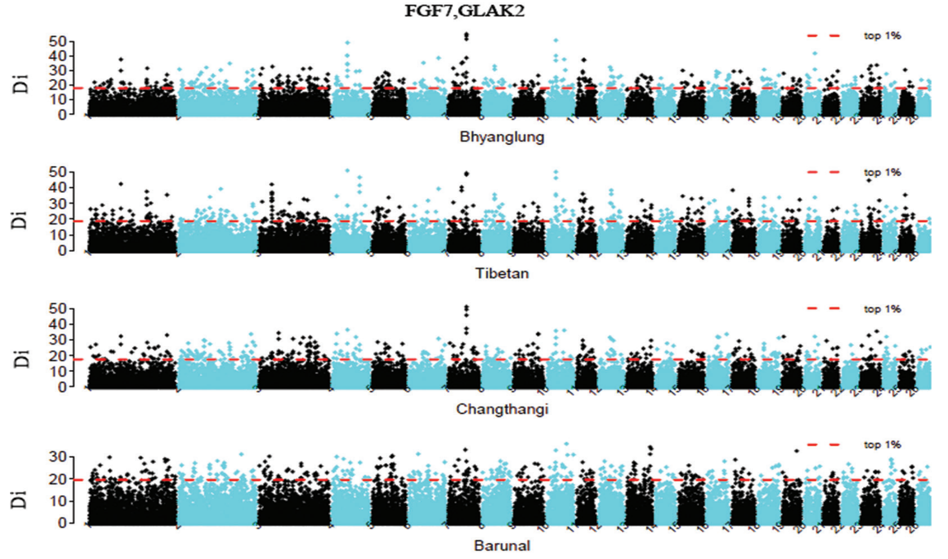

Figure 4.7 Distribution of di values in different breed comparisons (positive selection analysis on high altitude adaptation) *(Source: Gorkhali et al., 2016)*

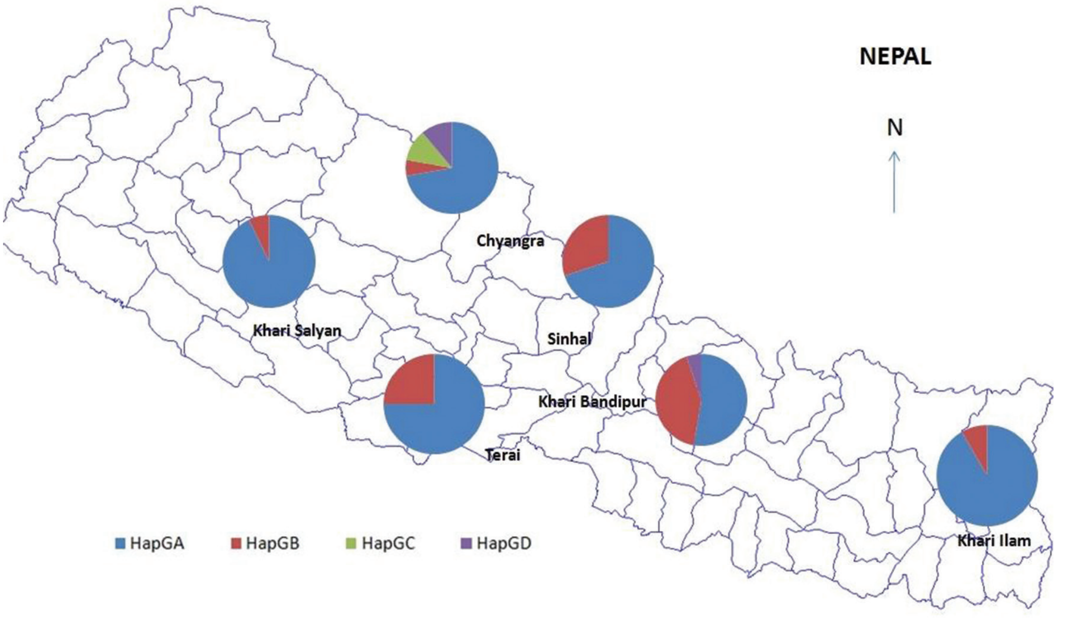

Figure 5.1 Haplogroups of Nepalese goats (haplogroups A-D)

Source: Gorkhali et al., 2014

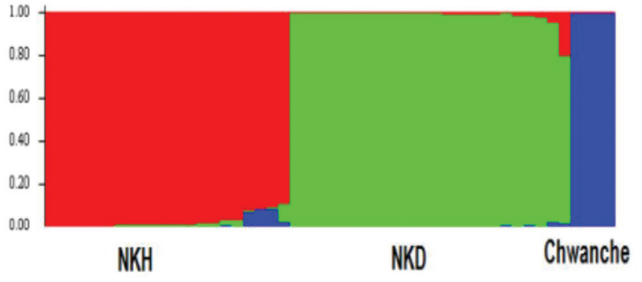

Figure 6.3 Inference of Nepalese pig populations shown distinct genetic background of three populations of pigs (Nidup K, 2011.

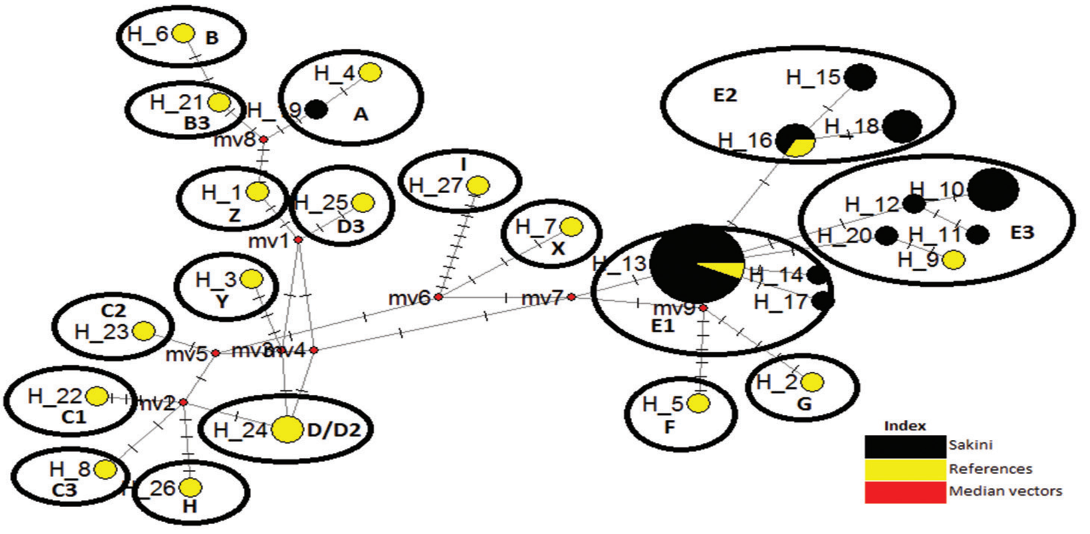

Figure 7.3 Network analysis of major haplogroups (A1, E1, E2, and E3) present in Nepalese Sakini chickens

Neena Amatya Gorkhali, PhD
Senior Scientist and Chief
National Animal Breeding & Genetics Research Center
Nepal Agricultural Research Council, Khumaltar, Lalitpur
Permanent Address: Kathmandu Metropolis -4, Baluwatar, Kathmandu
Mobile No.: 9851209135
Email: neenagorkhali@hotmail.com

Saroj Sapkota, PhD
Scientist
National Animal Breeding & Genetics Research Center
Nepal Agricultural Research Council, Khumaltar, Lalitpur
Permanent Address: Bharatpur Metropolis - 4, Dovan Chowk, Chitwan
Mobile No.: 9841596477
Email: sarose.sapkota@gmail.com

Nirajan Bhattarai, PhD
Associate Professor and Director
Continuing Education Center
Agriculture and Forestry University, Rampur, Chitwan
Permanent Address: Mechinagar -13, Charaali, Jhapa
Mobile No.: 9855060704
Email: nbhattarai@afu.edu.np

Bhoj Raj Pokhrel
Technical Officer
National Animal Breeding & Genetics Research Center
Nepal Agricultural Research Council, Khumaltar, Lalitpur
Permanent Address: Dhurkot -1, Araudi, Gulmi
Mobile No.: 9851145640
Email: pokhrel.bhojraj@gmail.com

Shishir Bhandari
Technical Officer
National Animal Breeding and Genetics Research Centre
Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal
Permanent Address: Sarawal-1, Basabasahi, Nawalparasi West
Mobile No.: +977 9841335276
Email: shishirbhandari84@gmail.com

Government of Nepal
Nepal Agricultural Research Council
National Animal Science Research Institute
National Animal Breeding & Genetics Reseach Center
Khumaltar, Lalitpur

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