MORPHOMETRIC CHARACTERIZATION AND FACTOR ANALYSIS OF BUFFALOES OF KOSI REGION OF BIHAR

Thesis

Submitted to the

Bihar Animal Sciences University, Patna

In partial fulfillment of the requirements for the degree of

MASTER OF VETERINARY SCIENCES

In

ANIMAL GENETICS AND BREEDING

By

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CERTIFICATE- I

This is to certify that the thesis entitled "**Morphometric Characterization and Factor Analysis of Buffaloes of Kosi Region of Bihar**" submitted in partial fulfilment of requirement for the award of degree of Master of Veterinary Sciences, (M.V.Sc.) in the discipline of, **Animal Genetics and Breeding** of faculty of Post-Graduate Studies, Bihar Animal Sciences University, Patna, is bonafide research work carried out by **Dr. Dhiraj Prasad**, Registration No-**VM0004/2018-19,** son of Shri **Govind Prasad** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation has been fully acknowledged.

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CERTIFICATE- II

This is to certify that the thesis "**Morphometric Characterization and Factor Analysis of Buffaloes of Kosi Region of Bihar**" submitted by **Dr. Dhiraj Prasad (**Registration No- **VM0004/2018-19),** son of Shri **Govind Prasad** to the Bihar Animal Sciences University, Patna in partial fulfilment of the requirement for the degree of Master of Veterinary Science (M.V.Sc.) in the discipline of, **Animal Genetics and Breeding** has been approval by the Student's Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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CONTENTS

LIST OF ABBREVIATIONS

ABBREVIATIONS

Kg	Kilogram
Cm	Centimeter
FAO	Food and Agriculture Organization
Fig.	Figure
PCA	Principle Component Analysis
CFA	Common Factor Analysis
M	Over all mean
MSA	KMO measure of sampling Adequacy (MSA)
KMO	Kasiser-meyer-olkein test
Pa	Principle Axis
ML	Maximum Likelihood
PC1	First Principle Component
PC2	Second Principle Component
P	Probability value of Significance

List of Codes

Codes		Traits Name
HW	:	Height at wither
BL	:	Body length
HG	:	Heart girth
PG	:	Paunch girth
NL	:	Neck length
ND	:	Neck diameter
FL	:	Face length
FW	:	Face width
EL	:	Ear length
DHB	:	Distance between hip bones
TLS	:	Tail length without switch
TL	:	Tail length with switch
HS	:	Height at Shoulder
DPB	:	Distance between Pin bones
DHPB	:	Distance between Hip and Pin bones

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DEPARTMENT OF ANIMAL GENETICS AND BREEDING

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Thesis Title "Morphometric characterization and factor analysis of buffaloes of Kosi region of bihar"

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ABSTRACT

The buffalo population of Kosi river basin area of districts Madhepura, Saharsa and Supaul of Bihar are fully adapted to the agro-climatic and socio-economic conditions of the state under low-input management system with respect to the scarcity of feeds and fodder in flood situation of long period, resistance to various diseases. The phenotypic characterization of domestic animals consists of describing the exterior traits of each group, differing from other groups when considered as a whole. This characterization included the biometric measurements of sample animals body structure. The biometric body traits can be studied by using measurements with appropriate instruments which are called morphometric traits. Morphometric measurement research of animals has as their main objective to study the individual conformation, allowing the racial characterization and classification of the population. In addition, this characterization allows the comparison between and within genetic groups and establishes the association between the animal's conformation and function. These traits also contribute to the selection process in identifying the morphologically superior animals as well as eliminating the unwanted traits. In the present study an attempt has been made to present the descriptive analysis of body morphometric traits, characterize the population of buffaloes of Kosi region through systematic survey in breeding trait and to reduction of dimensionality of data capacity maximum of its variation. Information on the genetic divergence to within and between different populations also needs to be evaluated before undertaking the suitable methods of conservation and genetic improvement programmes for sustainable utilization of buffaloes of Kosi region of Bihar. The present study is being taken with following objectives viz. a)

To morphometric characterization of Buffaloes of Kosi Region b) To study the principal components variables of morphometric traits of Buffaloes of Kosi Region

Data of present study was collected using survey and measurement of body dimensions from field visit of target area. All the measurement of body dimensions of buffaloes of Kosi region were recorded once in upright animal standing on a level ground and by the same technical person. All these body dimensions taken for different age and sex groups were measured by using measuring Tape in centimetres. Data of morphometric traits of Buffaloes of Kosi Region were analyzed to estimates the means, correlation, rotated and unrotated factors of multivariate analysis.

Buffaloes of Kosi region are medium to large built animals distributed in three districts namely Madhepura, Supaul and Saharsa of Koshi of Bihar. The region under Kosi basin is characterized by loamy soil texture and marshy land under certain period in a year. The animals and life of this area experienced harsh climatic conditions of all sorts viz. heavy flood, rainy season, hot and humid, hot & dry summer, chill winter, scarcity of food etc. The annual precipitation rate of rain varies from 990 mm to 1700 mm. The most of precipitation received during the month of July to September. The soil pH varied from 6.5 to 8.4. Primarily, the climate is sub-tropical with peak summer temperatures averaging around 35 degree Celsius during March-May and winter months during December-January recording temperatures averaging around 8 degree Celsius. Kharif, Rabi and Zaid are the three agricultural seasons in Bihar, with main crops being rice, wheat and maize, along with various horticultural crops.

The buffalo of Kosi region are dual purpose animals used for milk production as well as agricultural operations in wet fields. They are better suited than the local cattle for ploughing and puddling the wet fields meant for paddy cultivation. They are active, fast moving, hardy and can work continuously for four to six hours in the wet fields. Artificial Insemination (AI) is in practice for breeding in urban and peri-urban areas and occasionally in rural areas. The buffaloes of Kosi region are well-built medium to large sized animals. The coat color varies from Black to grey. The effect of sexes found non-significant on all traits except Leg Length and Face Length ($p < 0.05$). The age contributes significantly for variation among morphometric traits across all age groups of animals whereas sexes affect variation of only two traits namely Leg Length and Face Length.

Mean of biometric traits (cm) studied in buffaloes of Kosi region were 123.22 ± 1.38 for HW, 88.72 ± 1.15 for HS, 36.44 ± 0.73 for NL, 80.15 ± 1.31 for ND, 101.26 ± 1.30 for BL, 188.82 ± 3.39 for HG, 221.71 ± 4.13 for PG, 34.77 ± 1.05 for FL, 20.61 ± 0.73 for FW, 4.99 ± 0.76 for EL, 22.31 ± 0.98 for DBH, 37.02 ± 0.83 for DHB, 21.15 ± 0.48 for DPB, 36.02 ± 1.01 for DHP, 87.47 ± 1.62 for TL and 92.5 ± 1.6 for TLS. The means of body biometry showed that buffaloes of Kosi region were medium to larger in body size. The coefficient of variation (CV) for different morphometric traits ranges between 0.19 (height at wither) to 16.3 (face width). Majority of the biometric traits showed higher consistency except for face width and ear length which were comparatively more variable. The standard deviations were well within the normal range, showing that in buffaloes of Kosi region, body measurements were less affected by environment. All biometric traits studied show less variability, indicating that the buffaloes of Kosi region are almost similar shape and size in their natural habitat. This might be due to natural selection for better adaptability for particular shape and size. Correlation coefficient estimated ranged between 0.07 (FW and DBH) to 0.94 (PG and HG) among various biometric traits. Among these 101 were significant of which all 101 were positive correlations. The positive and significant ($p<0.05/0.01$) correlations among different biometric traits suggest high predictability among the different traits.

The estimate of sampling adequacy KMO and Bertlett's test of sphericity for the biometric traits provided enough support for the validity of the factor analysis of data. The first two components accounted for 59% of the total variance of which the eigenvalues were larger than 1.0 ($\lambda>1.0$). Scree plot also suggested that two components are appropriate for summarizing the data of buffaloes of Kosi region. The identified two components could explain cumulative percentage of variance of 60%. First component accounted for 50% of the variation. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, DHB, TL and TLS. First component seemed to be explaining the maximum of general body conformation in Buffaloes of Kosi region of Bihar. The second component explained 15% of total variance with high loading of distance between FL, NL, and FW.

The communality ranged from 0.17 (DBH) to 0.89 (PG) and unique factors ranged from 0.83 to 0.11 for all these 16 different biometric traits. The principal(PC1) and (PC2) components together explain highest variation 89% in PG trait and lowest in DBH trait. The two extracted common factors determine the source of shared variability to explain body conformation in Buffalo of Kosi Region. These common factors represent general size of Buffalo of Kosi Region with respect to their length, height and diameter size and front view of the buffalo. The communalities estimates indicated that FL, FW, EL, DBH, DPB and DHP did not contribute effectively to explain body conformation in Buffalo of Kosi Region. The remaining traits HW, HS, NL, MD, BL, HG, PG, TL and TLS contributed effectively and may be considered to explain the body conformation of the Buffalo of Kosi Region. The result suggests that common factor analysis (CFA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation. The significant level of variability in this population reflects that the local buffalo population contains a valuable and substantial amount of genetic diversity among the studied population but the study needs to be extended to include more number of observation to make in a large sample size to further validate the research. The application of Oblique characters (PC1 and PC2) derived from the PCA can be more reliable in predicting body size compared to the use of the original body measurements. The two extracted factors determine the source of shared variability to explain body conformation in Buffaloes of Kosi region of Bihar. These first two PC could be exploited in the evaluation and comparison of animals and thus provide an opportunity to select the animals based on a small group of traits rather than on isolated traits. Our results suggest that the present PCA provided a means for a reduction in the number of biometric traits to be recorded in Buffaloes of Kosi region of Bihar (PG, HG, HW, NL, ND, and FL) which could be used in ranking programs as a mean to explain the body conformation. The results also suggest that principal component analysis (PCA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

INTRODUCTION

In past recent years, Bihar has achieved appreciative growth rate and economic development with greater contribution of service sector in comparison to share of agriculture in State Domestic Product (SDP). The real development of Bihar lies in the economic development of rural masses those are mainly dependent on agriculture sector. They are primarily depending on agriculture as the prime source of livelihood which is characterized by subsistence, low- input/low-output, technologically lagged mixed farming system and is dominated by smallholders (more than 55% land is under 0-1 hectare's category). The mixed farming system is mostly followed by the farmers with cropping of cereals in major and livestock rearing. The productiveness from cereals is largely uncertain round the year in Bihar due to heavy and least rainfall depending on location as a result of ever changing climate. The livestock farming ensures round the year income in rain fed and semi-arid regions of Bihar and used them as an alternative source of income. The buffalo among different livestock is found more in number because of more sustainable in production in rural masses in all harsh conditions and low input management systems. India harbours all the recognized and high milk producing breeds of buffalo of the world. India has been the centre of dispersion of good germplasm of buffaloes for improvement of the species. There are fifteen well recognised breeds of buffalo in India which constitutes about 30% of the total buffalo population in the country. However, 70% of the total buffalo population in the country is classified as non-descript because efforts have not been made to characterize them phenotypically and genetically.

India is presently producing 187.7 million tonnes of milk with 6.6% annual growth rate of which 49% milk is being contributed by indigenous (35%) and Non-descript (14%) Buffalo population (BAHFS, 2018). The In-milk buffalo population in Bihar is 2.2 Million out of 43.2 Million of India. Bihar had presented increasing trend of milk production from 2012 to 2018 with annual growth rate of 6.1% and has produced 8.7 million tonnes milk (BAHFS, 2018). The Buffalo of Bihar contributes 3.6 Million Tonnes milk to the total 86.2 Million Tonnes Buffalo milk produced in India. The average yield of In-milk Buffalo of Bihar is 4.38 Kg / day against national average of 5.47 Kg / day. The average productivity of In-milk Buffaloes of Haryana and Punjab is 8.74 kg / day and 8.74 kg / day, respectively (BAHFS, 2018). Moreover, the indigenous Buffaloes of Bihar are kept under non-descript category and no buffalo populations under descript category. While majority states in India had categorised their indigenous buffaloes into descript and non-descript category after undertaken proper scientific study. Therefore, field level study of Buffaloes of Bihar needs to be undertaken to ensure livelihood of rural people with aim to enhance their productivity.

In Bihar, buffalo milk accounts for nearly 48% of the total milk production in the state. These are strong indications of the fact that buffaloes available in Bihar are efficient producers and thus, an important Animal Genetic Resource for augmenting milk production in the state. Although buffaloes are distributed throughout the length and breadth of the Bihar state but the buffaloes of Kosi River Basin of Kosi Division are able producer of milk and work under adverse condition of floods, high humidity and high rain fall. The one development objective of the Bihar in the targeted districts in the Kosi river basin is to enhance agricultural productivity and competitiveness among farmers to increase agricultural productivity by expanding their access to and adoption of innovative and climate-resilient farm technologies and practices (including irrigation) and extending their linkages to market infrastructure. When the flood water recedea, access remains difficult as neither bridges nor roads partially exist. The difficulties in accessing these areas mean that they are often relatively neglected. In order to effectively address the challenge of enhancing agricultural productivity, Livestock farming is one of major component and area which continuously supports farmers in all adverse and favourable situations throughout the year. Buffaloes farming is major livestock supports systems to people of Kosi area for food and income even in badly affected flood situations. The blocks around rivers Kosi, Kamala and Kareh have been taken as the ‘Kosi Area Blocks as this forms a continuous geographical zone and shares similar geodemographical features. This area extends from Supaul and Madhubani in north to Katihar and Purnia in southeast and involves 43 blocks of 12 districts. The Kosi division consists of three districts namely Madhepura, Saharsa and Supaul with 12 blocks of Bihar having 6.12 million populations. The total number of buffalo population in the Bihar state is 7.7 million (Livestock Census, 2019) and presented significant increase in number of buffaloes with 2.02% during the inter censuses period (2012 - 2019). From Livestock Census, (2012), it is evident that the female buffalo population has increased from 4.71 million in 2003 to 6.59 million in 2012. The female buffalo population has increased by 22.03% during the inter censuses period (2007-2012). The District of Madhepura has the highest contribution10.84% of buffalo population among different district of Bihar. The districts namely Madhepura, Saharsa and Supaul of Kosi division lying in Kosiriver basin contain 16.28% of buffaloes out of total buffaloes of Bihar. The Kosi Division consisting of districts Madhepura, Saharsa and Supaul falls under Agro-climatic Zone II (Northern East) of Bihar and is characterised by heavy annual rain fall 1200-1700 mms, temperature in range of 33.8 to 8.8^{0}C, full of river tributaries of Kosi and other rivers. The area in Kosi river basin is practically submerged under flood waters every year for 3-5 months. Under such adverse environmental condition of Kosi River basin area, Buffaloes are able to produce optimally to supports farmers for their livelihood, food, employment, work power etc. They may possess unique characteristics in comparison to other breeds of buffalo of India. The buffaloes of this region may be systematically investigated to ascertain phenotypically homogenous in certain characteristics and any unique features of them.

These buffalo are fully adapted to the agro-climatic and socio-economic conditions of the state under low-input management system in the Kosi river basin area of districts Madhepura, Saharsa and Supaul of Bihar with respect to the scarcity of feeds and fodder in flood situation of long period, resistance to various diseases viz bacterial, viral, fungal, parasitic etc. and able to tolerate hot humid conditions. These features of buffalo segregate other breeds of buffalo and add value to them. However, information on characteristics, performance levels and management practices are scant in the literature.

The buffaloes are originally Asian animals having as their ancestor the *Bubalus arnee*, Asian wild buffalo. The species presents great adaptive potential and milk production of high nutritional value with high yield in the production processes of excellent derivatives, especially mozzarella cheese. These traits have allowed advances in breeding practices of buffaloes in the world milk market, providing strong demand for genetically superior animals in milk production systems. However, according to Mar-condes (2011), it is necessary to support the use of tools to assist in the selection and mating processes, allied to good management practices, allowing greater gains in productivity and quality in breeding buffaloes.

The phenotypic characterization of domestic animals consists of describing the exterior traits of each group, differing from other groups when considered as a whole (Canelón 2005). This characterization included the biometric measurements of sample animals body structure. The biometric body traits can be studied by using measurements with appropriate instruments which are called morphometric traits. Morphometric measurement research of animals has as their main objective to study the individual conformation, allowing the racial characterization and classification of the population. In addition, this characterization allows the comparison between and within genetic groups and establishes the association between the animal's conformation and function. These traits also contribute to the selection process in identifying the morphologically superior animals as well as eliminating the unwanted traits (Carvalho *et al*. 2010); Lucena *et al*. 2015).

The estimates of morphometric traits are reported scanty in literature (Espinosa-Núnês *et al*. 2011; Johari *et al*. 2009; Vohra *et al*. 2015; Mirza et al. 2015; Dhillod *et al*. (2017) but studies about the correlation between them are also faced although they are very important to genetic improvement programmes. As reported by Aqudelo-Gómez *et al*. (2015) the body measurements of female buffaloes and their correlations can aid in predicting the potential and aptitudes of these animals. There is some association between the body measurements, the productive and reproductive traits in buffaloes (Thomas and Chakravarty 2000; Espinosa-Núnês *et al*. 2011; Kern *et al*. 2014) and in cattle (Wenceslau *et al*. 2000; Rennó *et al*. 2003; Lagrotta *et al*. 2010; Silva *et al*. 2011). Further, Biometric traits are forms larger numbers of vectors for its data. The selection and prediction of potential of animals based on large numbers of variables make this almost confusing and impossible. These data are only available for animals in accuracy at farmer level upon measurement of different morphometric traits. The statistical technique Factor Analysis is commonly used tools for multivariate data analysis to reduce the dimension of data and to identify the important traits linked to better production potential of animals. These tools may facilitate selection of animals at field level based measurement few variables for genetic improvement.

In the present study an attempt has been made to present the descriptive analysis of body morphometric traits, characterise the population of buffaloes of Kosi region through systematic survey in breeding trait and to reduction of dimensionality of data capacity maximum of its variation.

Information on the genetic divergence to within and between different populations also needs to be evaluated before undertaking the suitable methods of conservation and genetic improvement programmes for sustainable utilization of buffaloes of Kosi region of Bihar. The present was taken with following objectives.

OBJECTIVES:

1. To morphometric characterization of Buffaloes of Kosi Region.
2. To study the principal components variables of morphometric traits of Buffaloes of Kosi Region.

REVIEW OF LITERATURE

Buffaloes a patent milk producing species in India, has been an important subject of investigation for animal scientist since long. A large number of publications pertaining to different parameters of morphometric, production and reproduction traits estimated from farmer herds and organised herds were already published for buffaloes of various states of India. (The same of population were further recognised a breeds.) Further in subsequent studies on these buffalo were made to analyse data of various with Principal Component Analysis Method. This study segregates a group of variables which explains maximum variability. The reports on various expert management, production and reproduction traits of buffaloes of Bihar is sporadic and scanty. Therefore, some of the relevant research finding of studies conducted on buffaloes managed in different agrosoaoe. Economic condition of the country in Bihar particularly managed under farmers management system has been reviewed hence.

Pundir *et al.* (2000) studied Mehsana buffalo distributed in Mehsana, Banaskantha and Sabarkantha districts of North Gujarat in India. Mehsana buffalo were characterised phenotypically and genetically using microsatellite markers and was reported as distinct breed.

Soumi *et al.* (2006) studied six breeds of riverine buffalo viz. Murrah, Mehsana, Jaffrabadi, Nagpuri, Nili-Ravi and Bhadawari. They were characterized using FAO-recommended cattle specific microsatellite markers to explore genetic divergence among them.

Kathiravan *et al.* (2008) estimated the daily milk yield of Kanarese buffaloes about two to seven litres milk daily for a lactation period that ranged between 210 to 360 days. They are medium built animals distributed in the South Kanara region on the west coast of South India. They characterised the Kanarese buffaloes phenotypically and genetically using 10 microsatellite markers in a panel of 48 unrelated animals. The average number of alleles was estimated to be 6.30 with an average heterozygosity of 0.62 per locus. The population showed departure from the Hardy-Weinberg equilibrium at all of the 10 loci tested. The heterozygote deficiency was estimated as 9.2% suggesting the presence of considerable inbreeding in the population.

Bhardwaj *et al*.(2007) Study was conducted to establish relationship between some breed characteristics of Murrah buffaloes such as horn pattern, head, face, colour of skin coat, tail switch, udder and teat conformation, skin thickness and temperament with milk production. The results indicated that coat colour, head and face, tail switch, shape of udder and teats and skin thickness were associated with milk production. The lactation milk yield produced by buffaloes having jet black colour was significantly higher than buffaloes with dark tan colour, Lactation milk yield of buffaloes possessing flat head was significantly higher than buffaloes with bulging head. Morphometric trait of buffalo is important for milk yield of different breed of buffalo.

Singh *et al.* (2017) reported that buffalo population like Chilika of Odisha state helps to maintain the natural ecosystem besides the economic importance. The germplasm of this population needs to be preserved. The Chilika breed, which recently has been registered, is reared under unique management conditions, having quality products, like curd.

Dhillod *et al.* (2017) studied correlate the milk yield of Murrah buffaloes with certain body parts measurements on 70 lactating Murrah buffaloes maintained at Buffalo Farm, Lala Lajpat Rai University of Veterinary and Animal Science, Hisar. The different body measurements can be helpful as a selection tool to enhance and evaluate the production potential by setting standards of Murrah buffalo breed. BW, abdominal growth, muzzle thickness and STK were found key factors while selecting a dairy Murrah buffalo.

Gilbert *et al*. (1993) At weaning and again after post weaning gain tests, height and width at hips, height at withers, body length, girth, head length and width, muzzle width, and cannon bone circumference measurements were obtained from Angus and Hereford bulls and heifers born in 1964, 1984, and 1985. The cattle were from the initial and final two calf crops selected for post-weaning gain when fed either a high-concentrate diet or an all-hay diet. Analysis of variance and canonical discriminate analysis were used to examine the relationships among body measurements and major sources of variation Canonical discriminate analysis indicated that one underlying vitiate explained nearly 90% of the total variation among the weaning measurements, whereas three variates were required to account for that proportion in the end-of-test measurements. At both measurement times, the first canonical variate was associated with year of birth, the second with sex of calf, and the third with dietary energy. Correlations between each canonical variate and the original body measurements indicated that year of birth (variate 1) was most closely associated with body length and cannon bone circumference at weaning and with body length and height at hips (but not withers) at end of test. Sex of calf (variate 2) was associated most closely with width of muzzle and head. Diet (variate 3) was associated with heart girth. Faster-growing cattle were longer in body, but not necessarily taller.

Putra *et al.* (2020) Principal component analysis (PCA) is important for describing the body conformation in livestock. Total of seven body measurements and thirteen body indices parameters from 144 heads of Pasundan cow (average 3 years age) at West Java Province of Indonesia were used in this study for PCA analysis. The body measurements in this study consisted of withers height (WH), body length (BL), chest girth (CG), chest width (CW), rump height (RH), rump width (RW) and rump length (RL). Therefore, the body indices in this study consisted of height slope (HS), width slope (WS), body index (BI), area index (AI), rump length index (RLI), conformation index (CI), length index (LI), body ratio (BR), proportionality (Pr), thoracic development (TD), pelvic index (PI), transverse pelvic (TP) and longitudinal pelvic (LP). The highest of Pearson's coefficient of correlations (r) value in body measurements was showed between WH and RH (0.93). Hence, the highest r value in body indices was showed between WS and TP. The PCA for body measurements and body measurements was revealed two factors of PC1 (WH, BL, RH) and PC2 (CG, CW, RW, RL) that explained about 73.36% of the total variation. Meanwhile, the PCA for body indices was revealed four factors of PC1 (BI, AI, RLI, LI, Pr, LP), PC2 (CI, TD), PC3 (WS, PI, TP) and PC4 (HS, BR) that explained about 89.38% of the total variation. It was concluded that the seven body measurements is important for describing body conformation of Pasundan cows such as body size (PC1) and body shape (PC2).

Vohra *et al.* (2015) characterized phenotypically taking 233 records of adult Gojri buffaloes from Punjab and Himachal Pradesh states of India for 13 body biometric traits. Traits were analysed by using varimax rotated principal component analysis (PCA) with Kaiser Normalization to explain body conformation. The value of 13 body biometric traits revealed four components which explained about 70.9% of the total variation. First component described the general body conformation and explained 31.5% of total variation and can be used in the evaluation and comparison of body conformation in buffaloes and thus provides an opportunity to distinguish between early and late maturing to adult, based on a small group of biometric traits to explain body conformation in adult buffaloes.

Vohra *et al.* (2017) analysed 18 body biometric traits in 157 adult female water buffalo from Chhattisgarh state of India using Principal component analysis (PCA) with a varimax rotation to deduce the components that control body conformation, suitable for use in buffalo breeding, and to reveal the main sources of their shared variability. First principal component explained 34.47% of total variance in body biometric traits and can be used in the evaluation and comparison of body morphology in female water buffaloes using body height, neck circumference, rump width, leg length, paunch girth, chest girth and tail length. The shared variability due to common variance ranged from 92% (horn length) to 51% (rump length) whereas 8 to 49% of their variation was contributed by unique variance specific for each trait in Chhattisgarhi buffaloes.

Verma *et al.* (2015) in the present study, biometric traits (body length [BL], heart girth [HG], paunch girth (PG), forelimb length (FLL), hind limb length (HLL), face length, forehead width, forehead length, height at hump, hump length (HL), hook to hook distance, pin to pin distance, tail length (TL), TL up to switch, horn length, horn circumference, and ear length were studied in 218 adult hill cattle of Himachal Pradesh for phenotypic characterization.

Chandran *et al.* (2015) studied Morphometric and body weight traits of Diara buffaloes and found that they (Diara buffaloes) are medium-sized animals with prominent forehead and loosely curved horns. They are smaller than the heavy-sized breeds like Murrah, Jaffarabadi and Nili-Ravi. Diara buffaloes are good milkers with an average per day milk production was found to be 7.8 litre and peak yield reached up to 10.5 litre per day. Diara population is far largely untouched of breed improvement programmes involving selective breeding. It could be undertaken to further enhance the genetic potential of these buffaloes.

Mishra *et al.* (2009) analyzed data on 397 adult milking buffaloes of Banni buffaloes distributed in the Kachchh region of Gujarat state. Banni buffaloes are medium to large in body size with a compact body and typical coiled horns. Mean body length, heart girth and height at withers estimated during the survey were 153.7±0.4 cm, 205.5±0.6 cm and 136.7±0.2 cm, respectively. The various reproductive traits of Banni buffaloes reported the mean age at first calving to be 39.7±0.4 months, a mean service period of 66.4±1.3 days, a mean lactation length of 293.3±1.5 days and a mean peak yield of 15.7±0.1 litres.

Javed *et al.* (2013) analyzed 1180 records on linear type and body measurements traits maintained at 5 Institutional herds (Pattoki, Chack Katora, Haroonabad, Khushab, Rakh Ghulaman) in Punjab and few private breeder's farms of Pakistan. The results of the present study indicate positive correlation between milk yield and other traits like height at sacrum, ear length and rump length. It need further investigations to reach at some conclusion to include these traits in selection strategy for improvement in milk yield.

Sapkota *et al.* (2017) Conducted a field study understand the productive performance, morphometric measurements and qualitative traits of 20 adult buffaloes in Eastern Terai of Nepal. Results of present study may have great importance in developing effective buffalo improvement plans focusing Terai regions in the future.

Thiruvenkadan *et al.* (2013) studied the contribution of buffalo (*Bubalus bubalis*) to the Indian agrarian economy by way of milk, meat and draught power production and as a source of security that requires minimum inputs. The germplasm of such well-defined breeds constitute a valuable genetic resource which needs to be conserved on priority basis. The rich biological diversity of this species is progressively being eroded due to unplanned breeding.

Khan *et al.* (2013) studied Azikheli, an undocumented buffalo breed, in its home tract (Khwazakhela, Swat, Pakistan) under traditional farming conditions. For this purpose, 108 buffalo cows and 27 bulls were randomly selected. Mean, standard error, Student's *t* test and Chi-square test were used for various comparisons. The results show that the majority of animals have a brown coat colour. Cows have significantly higher heart girths, longer horns, longer necks and wider faces at the level of the eyes than bulls, whereas bulls have significantly longer bodies, longer ears, thicker horns, thicker necks and larger hooves than cows. Horns are flat laterally, directed backwards and then slightly upwards without twisting, leading to a sickle to semi-sickle appearance.

Salamena and Papilaja (2010) studied the variance of some morphmetric characteristics and morphology of Moa buffalo, and the genetic relationships analysis between buffalo subpopulations in Moa Island. Characterization was by using 174 buffalos from any group of ages and sex that were collected from West area, Central area, East area. The variables observed were morphmetric characters (body weight, shoulder height, body length, chest width, chest depth, chest girth, skull length, skull width, skull height, ear width, ear length, cannon girth, horn length, horn girth and distance between horns), body morphology characters (horn position, head color, body color and scheme of body color), and genetic distance between buffalo subpopulations. Body morphometric data were analyzed using mean, standard deviation and variance coefficient. Body morphology data were analyzed using relative frequencies.

Sahu *et al.* (2017) studied on records of 198adult animals (67male, 131female) Sambalpuri buffalo for conformation, production and reproduction traits at farmers' level. These data were subjected to least squares analysis and Duncan's multiple range test. Horn length difference was found to be significant ($P<0.01$) among localities but, between sex it was non-significant. All other conformation traits were found to be non-significant among localities. However, there exists a significant difference between two sexes ($P<0.01$) in relation to all conformation traits except horn length and tail length. The effect of localities was significant ($P<0.01$) on all the production and reproduction traits except for gestation period.

Shankar and Mandal (2014) conducted experiment on 60 randomly selected dairy units consisting of 116 Graded Murrah,70 Diara type and 121 Non-descript type buffalo cows utilizing the procedure of stratified random sampling with proportional allocation (Snedecor and Cochran,1967) in and around Patna. Genetic factors were the three different genetic groups of buffaloes viz. Graded Murrah, Diara and Non-descript types prevalent in Bihar Whereas Non-genetic factors included in the study were location of herd, faming system and sequence of lactation. The average estimates of body weight of Graded Murrah, Diara and Non-descript were found to be 508.972+3.36, 461.789+3.32 and 483.857+3.30 kg respectively.The three genetic groups of buffaloes differed significantly ($p<0.05$) among themselves with respect to their body weight. Farming system and lactation order had significant ($p<0.01$) influence on body weight. Body weight of the animals was the lowest at first parity and then increased significantly ($p<0.05$) in subsequent parities.

Bhinchhar *et al.* (2017) did the research work for characterization of Gangatiri cattle, was conducted on a herd maintained at Mirzapur district of Uttar Pardesh. This dual-purpose indigenous cattle breed is found mainly in Varanasi, Chandauli, Ghazipur and Ballia district of eastern Utter Pradesh and adjacent areas of Bihar state of India. Medium size muzzle, medium lustrous eyes was characteristics of the herd. Medium sized dewlap, small brisket, sharp and smooth shoulder with medium legs was present in most of the animals. Medium sized bowl shaped udder with cylindrical shaped medium sized teats and prominent, crooked and branched milk veins were the other characteristic features of the herd. The overall least squares' means for Ischium width of Rump (ISWR), Top line (TPL), Udder length (UL), Udder diameter (UD), Teat length (TtL), Udder circumference (UC), Distance between fore to fore (DFF) and rear to rear teats (DRR) were 20.79±0.57, 144.64±1.67, 26.17±1.21, 11.03±1.40, 5.33±0.31, 68.84±3.89, 6.03±0.50 and 4.93±0.21 cm respectively.

Vohra *et al.* (2015) Phenotypic characterization and body biometric in 13 traits (height at withers, body length, chest girth, paunch girth, ear length, tail length, length of tail up to switch, face length, face width, horn length, circumference of horn at base, distances between pin bone and hip bone) were recorded in 233 adult Gojri buffaloes from Punjab and Himachal Pradesh states of India. Traits were analysed by using varimax rotated principal component analysis (PCA) with Kaiser Normalization to explain body conformation. Present study suggests that first principal component can be used in the evaluation and comparison of body conformation in buffaloes and thus provides an opportunity to distinguish between early and late maturing to adult, based on a small group of biometric traits to explain body conformation in adult buffaloes.

Singh and Singh (2014) studied Sanchori cattle, having good milk production potential, are maintained by the farmers of Galore district of Rajasthan. The animals are kept in herds with size varying from 2–10 animals under semi-intensive production system and stall feeding. Age at first calving, lactation length, calving interval, dry period and service period of Sanchori cows were found in the range of 36–48 months (average 39.5 months), 8–15 months (average 10.16 months), 12–20 months (average 14.4 months), 0.5–

10 months (average 4.3 months) and 2–11 months (average 5.44 months), respectively. The life span of Sanchori cattle was found as 20–25 years with 12 to 15 lifetime calving. Average daily milk yield of Sanchori cows ranged from 3.05 to 16.3 litre with an average of 9.08 litre. Keeping in view the declining population status of Sanchori cattle, there is a need to take up suitable measures for its genetic improvement and conservation.

Santos *et al* (2019) statistical methods such as Principal Component Analysis (PCA) and Factor Analysis (FA) are increasingly popular in Nutritional Epidemiology studies. However, misunderstandings regarding the choice and application of these methods have been observed. This study aims to compare and present the main differences and similarities between FA and PCA, focusing on their applicability to nutritional studies.

Gomez *et al* (2015) Dual-purpose buffaloes born in Colombia between years 1996 and 2014 were used. The following traits were assessed using one trait models. Milk yield at 270 days (MY270), age at first calving (AFC), weaning weight (WW),and weights at the following ages: first year (W12), 18 months (W18), and 2 years (W24)Direct additive genetic and residual random effects were included in all the traits.PCA is an alternative approach for analyzing traits in dual-purpose buffaloes and reduces the dimension of the traits.

Pundir *et al.* (2011) studied eighteen different biometric traits in 407 Kankrej cows from Palampur district of Gujarat The traits were analyzed by factor analysis to explain body conformation. Most of the correlations were positive and significant. Factor analysis with promax rotation with power 3 revealed three factors which explained about 66.02% of the total variation. The result suggests that principal component analysis (PCA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain body conformation.

Tolenkhomba *et al.* (2012) studied eighteen different biometric traits in 250 local cows of Manipur. The traits were analysed by principal component analysis to explain body conformation. Factor analysis with promax rotation revealed seven factors which explained about 64.31% of the total variation. Factor 1 described the general body conformation and explained 17.74% of total variation.

de Melo *et al.* (2018) conducted the morphometry study of crossbred female Murrah buffaloes, aiming to give subsidies to the study of the relations between their body structures and productive or reproductive performances. The highest correlations were in range of 0.74 to 0.64 among traits. These correlation coefficients between the body morphometric measurements themselves can be used in the selections programme

Yakubu *et al.* (2009) performed a multivariate approach to be adopted to provide an objective description of the body shape of 204 White Fulani cattle of two age groups: 1.5-2.4 and 2.5-3.6 years. Age group significantly influenced all the fourteen morphometric measurements investigated. Gender was only a significant source of variation for heart girth, head width, cannon circumference, shoulder width, rump width and rump length, with higher means recorded for male animals. The correlation coefficients of the body measurements ranged from 0.50-0.98 and 0.22-0.91 for 1.5-2.4 and 2.5-3.6 years old animals respectively. In factor solution of the principal component analysis, two factors with ratio of variance of 85.37 were identified in the first age group. In the second age group, four factors which explained 86.47% of the generalized variance were extracted. The first factor accounted for 78.99% and 67.05% in the first and second age group respectively, thus appearing as an index of general size. The subsequent factors in both age groups presented patterns of variation independent of general size. These results suggest that principal component analysis could be employed in breeding programmes with a drastic reduction in the number of body measurements to be considered in the improvement of body conformation.

Oliveira *et al.* (2001) In vivo internal and external pelvimetry was carried out in 255 mixed female buffaloes. A Menissier-Vissac pelvimeter was used for the internal measurements. Positive significant correlations (p 0.01) were obtained for all measurements but heart girth was found to have the highest correlations to pelvic measurements internal pelvimetry was found to be less correlated to the body size and more evident.

CHAPTER – 3

MATERIALS and METHODS

3.1 Source of Data

The data for Morphometric Characteristics Ecological Settings, Status of Buffaloes in Breeding Tract, Buffalo Husbandry Practices (Housing, Feeding and Breeding), Management Practices, Physical Characteristics, Production Performance and Utility were collected using questionnaires, direct communication with farmers, direct observations and measurements. The breeding tract of buffalo lies in the Kosi sub-basin of Bihar.

3.2 Kosi Region

The geographical extent of the Kosi sub-basin lies between 85° to 87° 21' east longitudes and 25° 25' to 26° 48' north latitudes of the country. Kosi is a major tributary of the Ganga River which originates at an altitude of 7,000 m in the Himalayas. The total drainage area of the Kosi River is 74,500 Sq.Km out of which 11,000 Sq.Km lie in India. Nearly 80 percent of the Kosi catchment area is in Nepal and Tibet. About 77 percent of the area is under cultivation. The total catchment area of Kosi basin is 95,156 Sq.Km of which 18,413 Sq.Km lies in India. Other than the main rivers the Kosi and the Adhwara, the Bagmati, the Kareha, the Balan, the Kamla, the Lakhandal form some of the major river flowing in this sub-basin. The sub-basin completely falls in the Bihar state. The river is also known as Sorrow of the Bihar because of the frequent floods in the Kosi River. The sub basin map is shown below:

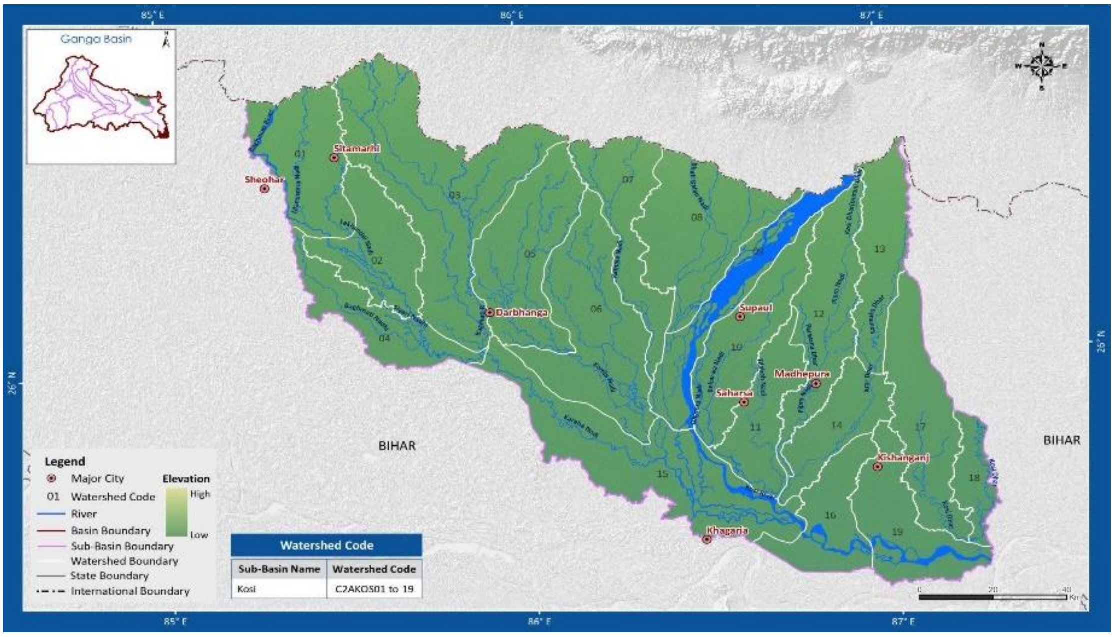

Figure 3.1: Map of Kosi sub-basin area of Bihar

3.3 Morphometric characterizations

The Survey on buffaloes of Kosi region was conducted at Lalitgram and Raghopur blocks of Supaul district, Bihariganj, Madhepura and Singheshwar blocks of Madhepura district and Mahishi and Saurbazar blocks of Saharsa district. A total of 250 farmers from different villages were interviewed to record information on various management practices opted by the livestock owners in the state. Kosi Buffaloes were randomly selected in a range from first to fifth parity on the basis of availability at farmers. Farmers were interviewed to know the habitat, status, management, utility and performance of the Buffaloes. Farmers were also enquired about choice of breed, sale and purchase of animals, animal housing, feeding, breeding and prevalent diseases in the area. Performance traits like age at first calving, age at first service, daily milk yield, calving interval, lactation yield, peak yield, lactation length, dry period, service period and calving interval were collected by conversing with the farmers from the surveyed villages using structured questionnaire.

Different body measurements and physical characteristics were recorded on 260 animals of different age and sex.

Table 3.1: Demographic Distribution of Surveyed Kosi Buffaloes with respect to various Age and Sex Groups

S. No.	Age Groups	Number of Animals
1	0-7 days	30
2	8 days to 1 year	30
3	1 year to 2 year	40
4	2 year to 3.5 year	40
5	More than 3.5 years (Adult Animals)	120

The survey included 76 male and 141 female animals. Age wise distribution of surveyed Kosi Buffaloes were as follows viz. 0 - 7 days (30), 8 days to 1 year (30), 1 year to 2 years (40), 2 years to 3.5 years (40) and more than 3.5 years of age or adult animal (120). All measurements were recorded twice by the same recorder to minimize the error and to avoid between recorder effects. All measurements were taken by a measuring tape. The body measurements (Height at withers, Height at shoulder, neck length, neck circumference, body length, heart girth, paunch girth, face length, face width, ear length, distance between hip bones, distance between pin bones, distance between pin and hip bones, tail length without switch and tail length up to switch) were recorded. The physical characteristics were recorded for hair colour and length, coat colour, skin colour, muzzle colour, hoof colour, tail switch colour, horn shape, horn size, horn orientation, head shape, head polls, naval flap, penis sheath flap, temperament, udder shape, teat shape, teat tip and milk vein.

Table 3.2: Description of Body Parts Measurements

Sl. No.	Traits Name	Descriptions
1	Height at wither (HW)	Distance from the highest point of wither to the ground
2	Body length (BL)	Distance from the point of the shoulder joint to the point of the pin bone
3	Heart girth (HG)	Circumference of the heart circumference around the chest
4	Paunch girth (PG)	Circumference around the chest
5	Neck length (NL)	Distance from neck attachment to breast
6	Neck diameter (ND)	Girth of the neck from mid neck
7	Face length (FL)	Distance from between the horn site to the lower lip
8	Face width (FW)	Distance between front of both the eyes
9	Ear length (EL)	Distance from the point of attachment of ear to the tip of the ear
10	Distance between hip bones (DHB)	Distance between both of the hip bones
11	Tail length without switch (TLS)	Measured from the tail droop to the tip of the tail excluding switch
12	Tail length with switch (TL)	Measured from the tail droop to the tip of the tail including switch
13	Height at Shoulder (HS)	Distance from the point of ground to the point of the shoulder
14	Distance between Pin bones (DPB)	Distance between both points of the pin bones.
16	Distance between Hip and Pin bones	Distance between points of the Hip to Pin bones

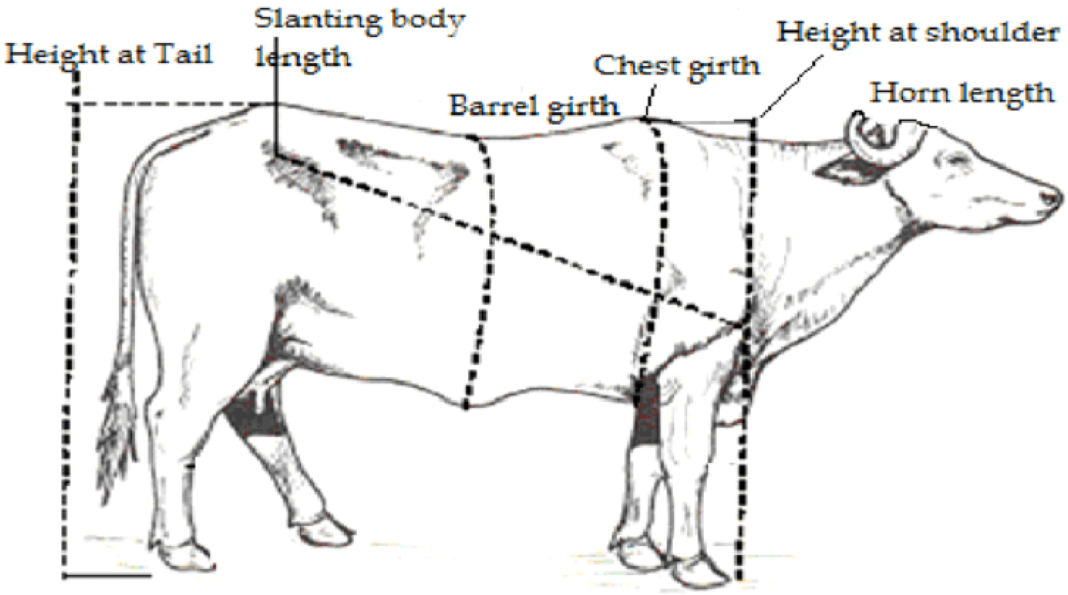

Figure 3.2: Body Part Measurements of Buffalo

All the measurement of body dimensions of buffaloes of kosi region were recorded once in upright animal standing on a level ground and by the same technical person to avoid between recorder effects. All these body dimensions taken for different age and sex groups were measured by using measuring Tape in centimetres. To ensure a consistent methodology, all measurements (Figure 1) were carried out by the same person.

3.4 STATISTICAL ANALYSIS

The statistical analysis was carried out for the data under the following headings:

3.4.1 Effect of Non-genetic factors age and sex affecting Morphometric traits

Least-squares fixed model analysis of data was carried out using Emmeans Package of R statistics to study the effects of non-genetic factors age and sex on different morphometric traits.

Model of choice

The effect of non-genetic factors (Age and Sex) on morphometric traits were analyzed using the following mixed model

$$Y_{ijk} = \mu + A_i + S_j + e_{ijk}$$

where, Y_{ijkl} is observation on the l^{th}progeny in k^{th} season, j^{th} sire and i^{th} period of birth

μ is overall mean

A_i is fixed effect of i^{th} groups of age

S_j is fixed effecting j^{th} sex

e_{ijk} is the random error associated with each record which is NID $(0, \sigma_e^2)$

3.4.2 Duncan's Multiple Range Test (DMRT)

DMRT as modified by Kramer, (1957) was used for testing differences among least square means (using the inverse coefficient matrix). The differences were considered, significant if

$$X_i - X_j = \sqrt{\frac{2}{C_{ii} + C_{jj} + 2C_{ij}}} > \sigma_e Zpn_2$$

Where, X_i and X_j are the least squares means for i^{th} and j^{th} treatment, and C_{ii}, C_{jj} and C_{ij} are diagonal and off-diagonal elements in the inverse of coefficient matrix in the least squares normal equations.

3.5 Phenotypic Correlations

The phenotypic correlations among morphometric traits were estimated using following Carl Pearson formula

Phenotypic correlations were estimated as

$$r_{p\rightarrow} = \frac{\text{Cov } S_{XY}}{\sqrt{(\sigma_X^2)(\sigma_Y^2)}}$$

where, Cov S_{XY} = Component of covariance between traits X and Y

σ_X^2 and σ_Y^2= Components of variance for traits X and Y

3.5.1 Standard error of phenotypic correlations

The standard error of phenotypic correlations was calculated as

$$SE(r_p) = \sqrt{\frac{[1 - r_p^2(XY)]}{[(N - 2)]}}$$

where, $r_p(XY)$ = Phenotypic correlation between the traits X and Y in the same individual

$N - 2$ = Degree of freedom

The statistical significance of correlations was tested by using the'‘t-test’.

3.6 Factor Analysis for Morphometric Traits of Buffalo of Kosi Region

Principal components and exploratory factor analysis are the two related but distinct methodologies called Factor Analysis for exploring and simplifying complex multivariate normal data. Factor analysis can be performed to combine a large number of variables to smaller number of factors. Factor analysis is a data reduction technique and is done usually for the following reasons: (i) Find interrelationships among different kinds of variables (ii) Identify common underlying dimension (iii) Data reduction and removing duplicacy of columns. Factor Analysis may be performed in many ways, among which two ways Principle component analysis and Common factor analysis are popular. Before proceeding to data analysis for factor analysis, data were prepared and standardized to make it fit for analysis.

3.6.1 Scaling of Data

- The data of morphometric variables were standardized for mean zero and unit variance in order to avoid the effect of different scaling and magnitudes using following formula.

$$Z_i = \frac{(X_i - \overline{X})}{S_i}$$

Where, Z_i = Standardized Value of X_i Variable

$\overline{X}$ = mean of ith trait

S_i = Corresponding Standard Deviation

(Boligon *et al*. 2016)

3.6.2 Checking of data suitability for Factor Analysis

The EFA methods require large samples to derive stable solutions. The data of variables should be normally distributed, pairs of variables should follow bivariate normal distribution and the dataset as a whole should follow multivariate normal distribution. Outliers should be omitted. Any variables uncorrelated with any other variables should be omitted. The any two variables which are perfectly correlated (r=1.0) with each other should not be included in analysis. One variable may be removed from each pair. The data should not have any missing values. The data is further checked for sample adequacy using Bartlett's Sphericity and the KMO index (Kaiser-Mayer-Olkin) tests for factor analysis. Bartlett's Sphericity and the KMO index tests are commonly used methods to check the adequacy sample data for its the factor analysis.

3.6.3 KMO Test

KMO test checks that we can factorize efficiently the original variables. It is based on correlation matrix. The range of KMO is from 0.0 to 1.0 and desired values are > 0.5. Variables with MSA being below 0.5 indicate that factor analysis may not be appropriate.

3.6.4 Bartlett's Sphericity test

The Bartlett's test tests the hypothesis that correlations between variables are greater than would be expected by chance. It checks if the observed correlation matrix $R=(r_{ij})_{(p \times p)}$ diverges significantly from the identity matrix. Technically, this tests is used to check that the matrix is an identity matrix. The PCA can perform a compression of the available information only if we reject the null hypothesis. It uses the following formula.

$$\chi^2 = -\left(n - 1 - \frac{2p+5}{6}\right) \times \text{In}|R|$$

Under H0, it follows a χ^2 distribution with a [p x (p-1) / 2] degree of freedom. We reject the null hypothesis at the 5% level (p-value = $4.35 \times 10^{-8} < 0.05$). We can perform efficiently a PCA on our dataset.

3.7 Factor Analysis steps for Principle Component Analysis (PCA) and Common Factor Analysis (CFA)

3.7.1 Principal component analysis

The goal of PCA is to replace a large number of correlated variables with a smaller number of uncorrelated variables while capturing as much information in the original variables as possible. These derived variables called principal components are linear combinations of the observed variables. Specifically, the first principal component

$$PC_1 = a_1X_1 + a_2X_2 + \ldots + a_kX_k$$

is the weighted combination of the k observed variables that accounts for the most variance in the original set of variables. The second principal component is the linear combination that accounts for the most variance in the original variables under the constraint that it's orthogonal (uncorrelated) to the first principal component. Each subsequent component maximizes the variance accounted for while at the same time remaining uncorrelated with all previous components. Theoretically, you can extract as many principal components as there are variables. PCA decomposes a correlation matrix with ones on the diagonals. The amount of variance is equal to the trace of the matrix, the sum of the diagonals, or the number of observed variables in the analysis. PCA minimizes the sum of the squared perpendicular distance to the component axis (Truxillo, 2003). Principal components retained account for a maximal amount of variance. The component score is a linear combination of observed variables weighted by eigenvectors. Component scores are a transformation of observed variables (C1 = b11x1 + b12x2 + b13x3 + . . .). The PCA is performed following the model in matrix notation as given below: -

$$Y = XB$$

Where, Y is a matrix of observed variables

X is a matrix of scores on components

B is a matrix of eigenvectors (weights)

3.7.2 Common Factor Analysis (CFA)

Factor analysis searches for joint variations in response to unobserved latent variables. The observed variables are modeled as linear combinations of the potential factors plus "error" terms. Common Factor Analysis (CFA) is a collection of methods designed to uncover the latent structure in a given set of variables. It looks for a smaller set of underlying or latent constructs that can explain the relationships among the observed or manifested variables.

CFA decomposes an adjusted correlation matrix of data. The diagonals have been adjusted for the unique factors. The amount of variance explained is equal to the trace of the matrix, the sum of the adjusted diagonals or communalities. Factors account for common variance in a data set. Squared multiple correlations (SMC) are used as communality estimates on the diagonals.

CFA = The Common Factor Analysis was performed following the model as

$$\text{CFA } Y = X\beta + E$$

where Y is a matrix of measured variables

X is a matrix of common factors

A is a matrix of weights (factor loadings)

E is a matrix of unique factors, error variation

3.8 Selecting the number of factors / components to extract

Number of components equal to number of variables, only the first few components were retained following several criteria for factor analysis (PCA and CFA) us given below.

Number of eigenvalues greater than 1

Scree Plot with Parallel analysis

Percentage of variation explained

3.9 The number of components to be retained for Factor Analysis

a. Eigenvalue > 1 criterion (Kaiser, 1960). Each observed variable contributes one unit of variance to the total variance. If the eigenvalue is greater than 1, then each principal component explains at least as much variance as 1 observed variable.

b. Scree test – We look for an elbow obtained in scree plots. The number of components following above the bendar elbow are retained for further analysis and interpretation.

c. Rotations is a linear transformation of the solution to make interpretation easier (Hatcher, p.28) with an orthogonal and oblique rotations.

d. Interpretation of rotated solution: - The Summeration Results in Tables for rotated solution is interpreted as objective of research.

e. Summarize results in a table: - The result of analysis solution of factor analysis were summarized in different tables for interpretation.

CHAPTER – 4

RESULTS & DISCUSSION

RESULTS AND DISCUSSION

4.1 BREEDING TRACT

Buffaloes of Kosi region are medium to large built animals distributed in three districts namely Madhepura, Supaul and Saharsa district of Koshi region of Bihar. The region under Kosi basin is characterized by loamy soil texture and marshy land under certain period in a year. The animals and life of this area experienced harsh climatic conditions of all sorts viz. heavy flood, rainy season, hot and humid, hot and dry summer, chill winter, scarcity of food etc. The annual precipitation rate of rain varies from 990 mm to 1700 mm. The most of precipitation received during the month of July to September. The soil pH varied from 6.5 to 8.4. There are three crop seasons Kharif, Rabi and Zaid. This region is located between 25 to 27degree North latitude. The climate of Kosi region falls under mostly sub-tropical region type.

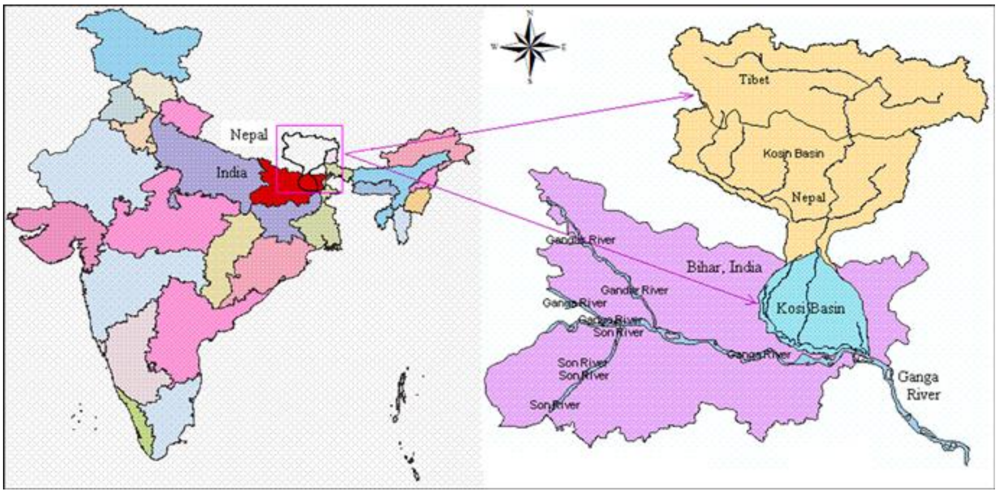

Figure 4.1: Breeding Tract of Buffalo of Kosi Region of Bihar

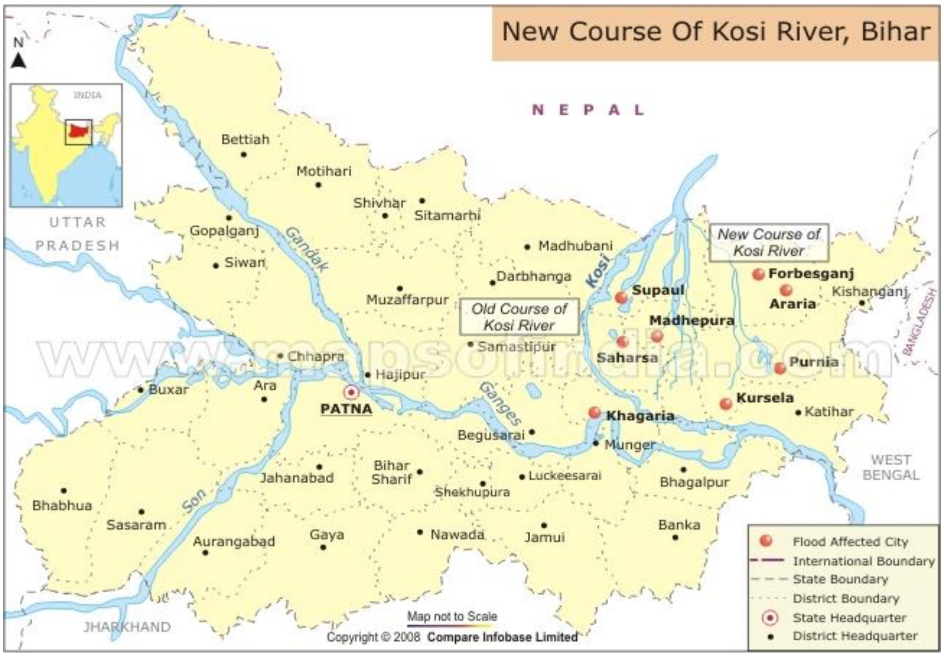

Figure 4.2: Breeding Tract of Buffalo of Kosi Region along with major river tributaries

Ecological settings

Kosi region is constituted of the three districts namely Saharsa, Madhepura and Supaul. This region is affected by recurrent floods by many rivers especially Koshi river. The river Kosi originates at an altitude of over 7000 M above MSL (Mean Sea Level) in the Himalayas. The highest peak of Mount Everest and Kanchanjunga falls within Kosi catchment area. This river brought heavy water flow along sediments.

Geographically, the breeding tract lies between 25°N latitude and between 86°E longitude. The catchment area of Kosi which falling in Bihar is only 31726 sq. km out of total 95156 Sq. km.

Primarily, the climate is sub-tropical type with peak summer temperatures averaging around 35 Degree Celsius during March-May and during winter months December-January average recorded temperatures averaging around 8 degree Celsius. Kharif, Rabi and Zaid are the three agricultural seasons in Bihar with main crops being rice, wheat and maize along with various horticultural crops. The Kosi region of Bihar come under agro-climatic zones II of Bihar. These features determine the soil characteristics, geographical terrain, rainfall and temperature which together influence its cropping pattern. The breeding tract of buffaloes is found in major the alluvial plains of Kosi region of Bihar which is generally characterized by relatively high average rainfall around 1303 mms. The average relative humidity lies between 40% to 60%. The humidity is high during the monsoon period when it is about 85%.

4.2 Buffalo Husbandry Practices

Housing

Buffaloes of Kosi region were surveyed in their breeding tract at farmers houses where it was observed that animals are housed close to the human dwellings. In most cases, closed housing is provided (80%). In most instances (70%), the animals and humans are housed in different parts of the same building. In the remaining cases, a separate structure was provided to animals away from farmer’s house. Most of the constructions are permanent (80%) with thatched roofs covered with paddy straw or tiled roofs. Asbestos roof was also observed in 5% animal houses. Floors are generally uneven without proper drainage facilities. In peri-urban areas, the animals are overcrowded with less than the minimum required floor space of 3.5 square meters (ICAR, 2002) being provided. In rural areas, the practice of allowing the animals to wallow in the nearby water sources is prevalent (95%). Mostly the animals wallow around noon after grazing in the fields under a hot sun. Animals are kept in night in closed house. In day time, animal was feed in open area of house where their Mengers are located. After morning feeding and milking, animals are either kept in open area away of house or let loose to graze in field and wallow. Similarly, in evening, animals were given feeds in their mengers and after milking they are brought in closed house. The buffaloes of Kosi region survives in marshy land in major part of the year and area getting dried for cultivation only during dry-weather conditions.

Herd structure

Rearing of cattle and buffaloes in India is mostly in hand of small and marginal farmers and part of small holder production system. In rural area of India, major livestock population is found where disorganized farming system is prevalent. The livestock reared in urban and peri-urban area constitute scanty population out of total population where to some extent organised farming systems is found. The management of buffaloes of Kosi region by the farmers in the breeding tract is no exception to it. The herd size of buffaloes of Kosi region is very small with an average being 3.1 which is in agreement with chandran *et al.* (2015). The herd structure included almost neglible adult males, 2.0 adult females, 0.2 male calves and 0.8 female calves. The disparity between male and female calves might be due to immediate disposal of male calves by the farmers once dam's milk yield ceases or even during milking period. Farmers take less interest in better caring of male because they find uneconomical to rear them. Due to mechanisation of agriculture systems, drought power of male buffaloes of Kosi region has also become unimportant. Adult male buffaloes are even almost unavailable at farmers house even for breeding.

Figure. 4.3: Herd Management of Buffaloes of Kosi Region

Feeding

Paddy straw, dry mixed grasses and green grasses are the main sources of roughage. Wheat bran, linseed oil cake, mustard oil cake and rice bran are given as concentrates. About one third (34%) of the farmers provide concentrates to the milking animals, 0.5 to 2 kg of concentrate is usually given to the lactating animals at the time of milking. Some farmers even feed the animals with kitchen wastes and hotel wastes. This practice is more prevalent in the urban areas.

Figure. 4.4: Feeding Management of Buffaloes of Kosi Region

Breeding

Breeding of buffaloes is highly disorganized in the breeding tract. Natural service practiced primarily by farmers of rural areas. Artificial Insemination (AI) is in practice for breeding in urban and peri-urban areas and occasionally in rural areas. In the rural areas A.I. is now getting priority due to unavailability of breeding bulls and practical difficulties of farmers. Breeding bulls those used for breeding in rural area are free ranged animals. Their ears are generally cut for certain rituals of locals people after which they are let loose to field for open grazing. Although A.I. services are available in urban and some rural areas, semen of buffaloes of Kosi region is not available and the farmers have to opt for either semen straws of other descript and non-descript animals. As a result, the proportion of graded buffaloes and non-descript animals are more common in the urban areas.

4.3 Physical characteristics

The buffaloes of Kosi region are well-built medium to large sized animals. The coat color varies from Black to grey. Their skin is black. The black colored buffaloes were found more efficient producer and popular among farmers in comparison to grey colored one. The head is long with a broad forehead. The face of buffalo of Kosi Region appear long in length and presents slight concave region on frontal bone region of face. It is a one distinctive feature of this buffalo Ears are moderately long and erect. The neck is moderately long with almost negligible dewlap.

Horns are medium sized, flat, corrugated and curved, projecting backward, sideward and upward at half of the neck. Shoulders are long and slope smoothly with the body. The barrel is well built and medium to large in size with a straight and wide back. Legs are strong with hard hooves. The udder is moderately developed with teats of medium size and squarely placed between the hind legs. The tail is fairly long, thin and flexible ending in a black, black and white switch. Figures 4.5 and 4.6 show typical male and female buffaloes of Kosi region, respectively.

Figure. 4.5: Male Buffalo of Kosi Region

Figure. 4.6: Female of Buffalo of Kosi Region

Figure. 4.7: Typical forehead feature of Buffalo of Kosi Region

Figure. 4.8: Different Typical feature of Body Colour and Sholder of Buffaloes of Kosi Region

4.4 Effect of fixed effects age and sex on morphometric traits

The effect of non-genetic factors age and sex was investigated in the study and presented in the Table 4.1. The effect of age taken in five groups (0-7 days, 8 days to 1 year, 1 year to 2 years, 2 years to 3.5 year, more than 3.5 years) were found significant on all morphometric traits of body dimensions taken in study ($p < 0.01$). The effect of sexes found non-significant on all traits except Height at shoulder (HS) and Face Length ($p < 0.05$). The age contributing significantly for variation among morphometric traits across all age groups of animals whereas sexes affecting variation of only two traits namely Height at shoulder (HS) and Face Length (FL). It indicate that the height and face length of male buffalo are larger than that of female buffalo across all age groups.

Table 4.1: Effect of non-genetic factors age and sex on different morphometric traits of body dimensions.

S. No.	Trait name	Age	Sex
1	Height at wither (HW)	S^{**}	NS
2	Body length (BL)	S^{**}	NS
3	Heart Girth (HG)	S^{**}	NS
4	Paunch Girth (PG)	S^{**}	NS
5	Height at shoulder (HS)	S^{**}	S^{*}
6	Neck Length (NL)	S^{**}	NS
7	Neck Diameter (ND)	S^{**}	NS
8	Face Length (FL)	S^{**}	S^{*}
9	Face Width (FW)	S^{**}	NS
10	Ear Length (EL)	S^{**}	NS
11	Horn Length (Inch)	S^{**}	NS
12	Distance between hip bones (DHB)	S^{**}	NS
13	Distance between Hip and Pin (DHP)	S^{**}	NS
14	Distance between Pin Bones (DPB)	S^{**}	NS
15	Tail length without switch (TLS)	S^{**}	NS
16	Tail length with switch (TL)	S^{**}	NS

Descriptive Statistics of Morphometric Traits

The descriptive statistics for all the biometric traits along with standard deviation (SD), coefficient of variation (CV) are given in Table 4.2.

Table 4.2: Descriptive statistics for all the biometric traits along with standard deviation

Traits	N	Mean	SD	CV (%)
HW	273	123.22 ± 1.38	22.79	18.50
HS	273	88.72 ± 1.15	19.03	21.45
NL	273	36.44 ± 0.73	12.06	33.10
ND	273	80.15 ± 1.31	21.65	27.01
BL	273	101.26 ± 1.30	21.45	21.18
HG	273	188.82 ± 3.39	56	29.66
PG	273	221.71 ± 4.13	68.21	30.77
FL	273	34.77 ± 1.05	17.3	49.76
FW	273	20.61 ± 0.73	12.11	58.76
EL	273	24.99 ± 0.76	12.63	50.54
DBH	273	22.31 ± 0.98	16.15	72.39
DHB	273	37.02 ± 0.83	13.7	37.01
DPB	273	21.15 ± 0.48	7.94	37.54
DHP	273	36.02 ± 1.01	16.67	46.28
TL	273	87.47 ± 1.62	26.82	30.66
TLS	273	92.5 ± 1.6	26.45	28.59

Mean of biometric traits

Mean of biometric traits (cm) studied in buffaloes of Kosi region were 123.22 ± 1.38 for HW, 88.72 ± 1.15 for HS, 36.44 ± 0.73 for NL, 80.15 ± 1.31 for ND, 101.26 ± 1.30 for BL, 188.82 ± 3.39 for HG, 221.71 ± 4.13 for PG, 34.77 ± 1.05 for FL, 20.61 ± 0.73 for FW, 4.99 ± 0.76 for EL, 22.31 ± 0.98 for DBH, 37.02 ± 0.83 for DHB, 21.15 ± 0.48 for DPB, 36.02 ± 1.01 for DHP, 87.47 ± 1.62 for TL and 92.5 ± 1.6 for TLS. The means of body biometry showed that buffaloes of Kosi region were medium to larger in body size. In Nilli Ravi breed of river buffalo, Nivsarkar *et al*. (2000) reported average HT, CG, and BL as 134.2, 207.7, and 165.4 cm respectively whereas Ahmad *et al.* (2013) reported HT to be 140.2 ± 7.2 cm in Nilli Ravi females. Based on comparison of biometric traits like average HT, CG and BL of Gojri buffaloes with Nilli Ravi buffaloes, which are also sharing their breeding tract, Gojri buffalo is lighter, smaller and shorter than Nilli Ravi buffaloes. The mean value of different traits of buffalo of Kosi region are slightly lower than that of Nilli Ravi Buffalo. It indicate that the Buffalo of Kosi region is slightly smaller in size than that of Nilli Ravi Buffalo. This may due to poor management condition given to Buffalo of Kosi region and harsh climatic condition of the region.

Coefficient of Variation (CV) Percent

The coefficient of variation (CV) for different morphometric traits ranges between 49.7% (face width) to 18.5 (Height at wither). Majority of the biometric traits showed higher consistency except for face width and ear length which were comparatively more variable.The range of coefficient of variation (CV) for different morphometric traits of buffaloes of Kosi region is comparable with finding of de Melo *et al.* (2018) who characterized the Murrah crossbred of Brazil.

Standard Deviations

The standard deviations were well within the normal range showing that in buffaloes of Kosi region, body measurements were less affected by environment. All biometric traits studied show less variability indicating that the buffaloes of Kosi region are almost similar shape and size in their natural habitat. This might be due to natural selection for better adaptability for particular shape and size. Similar finding was also reported by Tolenkhomba *et al.* (2013) in cattle of North East region. The variation among breeds can be caused by the difference of genetic, nutrition, management system and climate.

Table 4.3: Correlation among different biometric traits in buffaloes of Kosi Region

	HW	HS	NL	ND	BL	HG	PG	FL	FW	EL	DBH	DHB	DPB	DHP	TL
HW	1	0.61	0.48	0.71	0.68	0.81	0.82	0.21	0.27	0.34	0.32	0.69	0.57	0.37	0.68
HS	0.61	1	0.44	0.7	0.43	0.61	0.68	0.31	0.29	0.34	0.27	0.55	0.38	0.34	0.58
NL	0.48	0.44	1	0.22	0.3	0.36	0.45	0.59	0.28	0.19	0.19	0.47	0.45	0.24	0.46
ND	0.71	0.7	0.22	1	0.66	0.78	0.79	0.09	0.21	0.34	0.27	0.61	0.43	0.34	0.65
BL	0.68	0.43	0.3	0.66	1	0.76	0.75	0.13	0.18	0.24	0.22	0.62	0.49	0.35	0.6
HG	0.81	0.61	0.36	0.78	0.76	1	0.94	0.14	0.23	0.35	0.36	0.69	0.61	0.38	0.72
PG	0.82	0.68	0.45	0.79	0.75	0.94	1	0.22	0.28	0.36	0.35	0.71	0.58	0.41	0.77
FL	0.21	0.31	0.59	0.09	0.13	0.14	0.22	1	0.19	0.12	0.09	0.24	0.21	0.13	0.28
FW	0.27	0.29	0.28	0.21	0.18	0.23	0.28	0.19	1	0.1	0.07	0.2	0.12	0.14	0.24
EL	0.34	0.34	0.19	0.34	0.24	0.35	0.36	0.12	0.1	1	0.18	0.25	0.29	0.17	0.33
DBH	0.32	0.27	0.19	0.27	0.22	0.36	0.35	0.09	0.07	0.18	1	0.27	0.37	0.19	0.29
DHB	0.69	0.55	0.47	0.61	0.62	0.69	0.71	0.24	0.2	0.25	0.27	1	0.56	0.39	0.63
DPB	0.57	0.38	0.45	0.43	0.49	0.61	0.58	0.21	0.12	0.29	0.37	0.56	1	0.39	0.52
DHP	0.37	0.34	0.24	0.34	0.35	0.38	0.41	0.13	0.14	0.17	0.19	0.39	0.39	1	0.34
TL	0.68	0.58	0.46	0.65	0.6	0.72	0.77	0.28	0.24	0.33	0.29	0.63	0.52	0.34	1

Correlation coefficient

The correlation coefficients between studied biometric traits are given in Table 4.3. Correlation coefficient estimated ranged between 0.07 (FW and DBH) to 0.94 (PG and HG) among various biometric traits. A total of 105 correlations (in all combinations) were estimated. Among these 101 correlations were significant and positive (Table 4.3). Height at withers (HW) had significant. Higher correlations with HS (0.61), ND (0.71), BL (0.68), HG (0.81), PG (0.81) and DHB (0.69) while it showed lowest significant correlation with FL (0.21). Height at shoulder (HS) had significant higher correlations with HG (0.61), ND (0.71), PG (0.68), HG (0.81), PG (0.81) and DHB (0.69) while it showed lowest significant correlation with DBH (0.27). Neck Diameter (ND) had significant higher correlations with BL (0.66), HG (0.78) and PG (0.79) while it showed lowest significant correlation with FL (0.09). Body length (BL) had significant higher correlations with HG (0.76), PG (0.75), DHB (0.62) and TL (0.60) while it showed lowest significant correlation with FL (0.13). Heart Girth (HG) had higher correlations with HW (0.81), HS (0.61), ND (0.78), BL (0.76), PG (0.94), DHB (0.62), DPB (0.61) and TL (0.72) while HG had the lowest phenotypic correlation with FL (0.14). Paunch Girth (PG) had higher correlations with HW (0.82), HS (0.68), ND (0.79), BL (0.75), HG (0.94), DHB (0.71) and TL (0.77) while BL had the lowest phenotypic correlation with FL (0.22). These correlations among all 105 correlations were moderate to high in magnitude. All other correlations were low to moderate in magnitude. The result is in agreement with the findings of phenotypic correlations in Diara buffalo (Hitesh, 2020) with slight disagreements of Gojri buffalo where few correlations were negative (Vohra *et al.* 2015). The positive and significant ($p<0.05/0.01$) correlations among different biometric traits suggest high predictability among the different traits. Further, varying estimates of correlations in biometric traits could be attributed to the fact that postnatal growth does not take place proportionality in all tissue categories or body regions within those tissue categories.

Production performance

The buffalo of Kosi region were moderate milk producers and normally give four to nine litres of milk daily. Some animals in villages reach a peak yield of 9.65 litres per day. The average daily milk yield was estimated to be 4.9 ± 0.4 litres per day. The length of lactation varied from 210 days to more than 340 days with an average of 301.6 ± 10.3 days. The lactation milk yield varied from 650 ± 112 to 1430 ± 106 litres with a mean of

1210.86 ± 29.18 litres. The buffaloes of Kosi region have relatively long productive life spans as demonstrated by animals with more than five calvings commonly found in the villages. Age at first calving and calving interval was estimated to be 47.27 ± 0.63 months and 15.4 ± 2.78 months, respectively. The Dry Period, Age at First Service and Service Period was estimated to be 118.95 ± 5.64 days, 35.86 ± 0.78 months and 145.31 ± 3.06 days. The estimated results for different traits of production and reproduction were slightly lower than the reported by Chandran *et. al*. (2015) in Diara Buffalo.

Table No. 4.4: Production and Reproduction Performance of Buffaloes of Kosi Region

Milk Production traits of Buffaloes of Kosi Region	
Traits	**Estimate**
Lactation milk yield (kg)	1210.86 ± 29.18
Lactation length (days)	295.67 ± 11.87
Peak yield (kg)	8.45 ± 0.42
Reproduction traits of Buffaloes of Kosi region	
Dry period (days)	118.95 ± 5.64
Calving interval (Months)	15.4 ± 2.78
Age at first service (Months)	35.86 ± 0.78
Age at first calving (Months)	47.27 ± 0.63
Service period (days)	145.31 ± 3.06

Body measurements

The mean and standard error of different body measurements in different age groups are presented in Table 4.5. The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for the calves below the age of 7 days were found to be 87.4 ± 2.2, 73.3 ± 2.41, 94.4 ±5.07, 96.6 ± 5.73, 63.8 ± 2.34,73.3 ± 2.4, 50.3 ± 2.49, 22.1± 2.25, 13.2 ± 1.89, 16.6 ± 1.9, 18.7 ± 1.40, 12.9 ± .974, 19.4 ± 2.37, 43.1 ± 2.53 and 38.9 ± 2.68, respectively. The estimate obtained in the present study for calves of age 0-7 days was slightly higher of than that of respective reported in Diara Buffalo (Hitesh, 2020).

The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for young stock of age between one week to one year were found to be 110.7 ± 2.02, 88.9 ± 2.21, 159.0 ± 4.66, 184.9 ± 4.7, 79.8 ± 2.15, 88.9 ± 2.21, 69.4 ± 2.29, 27.5 ± 2.34, 19.9 ±1.74, 20.1 ± 1.75, 27.8 ± 1.28, 16.8 ± 0.895, 32.9 ± 2.19, 87.0 ± 2.33 and 81.4 ± 2.46, cm respectively. The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for young stock of age between one year to two year were found to be 121.6 ± 2.03, 98.5 ± 2.22, 188.6 ± 4.67, 223.9 ± 4.73, 88.1 ± 2.15, 98.5 ± 2.22, 80.1 ± 2.30, 31.0± 3.46, 21.0 ± 1.74, 26.0 ± 1.75, 33.3 ± 1.29, 18.4 ± 0.898, 34.1 ± 2.18, 99.4 ± 2.33 and 94.0± 2.47, cm respectively. The estimate obtained present study for the animals of 2 years of age was slightly higher than that of respective reported in (Hitesh, 2020).

Table 4.5: Least squares means of different Morphometric Traits of Buffaloes of Kosi

S.N.	Traits	Sex	Young Calves 0-7 days	Calves Of 7 days to 12 months	Calves Of 1 to 2 years	Calves Of 2 to 3.5 years	Greater than 3.5 years (Adult)	Overall Mean
1	Height at	**Female**	86.2 ± 2.46^{Aa}	109.4 ± 2.16^{Ab}	120.4 ± 2.16^{Ac}	130.6 ±2.88^{Ad}	139.5 ± 1.28^{Ae}	117 ±1.14 ^{Aa}
	wither	**Male**	88.7 ± 2.48^{Aa}	111.9 ± 2.43^{Ab}	122.9 ± 2.46^{Ac}	133.2 ±3.46^{Ad}	142.0 ± 2.5^{Ae}	120 ±1.87 ^{A}
	(HW)	**Mean**	87.4 ± 2.2	110.7 ± 2.02	121.6 ± 2.03	131.9 ±2.99	140 ± 1.65^{e}	
2	Body	**Female**	70.9 ± 2.69 ^{Ba}	86.6 ± 2.38^{Bb}	96.2 ± 2.36^{Bc}	110.0 ± 3.15^{Bd}	115.1 ± 1.4^{Bd}	95.8^{A}
	length	**Male**	75.6 ±2.71^{Aa}	91.2 ± 2.66^{Ab}	100.9 ±2.60^{Ac}	114.6 ± 3.78^{Ad}	119.8± 2.78^{Ad}	100.4^{A}
	(BL)	**Mean**	73.3 ± 2.41^{a}	88.9 ± 2.21^{b}	98.5 ± 2.22^{c}	112.3 ± 3.26^{d}	117.4 ± 1.8^{d}	
3	Heart	**Female**	93.0 ± 5.65 ^{Aa}	157.6 ± 5.62 ^{Ab}	187.1 ± 4.98 ^{Ac}	209.3 ± 6.64 ^{Ad}	228.5 ± 2.95^{Ae}	178 ± 4.3 ^{A}
	Girth	**Male**	95.8 ± 5.71 ^{Aa}	160.4 ±5.60 ^{Ab}	190.0 ± 5.66 ^{Ac}	212.2 ± 7.97 ^{Ad}	231.3 ± 5.76 ^{Ae}	175 ± 2.62 ^{A}
	(HG)	**Mean**	94.4 ±5.07 ^{a}	159.0 ± 4.66 ^{b}	188.6 ± 4.67 ^{c}	210.8 ± 6.87 ^{d}	229.9 ± 3.79 ^{d}	
4	Pauch	**Female**	97.7 ± 5.72 ^{Aa}	183.1 ± 5.08 ^{Ab}	222.1 ± 5.04 ^{Ac}	253.6 ± 8.06 ^{Ad}	272.0 ± 2.98 ^{Ae}	208 ± 4.35 ^{A}
	Girth	**Male**	98.4 ± 5.78 ^{Aa}	186.8 ± 5.66 ^{Ab}	225.7 ± 5.73 ^{Ac}	250.0 ± 6.71 ^{Ad}	275.6 ±5.82 ^{Ae}	204 ± 2.65 ^{A}
	(PG)	**Mean**	96.6 ± 5.73 ^{a}	184.9 ± 4.7 ^{b}	223.9 ± 4.73 ^{c}	251.8 ± 6.95 ^{d}	273.8 ±3.83 ^{e}	
5	Height at	**Female**	66.2 ± 2.61 ^{Ba}	82.2 ± 2.31 ^{Bb}	90.5 ± 2.29 ^{Bc}	95.0 ± 3.06 $^{\mathbf{Bcd}}$	99.4 ±1.36 ^{Bd}	86.7 ± 1.21 $^{\mathbf{B}}$
	shoulder	**Male**	61.4 ± 2.63 ^{Aa}	77.5 ± 2.58 ^{Ab}	85.8 ± 2.61 ^{Ac}	90.3 ± 3.67 ^{Acd}	94.7 ± 2.65 ^{Ad}	81.9 ± 1.98 ^{A}
	(HS)	**Mean**	63.8 ± 2.34 ^{a}	79.8 ± 2.15 ^{b}	88.1 ± 2.15 ^{c}	92.7 ± 3.17 ^{cd}	97.0 ± 1.75 ^{d}	
6	Neck	**Female**	70.9 ±2.69 ^{B}	86.6 ± 2.36 ^{B}	96.2 ± 2.36^{B}	110.0 ± 3.15 ^{B}	115.1 ± 1.4^{B}	34.1
	Length	**Male**	75.6 ± 2.71 ^{A}	91.2± 2.66 ^{A}	100.9 ± 2.69 ^{A}	114.6± 3.15 ^{A}	119.8 ± 2.78 ^{A}	34.2
	(NL)	**Mean**	73.3 ± 2.41 ^{a}	88.9 ± 2.21 ^{b}	98.5 ± 2.22 ^{C}	112.3±3.26 ^{d}	117.4 ±1.8 ^{d}	

Table 4.5: Least squares means of different Morphometric Traits of Buffaloes of Kosi

S.N.	Traits	Sex	Young Calves 0-7 days	Calves Of 7 days to 12 months	Calves Of 1 to 2 years	Calves Of 2 to 3.5 years	Greater than 3.5 years (Adult)	Overall Mean
7	Neck Diameter (ND)	**Female**	50.1 ± 2.78 ^{Aa}	69.2 ± 2.47^{Ab}	79.7± 2.45 ^{Ac}	90.9 ± 2.45 ^{Ad}	92.8±1.45 ^{Ad}	76.6± 2.11 ^{A}
		Male	50.5 ± 2.81 ^{Aa}	69.6 ± 2.75 ^{Ab}	80.3 ± 2.78 ^{Ac}	91.3 ± 3.92 ^{Ad}	93.2 ±2.83 ^{Ad}	77.0± 1.29 ^{A}
		Mean	50.3 ± 2.49 ^{a}	69.4 ± 2.29 ^{b}	80.1 ± 2.30 ^{c}	91.1 ± 3.38 ^{d}	93.0 ±1.86 ^{d}	
8	Face length (FL)	**Female**	19.2 ± 2.87 ^{B}	24.6± 2.82^{B}	36.9 ± 2.85^{B}	28.1 ± 4.01^{B}	34.0 ± 2.9^{B}	34.4 ± 1.32^{B}
		Male	25.0 ± 2.84 ^{A}	30.4 ± 2.53^{A}	42.6 ± 2.5^{A}	33.9 ± 3.34^{A}	39.8 ± 1.48^{A}	28.6 ± 2.16
		Mean	22.1± 2.25 ^{a}	27.5 ± 2.34^{A}	31.0± 3.46^{ab}	36.9 ± 1.91^{b}	39.8 ± 2.35^{b}	
9	Face width (FW)	**Female**	14.1 ±2.11	21.9 ± 1.87	20.8± 1.85	22.2 ± 2.47	22.8 ± 1.10	20.4±0.977^{A}
		Male	12.4 ± 2.13	20.1 ± 2.09	19.0 ± 2.11	20.4± 2.97	21.0 ± 2.14	18.6 ± 1.60^{A}
		Mean	13.2 ± 1.89	19.9 ±1.74	21.0 ± 1.74	21.3 ± 2.56	21.9 ± 1.41	
10	Ear length (EL)	**Female**	17.1 ± 2.12^{Aa}	20.6 ± 1.88^{Aab}	26.5 ±1.87^{Abc}	26.9±2.49^{Abc}	28.9 ± 1.11^{Ac}	24 ± 0.984^{A}
		Male	16.0 ± 2.14^{Aa}	19.6 ± 2.10^{Aab}	25.4 ± 2.12^{Abc}	25.9±2.99^{Abc}	27.9 ± 2.16^{Ac}	23 ± 1.61^{A}
		Mean	16.6 ± 1.9^{a}	20.1 ± 1.75^{ab}	26.0 ± 1.75^{bc}	26.4± 2.58^{bc}	28.4± 1.42^{c}	
11	Distance between hip bones(DHB)	**Female**	19.0 ±1.56^{A}	28.1 ± 1.38$^{\mathbf{B}}$	33.7± 1.37^{A}	41.0 ± 1.83	47.5 ± .81	33.9 ± 0.721
		Male	18.3 ± 1.57^{A}	27.4 ± 1.54^{A}	33.0 ± 1.56^{A}	40.3 ± 2.19	46.8 ± 1.58	33.2 ± 1.18
		Mean	18.7 ± 1.40	27.8 ± 1.28	33.3 ± 1.29	40.7 ± 1.89	47.2 ± 1.04	

Table 4.5: Least squares means of different Morphometric Traits of Buffaloes of Kosi Region

S.N.	Traits	Sex	Young Calves 0-7 days	Calves of 7 days to 12 months	Calves of 1 to 2 years	Calves of 2 to 3.5 years	Greater than 3.5 years (Adult)	Overall Mean
12	Distance between Pin bones	**Female**	13.4 ± 1.086^{Aa}	17.4± 0.964^{Ab}	19.0 ± 0.956^{Abc}	21.9±1.275^{Ac}	26.6± 0.566^{Ad}	19.7 ± 0.504^{Aa}
		Male	12.3 ± 1.097^{Aa}	16.2 ± 1.075^{Ab}	17.8 ± 1.087^{Abc}	20.7±1.53^{Ac}	25.4 ± 1.106^{Ad}	18.5 ± 0.826^{A}
		Mean	12.9 ± .974^{a}	16.8 ± 0.895^{b}	18.4 ± 0.898^{bc}	21.3 ± 1.32^{c}	26.0 ± 0.727^{d}	
13	Distance between Hip &Pin	**Female**	21.2 ± 2.65	36.0± 2.35	34.8 ± 2.33	38.6 ± 3.11	42.9 ± 1.38	31.0 ± 2.01^{A}
		Male	17.5 ± 2.67	32.3 ± 2.62	31.1 ± 2.65	35.0 ± 3.73	39.2 ± 2.70	34.7 ± 1.23^{B}
			19.4 ± 2.37^{a}	32.9 ± 2.19^{bc}	34.1 ± 2.18^{bc}	36.8 ± 3.22^{bc}	41.1 ± 1.77^{c}	
14	Tail length without switch	**Female**	42.6 ± 2.82^{Aa}	86.5 ± 2.51^{Ab}	98.9 ± 2.49^{Ac}	105.0 ±	105.9 ± 1.47^{Ac}	87.8 ± 1.31^{A}
		Male	43.7 ± 2.85^{Aa}	87.6 ± 2.80^{Ab}	99.9 ± 2.83^{Ac}	106.1 ±	107 ± 2.88^{Ac}	88.9 ± 2.15
		Mean	43.1 ± 2.53^{a}	87.0 ± 2.33^{b}	99.4 ± 2.33^{c}	105 ± 3.43^{c}	106.4 ± 1.89^{c}	
15	Tail Length with switch (TL)	**Female**	38.6 ± 2.99	81.1 ± 2.65	93.7 ± 2.63	101.3 ± 3.51	100.8 ± 1.56	83.1 ± 1.39
		Male	39.2 ± 3.02	81.8± 2.96	94.4 ± 2.99	101.9 ± 4.21	101.4 ± 3.04	83.7 ± 2.27
		Mean	38.9 ± 2.68^{a}	81.4 ± 2.46^{b}	94.0± 2.47^{c}	101.1 ± 8.00^{c}	101.6 ± 3.63^{c}	

Mean in different supervision different significantly ($p<0.01$)

Figure 4.9: Body measurements of Buffaloes of Kosi region

The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for adult male Diara buffalo of age between 2 years to 3.5 years of age were found to be 131.9 ±2.99, 112.3 ± 3.26, 210.8 ± 6.87, 251.8 ± 6.95, 92.7 ± 3.17, 112.3±3.26, 91.1 ± 3.38, 36.9 ± 1.91, 21.3 ± 2.56, 26.4± 2.58, 40.7 ± 1.89, 21.3 ± 1.32, 36.8 ± 3.22, 105 ± 3.43 and 101.1 ± 8.00, cm respectively. The estimate obtained present study for the animals of 2 years of age was slightly higher than that of respective reported in (Hitesh, 2020).

The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for adult male Diara buffalo of age above the 3.5 years were found to be 140 ± 1.65, 117.4 ± 1.8, 229.9 ± 3.79, 273.8 ±3.83, 97.0 ± 1.75, 117.4 ±1.8, 93.0 ±1.86, 39.8 ± 2.35, 21.9 ± 1.41, 28.4± 1.42, 47.2 ± 1.04, 26.0 ± 0.727, 41.1 ± 1.77, 106.4 ± 1.89 and 101.6 ± 3.63, cm respectively. The estimate obtained present study for adult animals was slightly higher of than that of respective reported in Diara Buffalo (Hitesh, 2020). There was no significant difference found between male and female Diara buffalo for morphometric traits. This is in agreement with Chandran *et. al*. (2015).

Utility

The buffaloes of Kosi region are dual purpose animals used for milk production as well as agricultural operations in wet fields. They are better suited than are local cattle to ploughing and puddling the wet fields meant for paddy cultivation. They are active, fast moving, hardy and can work continuously for four to six hours in the wet fields. Generally, males are used for the purpose, males are preferred (Figures 4.5).

Principal component analysis

Sampling Adequacy Test of Data

The PCA was applied on 16 body conformation traits of Buffaloes of Kosi region of Bihar. The Anti-image correlations computed showed that the partial correlations were low, indicating that true factors existed in the data. The KMO measure of sampling adequacy (MSA) was obtained as 0.907. The estimate of sampling adequacy KMO revealed the proportion of the variance in different biometric traits caused by the underlying components (Kaiser, 1958). The overall significance of the correlation matrix was tested with Bertlett's test of sphericity for the biometric traits (chi-square was 3575.5 $p<0.01$) was significant, it means correlation matrix is not an identity matrix and provided enough support for the validity of the factor analysis of data. The MSA below 0.5 was not accepted and KMO-MSA greater than 0.5 is must for satisfactory factor analysis to proceed. Yakuba *et al*. (2009) reported in close agreement of our estimates of sampling adequacy were 0.90 and 0.92 in age groups of 1.5 to 2.4 years and 2.5 to 3.6 years, respectively in White Fulani cattle. However, Vohra *et al*. (2015) and Pundir *et al*. (2011) reported lower estimates of sampling adequacy as 0.74 in Gojri buffalo and 0.891 in Kankrej cows, respectively.

Extraction of Principal components

The eigenvalues and percentages of the explained variance and accumulated variance for body morphometric traits are presented in Table 4.6. The results show that the first two components accounted for 59% of the total variance of which the eigenvalues were larger than (Table 4.6). The remaining fourteen PCs had lower variance. The second (PC_2) principal components accounted for 9.00% of the total variance while the remaining 14 PCs jointly accounted for 41% of the total variation.

Scree Plot with parallel Analysis

There could be more than one criterion to decide how many components can be extracted. Another criterion for determination of number of component is scree plot that could be used to decide the actual number of component to be retained for analysis. Scree plot can depict various components and the component having eigenvalue up to the bent of elbow are usually considered. Two Principal Components above the bend or elbow are indicated in plot (Figure 4.10, 4.11, 4.12 and 4.13) which suggest its retention for extraction. The parallel analysis involves creation of simulation for extracting eigenvalues from random data matrices of the same size as the original matrix of observable data. If an eigenvalues based on real data is larger than the average corresponding eigenvalues from a set of random data matrices, that component is retained. The two components presenting large eigenvalues than real values as indicated by dotted line in the plot (Figure 4.10) retained for further analysis. Figure 4.10 displays the Scree test based on observed eigenvalues, the mean eigenvalues derived from 100 random data matrices (dashed line) and the eigenvalues greater than 1 criterion (as horizontal) line. All three criteria suggest that two components are appropriate for summarizing the data of buffaloes of Kosi region.

Table 4.6: Total variance, Eigenvalues and Proportion of variances explained by different Principal Components for morphometric traits of buffalo of Kosi Region

Principal Components	SS loadings or Eigenvalues	Proportion Var	Cumulative Var	Proportion Explained	Cumulative Proportion
PC1	7.96	0.5	0.5	0.5	0.5
PC2	1.44	0.09	0.59	0.09	0.59
PC3	1.00	0.06	0.65	0.06	0.65
PC4	0.89	0.06	0.71	0.06	0.71
PC5	0.84	0.05	0.76	0.05	0.76
PC6	0.79	0.05	0.81	0.05	0.81

PC7	0.64	0.04	0.85	0.04	0.85
PC8	0.58	0.04	0.88	0.04	0.88
PC9	0.45	0.03	0.91	0.03	0.91
PC10	0.37	0.02	0.94	0.02	0.94
PC11	0.34	0.02	0.96	0.02	0.96
PC12	0.25	0.02	0.97	0.02	0.97
PC13	0.20	0.01	0.98	0.01	0.98
PC14	0.18	0.01	1	0.01	1
PC15	0.05	0	1	0	1
PC16	0.03	0	1	0	1

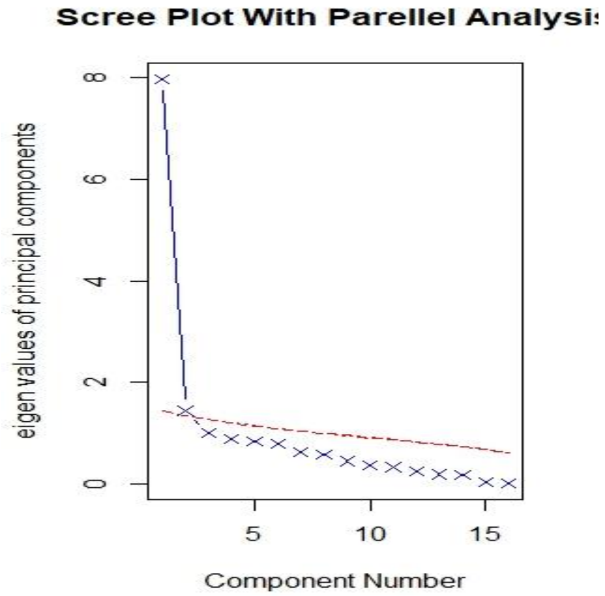

Figure 4.10: Scree plot with parallel analysis of components and eigenvalues for body morphometric traits of buffalo of Kosi Region

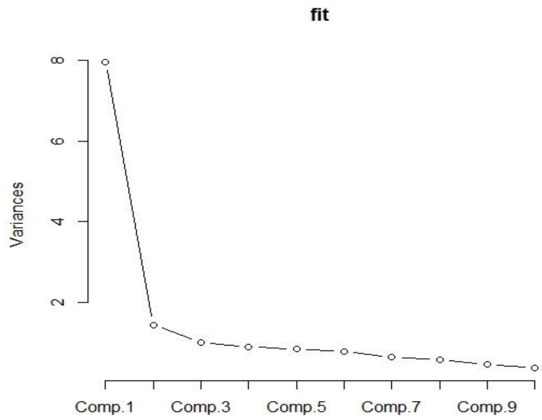

Figure 4.11: Scree plot of components and eigenvalues for body morphometric traits of buffalo of Kosi Region

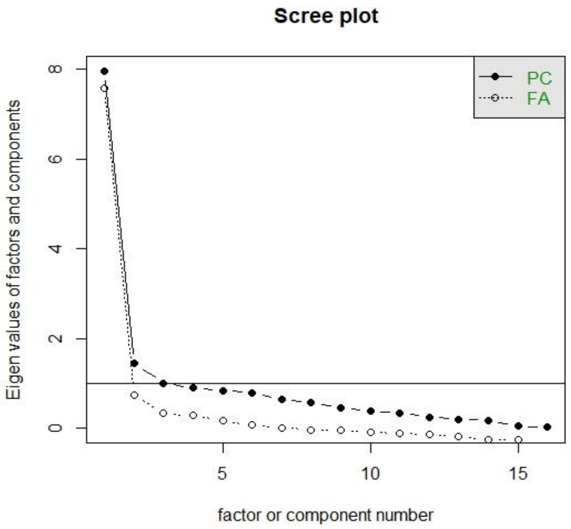

Figure 4.12: Scree plot of components and eigenvalues for body morphometric traits of buffalo of Kosi Region

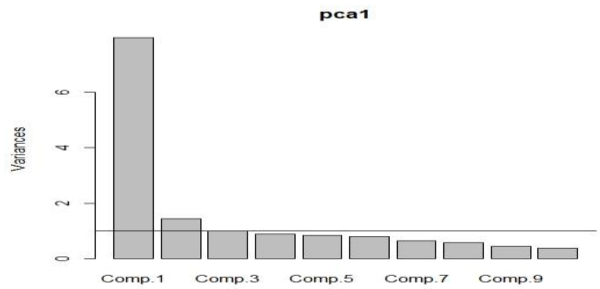

Figure 4.13: Scree plot of components and eigenvalues for body morphometric traits of buffalo of Kosi Region

Principal Components

The identified two components could explain cumulative percentage of variance of 60%. First component accounted for 50% of the variation. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, DHB, TL and TLS. First component seemed to be explaining the maximum of general body conformation in Boffaloes of Kosi region of Bihar. The second component explained 15% of total variance with high loading of distance between FL, NL, and FW. Vohra *et al.* (2013) used factor analysis with promax rotation revealed 4 components which explained about 70.86% variation which is slightly higher to our finding but the total variation with first component explained 31.45% of total variation and was represented by significant positive high loading of height at wither (HW), BL, FL, FW, HL and CG in Gojri buffalo. In Egyptian buffalo bull Shahin *et al*. (1993) reported that most of the common variability (88%) in body dimensions could be accounted for by components representing general size, body depth and height and head width. Tolenkhomba *et al*. (2013) used factor analysis with promax rotation revealed 6 components which explained about 69.77% which is slightly higher to our finding but the total variation with first component explained 21.93% of total variation and was represented by significant positive high loading of height at wither, BL, heart girth, PG, and EL in local cattle of Manipur. The proportion of total variance explained by first component was more in this study (50%) compared to by Tolenkhomba *et al*. (2013) and Vohra *et al*. (2015). Yakubu *et al*. (2009) extracted 2 factors in the age group of 2.5 to 3.6 years explained 86.47% of the total variation by studying the 14 morphostructural traits of White Fulani cattle. The slight lower estimate explained by Principle Components may be attributed lower sample size of data.

Table 4.7: Variance and Proportion of variances explained by Principal Components for morphometric traits of buffalo of Kosi Region

Variance Name	PC_1	PC_2
SS loadings	7.96	1.44
Proportion Var	0.5	0.09
Cumulative Var	0.5	0.59
Proportion Explained	0.85	0.15
Cumulative Proportion	0.85	1

Table 4.8: Component Matrix or Standardized loading of different factors for Biometric traits of buffalo of Kosi Region

Traits	PC_1	PC_2	Communalities (h_2)	Uniqueness (u_2)
HW	0.87	-0.07	0.77	0.23
HS	0.75	0.1	0.57	0.43
NL	0.57	0.67	0.77	0.23
ND	0.81	-0.3	0.75	0.25
BL	0.77	-0.24	0.64	0.36
HG	0.90	-0.24	0.87	0.13
PG	0.93	-0.13	0.89	0.11
FL	0.33	0.8	0.75	0.25
FW	0.32	0.34	0.22	0.78
EL	0.42	-0.04	0.18	0.82
DBH	0.41	-0.05	0.17	**0.83**
DHB	0.8	0	0.64	0.36
DPB	0.69	0.03	0.47	0.53
DHP	0.49	-0.01	0.24	0.76
TL	0.85	0.01	0.73	0.27
TLS	0.86	0.02	0.75	0.25

First component accounted for 50% of the variation. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, DHB, TL and TLS. First component seemed to be explaining the maximum of general body conformation in Boffaloes of Kosi region of Bihar. The proportion of total variance explained by the first component was more in present investigation compared to earlier study Assam hill cattle (21.93%) and in Gojri buffalo (31.45) (Vohra *et al*. 2015) but lowered than those reported White Fulani cattle.

The second component explained 15% of total variance with high loading of FL, NL and FW. The proportion of total variance explained by the second component was more in present investigation compared to earlier study 17.15% in Gojri buffalo Vohra *et al.* (2013) and 16 % in crossbred buffalo Melo *et al.* (2020)

Communality

The communality ranged from 0.17 (DBH) to 0.89 (PG) and unique factors ranged from 0.83 to 0.11 for all these 16 different biometric traits (Table 4.8). The principal (PC_1) and (PC_2) components together explain highest variation 89% in PG trait and lowest in DBH trait. Similar communality ranged from 0.44 to 0.83 for 13 different biometric traits in Gojri buffalo was reported by Vohra *et al.* (2013). In Egyptian buffalo the communalities ranged from 0.96 (height at hips, HT) to 0.78 (rump width) Shahin et al. (1993). Approximate range of communality i.e. 0.42 to 0.87 was reported by Sadek *et al.* (2006) in Arabian mares. Higher estimates of communality (ranged from 0.79 to 0.93) were observed by Yakubu *et al.* (2009). The lower estimates of communalities of HL and PG indicates that they did not explain the body conformation in Gojri buffaloes. All the biometric traits of buffalo of Kosi region presents moderate to higher estimate of community except FW, EL, DBH, DPB AND DHP. The moderate to higher estimates of communalities for biometric traits indicates that the extracted two principal components explain maximum variation of data of various variables.

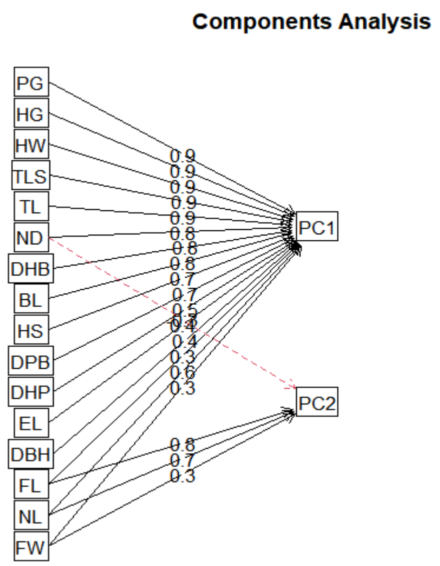

Figure 4.14: Diagram of the Two Factor Loading (Solution) for Biometric traits of Buffalo of Kosi Region

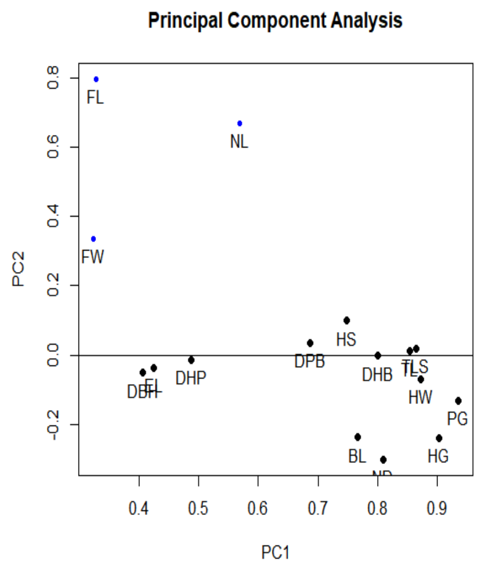

Figure 4.15: Two Factor Plot for Loading (Solution) of Biometric traits of Buffalo of Kosi Region

Varimax Rotation of Principle Components

The identified two components after orthogonal Varimax rotation could explain cumulative percentage of variance of 59%. First component accounted for 44% of the variation. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, EL, DBH, DHB, DPB, DHP, TL and TLS. First component seemed to be explaining the maximum of general body conformation in Boffaloes of Kosi region of Bihar. The second component explained 14% of total variance with high loading of distance between HS, NL, FL, FW, TL and TLS. Vohra *et al.* (2013) used factor analysis with Varimax rotation revealed 4 components in Gojri buffalo which explained about 70.86% which is slightly higher to our finding in Boffaloes of Kosi region of Bihar.

First component after orthogonal Varimax rotation of PCA accounted for 44% of the variation of Morphometric traits in Boffaloes of Kosi region of Bihar with significant high positive loading of height at wither (HW), HS, ND, BL, HG, PG, EL, DBH, DHB, DPB, DHP, TL and TLS. It is slightly higher to the variation 31.45% explained with first component of total variation with significant positive high loading of height at wither (HW), BL, FL, FW, HL and CG traits in Gojri buffalo. In Egyptian buffalo bull Shahin *et al*. (1993) reported that most of the common variability (88%) in body dimensions could be accounted for by components representing general size, body depth and height and head width.

The second component after orthogonal Varimax rotation of PCA explained 14% of total variance with high loading of distance between HS, NL, FL, FW, TL and TLS morphometric traits in buffaloes of Kosi region. The present study is in corroboration with the result of second component explained 17.15% of total variance with high loading of distance between HB, TL, and EL in Gojri buffalo by Vohra *et al.* (2013).

Communality

The communality ranged from 0.17 (DBH) to 0.89 (PG) and unique factors ranged from 0.83 to 0.11 for all these 16 different biometric traits (Table 4.9). The principal (PC_1) and (PC_2) components together explain highest variation 89% in PG trait and lowest 17% in DBH trait. Similar communality ranged from 0.44 to 0.83 for 13 different biometric traits in Gojri buffalo was reported by Vohra *et al.* (2013). In Egyptian buffalo the communalities ranged from 0.96 (height at hips, HT) to 0.78 (rump width) Shahin *et al*. (1993).

The lower estimates of communalities of HS, FW, DBH, DPB and DHP indicates that they did not explain the body conformation in Boffaloes of Kosi region. The lower estimates of communalities were reported for HL and PG traits of body conformation in Gojri buffaloes by Vohra *et al.* (2013). The lower estimates of communality indicate that components have lesser contribution in explaining the variation of traits whereas error factor have more contribution in variation of traits.

Table 4.9: Component Matrix or Standardized loading of different Varimax Rotated Component for Biometric traits of buffalo of Kosi Region

Traits	**PC_1**	**PC_2**	**Communalities (h_2)**	**Uniqueness (u_2)**
	RC1	RC2	h2	u2
HW	0.84	0.25	0.77	0.23
HS	0.66	0.36	0.57	0.43
NL	0.28	0.83	0.77	0.23
ND	0.86	0.01	0.75	0.25
BL	0.8	0.06	0.64	0.36
HG	0.93	0.11	0.87	0.13
PG	0.92	0.22	0.89	0.11
FL	0.01	0.86	0.75	0.25
FW	0.18	0.43	0.22	0.78
EL	0.41	0.12	0.18	0.82
DBH	0.4	0.1	0.17	0.83
DHB	0.75	0.29	0.64	0.36
DPB	0.63	0.28	0.47	0.53
DHP	0.46	0.17	0.24	0.76
TL	0.79	0.32	0.73	0.27
TLS	0.8	0.33	0.75	0.25

Table 4.10: Total Variance and Proportions of Variances explained by Varimax Rotated Components for morphometric traits of buffalo of Kosi Region of Bihar.

Variance Name	PC_1	PC_2
SS loadings	7.09	2.31
Proportion Variance	0.44	0.14
Cumulative Variance	0.44	0.59
Proportion Explained	0.75	0.25
Cumulative Proportion	0.75	1

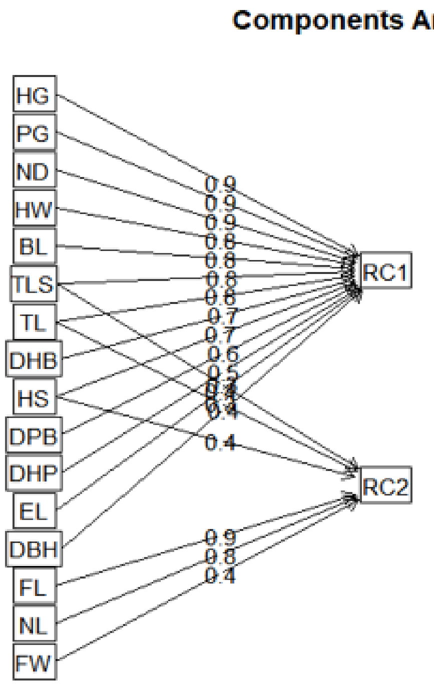

Figure 4.16: Diagram of the Two Varimax Rotated Component Loading (Solution) for Biometric traits of Buffalo of Kosi Region

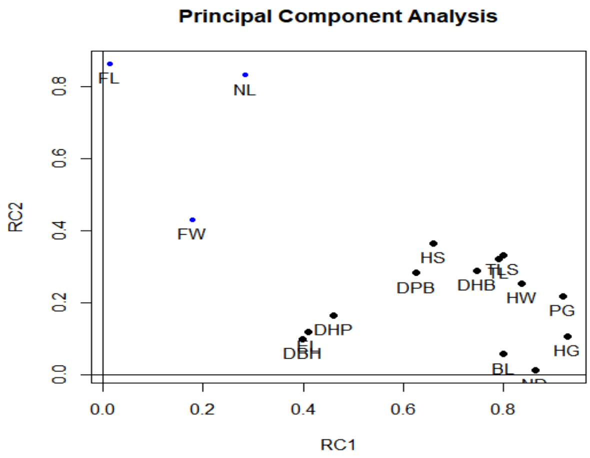

Figure 4.17: Varimax Rotated Two Component Plot for Loading (Solution) of Biometric traits of Buffalo of Kosi Region

Promax Rotation of Principle Components

The identified two components after oblique rotation i.e. Promax could explain cumulative percentage of variance of 59%. First component accounted for 46% of the variation. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, EL, DBH, DHB, DPB, DHP, TL and TLS. First component seemed to be explaining the maximum of general body conformation in Boffaloes of Kosi region. The second component explained 13% of total variance with high loading of FL, NL, and FW, traits. Vohra *et al.* (2013) used factor analysis with promax rotation revealed 4 components which explained about 70.86% which is slightly higher to our finding. The first component after Promax rotation explained 31.45% of total variation and was represented by significant positive high loading of height at wither (HW), BL, FL, FW, HL and CG in Gojri buffalo Vohara *et al.* (2013). It is lower than the first component value of promax rotation obtained in buffaloes of Kosi region. Tolenkhomba *et al.* (2013) used factor analysis with promax rotation revealed 6 components which explained about 69.77% which is slightly higher to our finding but the total variation with first component explained 21.93% of total variation and was represented by significant positive high loading of height at wither, BL, heart girth, PG, and EL in local cattle of Manipur. However, Yakubu *et al.* (2009) and Putra *et al.* (2020) extracted two factors each explaining 86.47% and 73.36% of the total variation in White Fulani bulls and Pasundan cows, respectively.

In the present study, the first factor accounted for 46 % of the variation of Biometric traits data. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, EL, DBH, DHB, DPB, DHP, TL and TLS. First component seemed to be explaining the maximum of general body conformation in buffaloes of Kosi region. Lower estimates of first factor after Promax rotation than our present findings (46%) were reported by several workers in previous studies Tolenkhomba *et al.* (2021), Tolenkhomba *et al.* (2012) and Pundir *et al*. (2011). Tolenkhomba *et al.* (2021) reported the first factor accounted for 34.117% of the variation of 20 original measurements in Local Hill Cattle of Mizoram, India. It was represented by significant positive high loading for leg characteristics (viz. arm length, elbow length, fore shank length, thigh length and hind shank length) and neck length. Tolenkhomba *et al.* (2012) extracted lower first factor accounting for 17.37% of the variation out of the total of 15 original measurements in Manipuri cows. It was represented by height at wither, heart girth, paunch girth and ear length. Pundir *et al*. (2011) reported in Kankrej cows that the first factor explained 38.89% of total variation.

The second component explained 13% of total variance with high loading of traits FL, NL, and FW obtained in buffaloes of Kosi region. Slightly lower estimate for the second factor accounted for 11.711% of total variability with comparatively higher loading for body length and leg length in cows of local cattle of Manipur was reported by Tolenkhomba *et al.* (2012). Slightly higher estimate for second factor accounted for 16.328% of total variability in local cows of Mizoram which had comparatively higher loading for body length, hearth girth and paunch girth was reported by Tolenkhomba *et al.* (2021).

Communality

The communality ranged from 0.89 (PG) to 0.17 (DBH) and unique factors ranged from 0.11 to 0.83for all the 16 different biometric traits (Table 4.11). The communality obtained in in buffaloes of Kosi region corroborates with the findings of other authors. The communality ranged from 0.51 (circumference of horn) to 0.94 (hind shank length) and unique factors ranged from 0.48 to 0.04 for all the 20 different biometric traits by Tolenkhomba *et al.* (2021). Tolenkhomba *et al.* (2013) reported communality ranged from 0.59 (body length) to 0.85 (hind girth) in local bulls of Manipur. Similar estimates of communality (ranged from 0.79 to 0.93) were observed by Yakubu *et al*. (2009) in White Fulani cattle.

The inter-factor correlations between two components were positive and significant (0.52) between first and second components in buffaloes of Kosi region. The inter-factor correlations between different factors ranged from -0.042 to 0.358 in cows reported by Tolenkhomba *et al.* (2021) after Promax rotation.

The application of Oblique characters (PC1 and PC2) derived from the PCA can be more reliable in predicting body size compared to the use of the original body measurements. The two extracted factors determine the source of shared variability to explain body conformation in buffaloes of Kosi region. These first two PC could be exploited in the evaluation and comparison of animals and thus provide an opportunity to select the animals based on a small group of traits rather than on isolated traits. Our results suggest that the present PCA provided a means for a reduction in the number of biometric traits to be recorded in buffaloes of Kosi region (PG, HG, HW, NL, ND, and FL) which could be used in ranking programs as a mean to explain the body conformation. The results suggests that principal component analysis (PCA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

Table 4.11: Component Matrix or Standardized loading of different Promax Rotated Component for Biometric traits of buffalo of Kosi Region

Traits	RC_1	RC_2	Communalities (h_2)	Uniqueness (u_2)
HW	0.85	0.04	0.77	0.23
HS	0.62	0.22	0.57	0.43
NL	0.04	0.86	0.77	0.23
ND	0.96	-0.24	0.75	0.25
BL	0.88	-0.17	0.64	0.36
HG	1	-0.15	0.87	0.13
PG	0.96	-0.02	0.89	0.11
FL	-0.28	0.97	0.75	0.25
FW	0.06	0.44	0.22	0.78
EL	0.42	0.02	0.18	0.82
DBH	0.41	0	0.17	0.83
DHB	0.74	0.11	0.64	0.36
DPB	0.61	0.14	0.47	0.53
DHP	0.46	0.05	0.24	0.76
TL	0.78	0.13	0.73	0.27
TLS	0.78	0.14	0.75	0.25

Table 4.12: Total Variance and Proportions of Variances explained by Promax Rotated Components for morphometric traits of buffalo of Kosi Region.

Variances	PC_1	PC_2
SS loadings	7.4	2.01
Proportion Var	0.46	0.13
Cumulative Var	0.46	0.59
Proportion Explained	0.79	0.21
Cumulative Proportion	0.79	1

Table 4.13: Correlation between Promax Components

Components	RC_1	RC_2
RC_1	1	0.52
RC_2	0.52	1

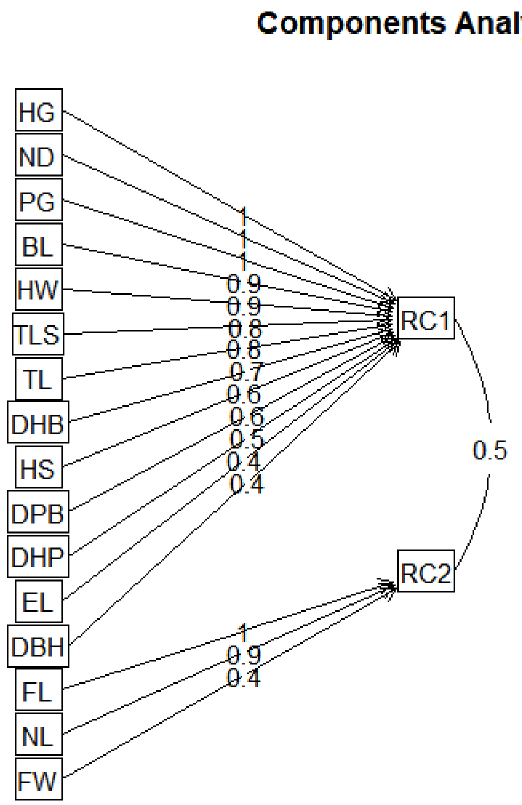

Figure 4.18: Diagram of the Two Promax Rotated Component Loading (Solution) for Biometric traits of Buffalo of Kosi Region

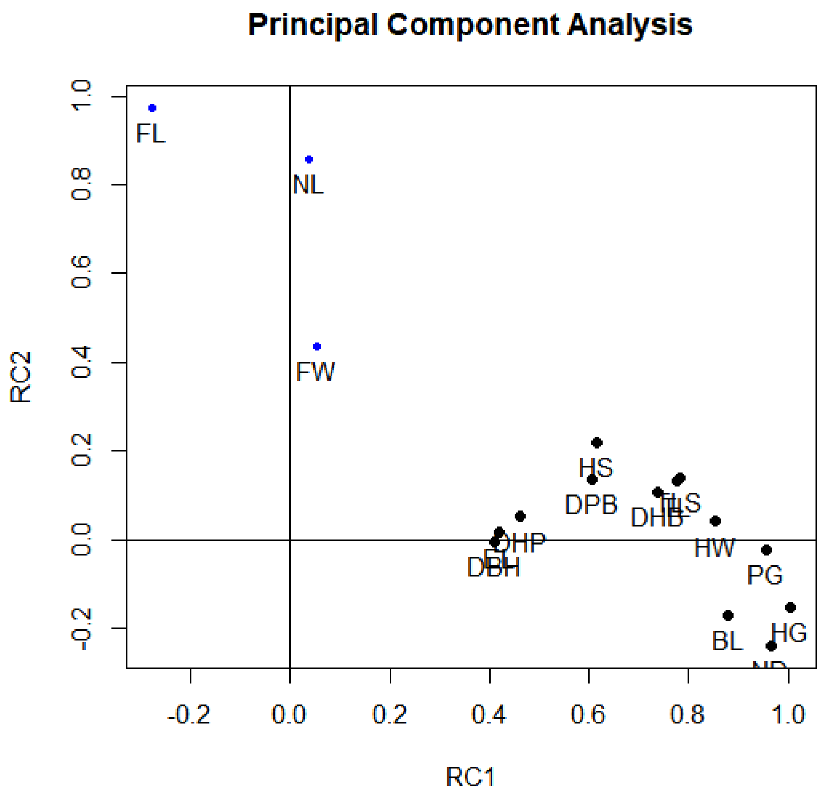

Figure 4.19: Promax Rotated Two Component Plot for Loading (Solution) of Biometric traits of Buffalo of Kosi Region

Common Factor Analysis (CFA)

The Common Factor Analysis (CFA) was applied on 16 body conformation traits of buffaloes of Kosi region of Bihar.

Scree Plot Test with Parallel Analysis of Common Factor Analysis (CFA)

Scree Plot Test with Parallel Analysis was used for determination of Common Factor to be retained for analysis. Scree plot depicting various factors having eigenvalue up to the bent of elbow were considered to be retained for further analysis (Figure 4.20). Two Principal Components above the bend or elbow are indicated in plot (Figure 4.20) which suggest its retention for extraction. The parallel analysis involves creation of simulated data for extracting eigenvalues from random data matrices of the same size as the original matrix of observable data. If an eigenvalues based on real data is larger than the average corresponding eigenvalues from a set of random data matrices that components were retained. The Latent factors presenting large eigenvalues than real values as indicated by dotted line in the plot (Figure 4.20) retained for further analysis. The plot shown in Figure 4.14 displays the Scree test based on observed eigenvalues, the mean eigenvalues derived from 100 random data matrices (dashed line) and the eigenvalues greater than 1 criterion (as horizontal) line. All three criteria suggest that two omponents are appropriate for summarizing the data of buffaloes of Kosi region.

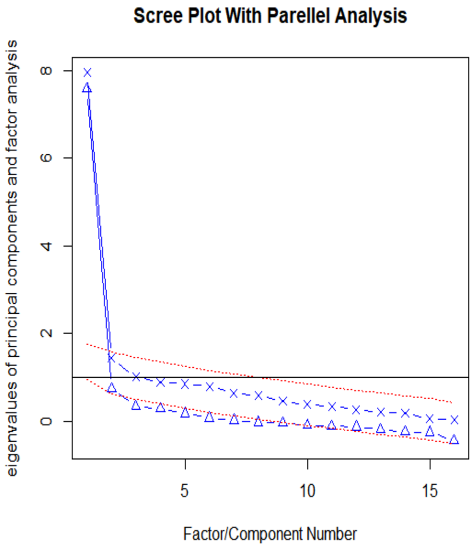

Figure 4.20: Scree plot with parallel analysis of both Latent and Principal Component Factors and eigenvalues for body morphometric traits of buffalo of Kosi Region

Common Factor Analysis (CFA)

Extraction of Latent Factors

The two common factors were extracted for body morphometric traits of buffalo of Kosi Region based on Scree Plot Test with Parallel Analysis. The eigenvalues and percentages of the explained variance and cumulative variance for body morphometric traits are presented in Table 4.14a. The results showed that the first two factors accounted for 54% of the total variance of data taken on 16 body conformation traits of buffaloes of Kosi region. The factors extracted presented the eigenvalues (λ) larger than 0.0 (λ>0.0): Fig 4.14. The remaining fourteen PCs had lower variance. The second (PC/2) principal components accounted for 7% of the total variance while the remaining PCs jointly accounted for 46% of the total variation. The unrotated common factors jointly explain 54% of the total variance of data taken on 16 body conformation traits of buffaloes of Kosi region.

Table 4.14: Unrotated Component Matrix explained by different Common Factors for morphometric traits of buffalo of Kosi Region

Traits	PA1	PA2	Communalities (h_2)	Uniqueness (u_2)
HW	0.86	-0.05	0.75	0.252
HS	0.72	0.07	0.52	0.48
NL	0.57	0.7	0.81	0.189
ND	0.8	-0.29	0.72	0.276
BL	0.74	-0.19	0.59	0.41
HG	0.91	-0.25	0.89	0.109
PG	0.95	-0.14	0.91	0.087
FL	0.31	0.58	0.43	0.566
FW	0.29	0.15	0.11	0.89
EL	0.39	-0.01	0.15	0.85
DBH	0.37	-0.01	0.14	0.863
DHB	0.78	0.02	0.6	0.396
DPB	0.65	0.07	0.43	0.573
DHP	0.45	0	0.2	0.799
TL	0.84	0.03	0.71	0.294
TLS	0.85	0.03	0.73	0.269

Table 4.14a : Variance and Proportion of variance explained by Principal Components for morphometric traits of buffalo of Kosi Region

Variance Name	PA1	PA2
SS loadings	7.76	1.07
Proportion Var	0.48	0.07
Cumulative Var	0.48	0.54
Proportion Explained	0.88	0.12
Cumulative Proportion	0.88	1.0

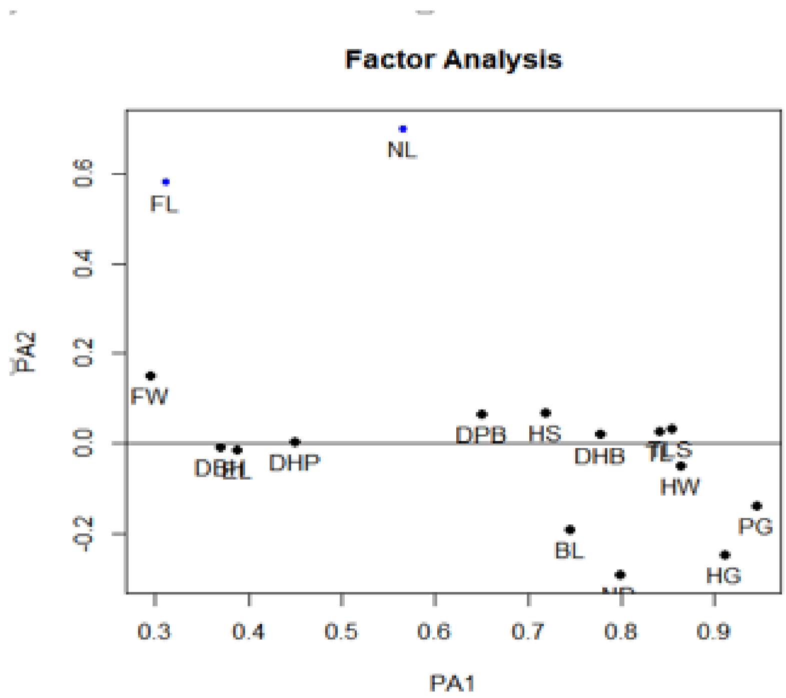

Figure 4.22: Two Latent Factors Plot for Loadings (Solutions) of Biometric traits of Buffalo of Kosi Region

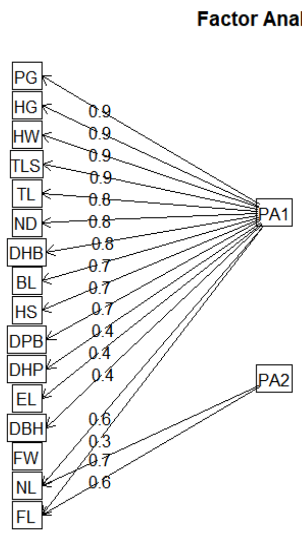

Figure 4.23: Diagram of the Two Common Factor Loadings (Solutions) for Biometric traits of Buffalo of Kosi Region

The correlation between Factors and variables (Loading) were presented in Table 4.14, Figure 4.22 and Figure 4.23 in the form of loadings. The estimated factors loading extracted by factor analysis, eigen values and variation explained by each factor are presented in Table 4.14a . In the present study, the first factor accounted for 48% of the variation of total 16 original measurements. It was represented by significant positive high loading of PG, HG, HW, TLS, TL, ND, DHB, BL, HS, DPB, DHP and EL with First Factor. Out of these, variables PG, HG, HW, TLS had significant positive very high loading (r > 0.9) with First Factor. The First factor seemed to be explaining general size of Buffalo of Kosi Region with respect to their length, height and diameter size. The second factor accounted for 7% of total variability. It had high loading for NL and FL and form a group representing the front view of the buffalo.

Communality

The communality ranged from 0.91 (PG) to 0.20 (DHP) and unique factors ranged from 0.087 (PG) to 0.86 (FW) for all these 16 different biometric traits (Table 4.14). The lower estimates of communality of different traits indicates that they did not explain the body conformation in Buffalo of Kosi Region. The two extracted common factors determine the source of shared variability to explain body conformation in buffalo of Kosi Region. These common factors represent general size of Buffalo of Kosi Region with respect to their length, height and diameter size and front view of the buffalo. The communalities estimates indicated that FL, FW, DBH and DPB did not contribute effectively to explain body conformation in Buffalo of Kosi Region. The remaining traits contributed effectively and may be considered to explain the body conformation of the in buffalo of Kosi Region. The result suggests that common factor analysis (CFA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

Varimax Rotation of Common Factors

In order to more refine or purify the common factors, the two common factors were extracted with orthogonal rotation by Varimax method to make uncorrelated with each other. The eigenvalues and percentages of the explained variance and cumulative variance for body morphometric traits are presented in Table 4.16. The results show that the first rotated factor accounted for 42% of the total variance of data taken on 16 body conformation traits of buffaloes of Kosi region. The second rotated factors accounted for 13% of the total variance while the remaining PCs jointly accounted for 46% of the total variation. The both Varimax rotated common factors jointly explain 54% of the total variance of data taken on 16 body conformation traits of Buffaloes of Kosi region.

Table 4.15: Varimax Rotated Component Matrix explained by different Common Factors for morphometric traits of buffalo of Kosi Region

Traits	PA1	PA2	Communalities (h_2)	Uniqueness (u_2)
HW	0.82	0.29	0.75	0.252
HS	0.64	0.34	0.52	0.48
NL	0.25	0.86	0.81	0.189
ND	0.85	0.04	0.72	0.276
BL	0.76	0.11	0.59	0.41
HG	0.94	0.12	0.89	0.109
PG	0.92	0.24	0.91	0.087
FL	0.06	0.66	0.43	0.566
FW	0.21	0.25	0.11	0.89
EL	0.36	0.14	0.15	0.85
DBH	0.34	0.14	0.14	0.863
DHB	0.71	0.32	0.6	0.396
DPB	0.57	0.31	0.43	0.573
DHP	0.41	0.18	0.2	0.799
TL	0.76	0.35	0.71	0.294
TLS	0.77	0.36	0.73	0.269

Table 4.16: Total Variance and Proportions of Variances explained by Varimax Rotated Latent Factors for morphometric traits of buffalo of Kosi Region of Bihar

Variance Name	PA1	PA2
SS loadings	6.65	2.05
Proportion Variance	0.42	0.13
Cumulative Variance	0.42	0.54
Proportion Explained	0.76	0.24
Cumulative Proportion	0.76	1.0

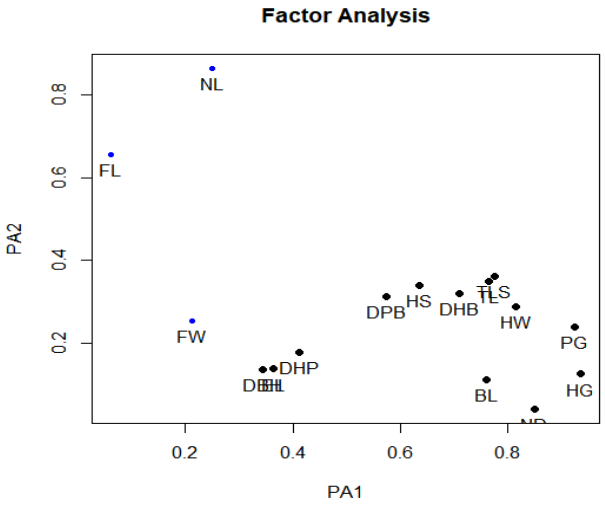

Figure 4.24: Varimax Rotated Two Latent Factors Plot for Loadings (Solutions) of Biometric traits of Buffalo of Kosi Region

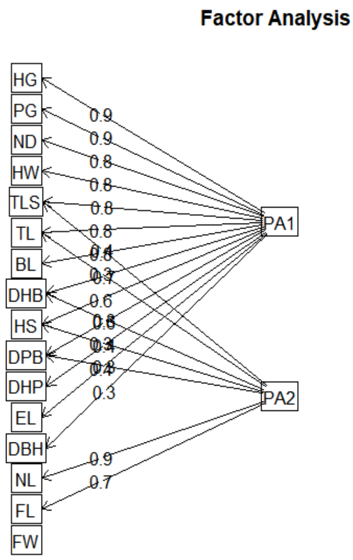

Figure 4.25: Varimax Rotated Diagram of the Two Latent Factors Loading (Solution) for Biometric traits of Buffalo of Kosi Region

The correlation between Factors and variables (Loading) were presented in Table 4.15, Figure 4.24 and Figure 4.25. The estimated factors loading extracted by factor analysis, Eigen values and variation explained by each factor are presented in Table 4.16. In the present study, the first factor accounted for 42% of the variation out of total 16 original measurements. It was represented by significant positive high loading of HG, PG, ND, HW, TLS, TL, BL, DHB, HS, DPB, DHP EL and DBH with First Factor. Out of these, variables PG and HG had significant positive very high loading ($r > 0.9$) with First Factor. The First factor seemed to be explaining general size of Buffalo of Kosi Region with respect to their length, height and diameter size. The second factor accounted for 13% of total variability. It had high loading for NL FL and FW and form a group representing the front view of the buffalo.

Communality

The communality ranged from 0.91 (PG) to 0.11 (FW) and unique factors ranged from 0.087 (PG) to 0.89 (FW) for all these 16 different biometric traits (Table 4.15). The lower estimates of communality of different traits indicates that they did not explain the body conformation in Buffalo of Kosi Region.

The two extracted common factors determine the source of shared variability to explain body conformation in buffalo of Kosi Region. These common factors represent general size of Buffalo of Kosi Region with respect to their length, height and diameter size and front view of the buffalo. The communalities estimates indicated that FL, FW, EL, DBH, DPB and DHP did not contribute effectively to explain body conformation in Buffalo of Kosi Region. The remaining traits contributed effectively and may be considered to explain the body conformation of the in Buffalo of Kosi Region. The result suggests that common factor analysis (CFA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

Promax Rotation of Common Factors

In order to more refine or purify the common factors, the two common factors were extracted with oblique rotation by Promax method to make correlated with each other. The eigenvalues and percentages of the explained variance and cumulative variance for body morphometric traits are presented in Table 4.17. The results show that the first rotated factors accounted for 45% of the total variance of data taken on 16 body conformation traits of buffaloes of Kosi region. The second rotated factors accounted for 10.00% of the total variance while the remaining PCs jointly accounted for 46% of the total variation. The both Promax rotated common factors jointly explain 54% of the total variance of data taken on 16 body conformation traits of Buffaloes of Kosi region with significantly high 0.6 correlation coefficient between factors,

Table 4.17: Promax Rotated Total variance, Eigenvalues and Proportion of variances explained by different Common Factors for morphometric traits of buffalo of Kosi

Traits	PA1	PA2	Communalities (h_2)	Uniqueness (u_2)
HW	0.85	0.03	0.75	0.252
HS	0.62	0.16	0.52	0.48
NL	-0.02	0.91	0.81	0.189
ND	0.98	-0.27	0.72	0.276
BL	0.85	-0.15	0.59	0.41
HG	1.04	-0.2	0.89	0.109
PG	0.99	-0.06	0.91	0.087
FL	-0.17	0.74	0.43	0.566
FW	0.16	0.22	0.11	0.89
EL	0.37	0.03	0.15	0.85
DBH	0.35	0.03	0.14	0.863
DHB	0.71	0.11	0.6	0.396
DPB	0.56	0.15	0.43	0.573
DHP	0.42	0.05	0.2	0.799
TL	0.76	0.12	0.71	0.294
TLS	0.77	0.13	0.73	0.269

Region

Table 4.18: Total Variance and Proportions of Variances explained by Promax Rotated Latent Factors for morphometric traits of buffalo of Kosi Region

Variance Name	PA1	PA2
SS loadings	7.17	1.52
Proportion Variance	0.45	0.10
Cumulative Variance	0.45	0.54
Proportion Explained	0.82	0.18
Cumulative Proportion	0.82	1

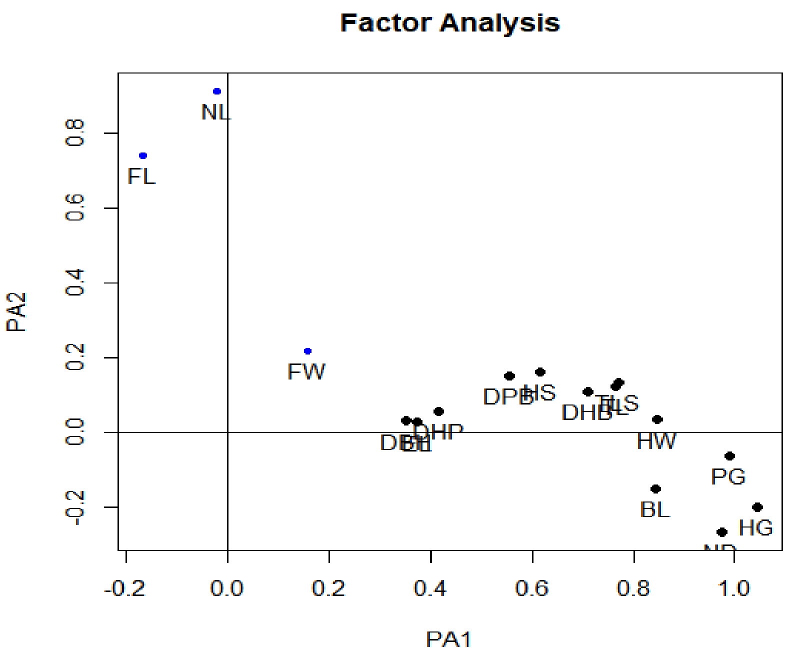

Figure 4.26: Promax Rotated Two Latent Factors Plot for Loadings (Solutions) of Biometric traits of Buffalo of Kosi Region

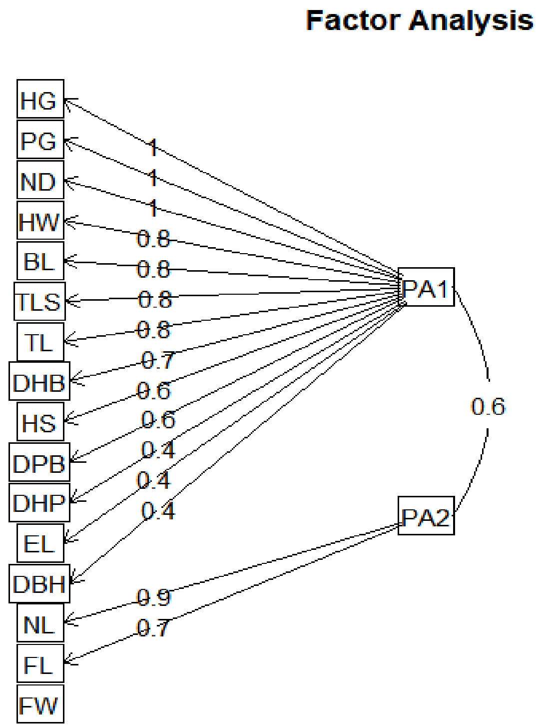

Figure 4.27: Promax Rotated Diagram of the Two Latent Factors Loading (Solution) for Biometric traits of Buffalo of Kosi Region

The correlation between Factors and variables (Loading) were presented in Table 4.17, Figure 4.26 and Figure 4.27. The estimated factors loading extracted by factor analysis, eigenvalues and variation explained by each factor are presented in Table 4.18. In the present study, the first factor accounted for 45% of the variation of total of 16 original measurements. It was represented by significant positive high loading of HG, PG, ND, HW, BL, TLS, TL, DHB, HS, DPB, DHP EL and DBH with First Factor. Out of these, variables PG HG and ND had significant positive very high loading ($r > 0.9$) with First Factor. The NL and FL presents non-significant negative correlation with first common factor. The first factor seemed to be explaining general size of Buffalo of Kosi Region with respect to their length, height and diameter size. The second factor accounted for 10% of total variability. The ND, BL, HG and PG presents non-significant negative correlation with second common factor. It had high loading for NL and FL and form a group representing the front view of the buffalo.

Communality

The communality ranged from 0.91 (PG) to 0.11 (FW) and unique factors ranged from 0.087 (PG) to 0.89 (FW) for all these 16 different biometric traits (Table 4.17). The lower estimates of communality of different traits indicates that they did not explain the body conformation in buffalo of Kosi Region.

The two extracted common factors determine the source of shared variability to explain body conformation in Buffalo of Kosi Region. These common factors represent general size of buffalo of Kosi Region with respect to their length, height and diameter size and front view of the buffalo. The communalities estimates indicated that FL, FW, EL, DBH, DPB and DHP did not contribute effectively to explain body conformation in buffalo of Kosi Region. The remaining traits contributed effectively and may be considered to explain the body conformation of buffalo of Kosi Region. The result suggests that common factor analysis (CFA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

Summary and Conclusions

Buffaloes of Kosi region are medium to large built animals distributed in three districts namely Madhepura, Supaul and Saharsa of Koshi of Bihar. The region under Kosi basin is characterized by loamy soil texture and marshy land under certain period in a year. The animals and life of this area experienced harsh climatic conditions of all sorts viz. heavy flood, rainy season, hot and humid, hot & dry summer, chill winter, scarcity of food etc. The annual precipitation rate of rain varies from 990 mm to 1700 mm. The most of precipitation received during the month of July to September. The soil pH varied from 6.5 to 8.4. Primarily, the climate is sub-tropical with peak summer temperatures averaging around 35 degree Celsius during March-May and winter months during December-January recording temperatures averaging around 8 degree Celsius. Kharif, Rabi and Zaid are the three agricultural seasons in Bihar, with main crops being rice, wheat and maize, along with various horticultural crops.

The Kosi region of Bihar come under agro-climatic zones II of Bihar. The breeding tract of buffaloes is found in major the alluvial plains of Kosi region of Bihar which is generally characterized by relatively high average rainfall around 1303 mms. The average relative humidity lies between 40% to 60%. The humidity is high during the monsoon period when it is about 85%.

The animals are housed close to the human dwellings. In most cases, closed housing is provided (80%). In most instances (70%), the animals and humans are housed in different parts of the same building. In the remaining cases, a separate structure was provided to animals away from farmer's house. Most of the constructions are permanent (80%) with thatched roofs covered with paddy straw or tiled roofs. Asbestos roof was also observed in 5% animal houses. Floors are generally uneven without proper drainage facilities. In peri-urban areas, the animals are overcrowded with less than the minimum required floor space of 3.5 square meters. In rural areas, the practice of allowing the animals to wallow in the nearby water sources is prevalent (95 %). The buffaloes of Kosi region where survives in marshy land in major part of the year and getting dried for cultivation only during dry-weather conditions.

The herd size of buffaloes of Kosi region is very small with an average being 3.1 animals. The herd structure included almost nil adult males, 2.0 adult females, 0.2 male calves and 0.8 female calves.

Paddy straw, dry mixed grasses and green grasses are the main sources of roughage. Wheat bran, linseed oil cake, mustard oil cake and rice bran are given as concentrates. About one third (34%) of the farmers provide concentrates to the milking animals; 0.5 to 2 kg of concentrate is usually given to the lactating animals at the time of milking. Some farmers even feed the animals with kitchen wastes and hotel wastes. This practice is more prevalent in the urban areas.

Breeding of buffaloes is highly disorganized in the breeding tract. Natural service practiced primarily by farmers of rural areas. Artificial Insemination (AI) is in practice for breeding in urban and peri-urban areas and occasionally in rural areas. In the rural areas A.I. is now getting priority due to unavailability of breeding bulls and practical difficulties of farmers.

The buffaloes of Kosi region are well-built medium to large sized animals. The coat color varies from Black to grey. Their skin is black. The black colored buffaloes were found more efficient producer and popular among farmers in comparison to grey colored one. The head is long with a broad forehead. Ears are moderately long and erect. The neck is moderately long with almost negligible dewlap.

Horns are medium sized, flat, corrugated and curved, projecting backward, sideward and upward at half of the neck. Shoulders are long and slope smoothly with the body. The barrel is well built and medium to large in size with a straight and wide back. Legs are strong with hard hooves. The udder is moderately developed with teats of medium size and squarely placed between the hind legs. The tail is fairly long, thin and flexible ending in a black, black and white switch.

The effect of age taken in five groups (0-7 days, 8 days to 1 year, 1 year to 2 years, 2 years to 3.5 year, more than 3.5 years) were found significant on all morphometric traits of body dimensions taken in study ($p < 0.01$). The effect of sexes found non-significant on all traits except Leg Length and Face Length ($p < 0.05$). The age contributing significantly for variation among morphometric traits across all age groups of animals whereas sexes affecting variation of only two traits namely Leg Length and Face Length.

Mean of biometric traits (cm) studied in buffaloes of Kosi region were 123.22 cm ± 1.38 for HW, 88.72 cm ± 1.15 for HS, 36.44 cm ± 0.73 for NL, 80.15 cm ± 1.31 for ND, 101.26 cm ± 1.30 for BL, 188.82 cm ± 3.39 for HG, 221.71 cm ± 4.13 for PG, 34.77 cm ± 1.05 for FL, 20.61 cm ± 0.73 for FW, 4.99 cm ± 0.76 for EL, 22.31 cm ± 0.98 for DBH, 37.02 cm ± 0.83 for DHB, 21.15 cm ± 0.48 for DPB, 36.02 cm ± 1.01 for DHP, 87.47 cm ± 1.62 for TL and 92.5 cm ± 1.6 for TLS. The means of body biometry showed that buffaloes of Kosi region were medium to larger in body size.

The coefficient of variation (CV) for different morphometric traits ranges between 0.19 (height at wither) to 16.3 (face width). Majority of the biometric traits showed higher consistency except for face width and ear length which were comparatively more variable.

The standard deviations were well within the normal range, showing that in buffaloes of Kosi region, body measurements were less affected by environment. All biometric traits studied show less variability, indicating that the buffaloes of Kosi region are almost similar shape and size in their natural habitat. This might be due to natural selection for better adaptability for particular shape and size.

Correlation coefficient estimated ranged between 0.07 (FW and DBH) to 0.94 (PG and HG) among various biometric traits. Among these 101 were significant of which all 101 were positive correlations. The positive and significant ($p<0.05/0.01$) correlations among different biometric traits suggest high predictability among the different traits.

The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for adult male buffalo of Kosi Region of age between 1 to 7 days of age were found to be 131.9 ± 2.99, 112.3 ± 3.26, 210.8 ± 6.87, 251.8 ± 6.95, 92.7. ± 3.17, 112.3 ± 3.26, 91.1 ± 3.38, 36.9 ± 1.91, 21.3 ± 2.56, 26.4 ± 2.58, 40.7 ± 1.89, 21.3 ± 1.32, 36.8 ± 3.22, 105 ± 3.43 and 101.1 ± 8.00, cm respectively.

The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for young stock of age between one week to one year were found to be 110.7 ± 2.02, 88.9 ± 2.21, 159.0 ± 4.66, 184.9 ± 4.7, 79.8 ± 2.15, 88.9 ± 2.21, 69.4 ± 2.29, 27.5 ± 2.34, 19.9 ±1.74, 20.1 ± 1.75, 27.8 ± 1.28, 16.8 ± 0.895, 32.9 ± 2.19, 87.0 ± 2.33 and 81.4 ± 2.46, cm respectively.

The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for young stock of age between one year to two year were found to be 121.6 ± 2.03, 98.5 ± 2.22, 188.6 ± 4.67, 223.9 ± 4.73, 88.1 ± 2.15, 98.5 ± 2.22, 80.1 ± 2.30, 31.0± 3.46, 21.0 ± 1.74, 26.0 ± 1.75, 33.3 ± 1.29, 18.4 ± 0.898, 34.1 ± 2.18, 99.4 ± 2.33 and 94.0± 2.47, cm respectively.

The Height at wither (HW), Body Length (BL), Heart girth (HG), Pauch girth (PG), Height at shoulder (HS), Neck Length (NL), Neck Diameter (ND), Face Length (FL), Face Width (FW), Ear Length (EL), Distance between hip bones (DHB), Distance between Pin bones (DPB), Distance between Hip and Pin (DHP), Tail length without switch (TLS) and Tail length with switch (TL) for adult male buffalo of age above the 3.5 years were found to be 140 ± 1.65, 117.4 ± 1.8, 229.9 ± 3.79, 273.8 ±3.83, 97.0 ± 1.75, 117.4 ±1.8, 93.0 ±1.86, 39.8 ± 2.35, 21.9 ± 1.41, 28.4± 1.42, 47.2 ± 1.04, 26.0 ± 0.727, 41.1 ± 1.77, 106.4 ± 1.89 and 101.6 ± 3.63, cm respectively. There was no significant difference found between male and female of buffalo of Kosi region for morphometric traits across all age groups.

The buffalo of Kosi region are moderate milk producers and normally give four to nine litres of milk daily. Some animals in villages reach a peak yield of more than 9.65 litres per day. The average daily milk yield was 4.9 ± 0.4 litres as reported by the farmers. The length of lactation varied from 210 to more than 340 days with an average of 301.6 ± 10.3 days. The lactation milk yield varied from 1008.4 ± 95.7 to 1635.6 ± 112 litres with a mean of 1450.87 ± 28.7 litres. Diara buffaloes have relatively long productive life spans as demonstrated by animals with more than five calvings commonly found in the villages. Age at first calving and calving interval was estimated to be 46.27 ± 0.63 months and 14.4 ± 0.13 months, respectively. The dry period, average age at first service and Service period was estimated to be 89.87 ± 4.25 days, 34.86 ± 0.78 months and 131.31 ± 3.06 days.

The buffalo of Kosi region are dual purpose animals used for milk production as well as agricultural operations in wet fields. They are better suited than are local cattle to ploughing and puddling the wet fields meant for paddy cultivation. They are active, fast moving, hardy and can work continuously for four to six hours in the wet fields.

The estimate of sampling adequacy KMO and Anti-image corruptions revealed the proportion of the variance in different biometric traits caused by the underlying components (Kaiser, 1958). The overall significance of the correlation matrix was tested with Bertlett's test of sphericity for the biometric traits (chi-square was 3575.5 $p<0.01$) was significant, it means correlation matrix is not an identity matrix and provided enough support for the validity of the factor analysis of data.

The first two components accounted for 59% of the total variance of which the eigenvalues were larger than 1.0 ($\lambda>1.0$). The second (PC2) principal components accounted for 9.00% of the total variance while the remaining PCs jointly accounted for 41% of the total variation.

Scree plot suggested that two components are appropriate for summarizing the data of buffaloes of Kosi region. The identified two components could explain cumulative percentage of variance of 60%. First component accounted for 50% of the variation. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, DHB, TL and TLS. First component seemed to be explaining the maximum of general body conformation in Boffaloes of Kosi region of Bihar. The second component explained 15% of total variance with high loading of distance between FL, NL, and FW. The communality ranged from 0.17 (DBH) to 0.89 (PG) and unique factors ranged from

0.83 to 0.11 for all these 16 different biometric traits. The principal(PC1) and (PC2) components together explain highest variation 89% in PG trait and lowest in DBH trait.

The identified two components after orthogonal Varimax rotation could explain cumulative percentage of variance of 59%. First component accounted for 44% of the variation. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, EL, DBH, DHB, DPB, DHP, TL and TLS. First component seemed to be explaining the maximum of general body conformation in Boffaloes of Kosi region. The second component explained 14% of total variance with high loading of distance between HS, NL, FL, FW, TL and TLS. The communality ranged from 0.17 (DBH) to 0.89 (PG) and unique factors ranged from 0.83 to 0.11 for all these 16 different biometric traits. The principal(PC1) and (PC2) components together explain highest variation 89% in PG trait and lowest 17% in DBH trait. The lower estimates of communalities of HS, FW, DBH, DPB and DHP indicates that they did not explain the body conformation in buffaloes of Kosi region.

The identified two components after oblique rotation i.e. Promax could explain cumulative percentage of variance of 59%. First component accounted for 46% of the variation. It was represented by significant positive high loading of height at wither (HW), HS, ND, BL, HG, PG, EL, DBH, DHB, DPB, DHP, TL and TLS. First component seemed to be explaining the maximum of general body conformation in buffaloes of Kosi region. The second component explained 13% of total variance with high loading of distance between FL, NL and FW. The communality ranged from 0.89 (PG) to 0.17 (DBH) and unique factors ranged from 0.11 to 0.83for all the 16 different biometric traits. The inter-factor correlations between two components were positive and significant (0.52) between first and second components in Boffaloes of Kosi region of Bihar.

The Common Factor Analysis (CFA) was applied on 16 body conformation traits of Buffaloes of Kosi region. Scree plot suggested that two omponents are appropriate for summarizing the data of buffaloes of Kosi region. The first two factors accounted for 54% of the total variance of data taken on 16 body conformation traits of Buffaloes of Kosi region. The second latent factor accounted for 7.00% of the total variance. The remaining factors jointly accounted for 46% of the total variation. It was represented by significant positive high loading of PG, HG, HW, TLS, TL, ND, DHB, BL, HS, DPB, DHP and EL with First Factor. Out of these, variables PG, HG, HW, TLS had significant positive very high loading (r > 0.9) with First Factor. The First factor seemed to be explaining general size of Buffalo of Kosi Region with respect to their length, height and diameter size. The second factor had high loading for NL and FL and form a group representing the front view of the buffalo. The communality ranged from 0.91 (PG) to 0.20 (DHP) and unique factors ranged from 0.087 (PG) to 0.86 (FW) for all these 16 different biometric traits. The lower estimates of communality of different traits indicates that they did not explain the body conformation in Buffalo of Kosi Region.

In order to more refine or purify the common factors, the two common factors were extracted with orthogonal rotation by Varimax method to make uncorrelated with each other. The first rotated factors accounted for 42% of the total variance of data taken on 16 body conformation traits of Buffaloes of Kosi region. The second rotated factors accounted for 13.00% of the total variance while the remaining PCs jointly accounted for 46% of the total variation. The both Varimax rotated common factors jointly explain 54% of the total variance of data taken on 16 body conformation traits of Buffaloes of Kosi region. It was represented by significant positive high loading of HG, PG, ND, HW, TLS, TL, BL, DHB, HS, DPB, DHP EL and DBH with First Factor. Out of these, variables PG and HG had significant positive very high loading (r > 0.9) with First Factor. The First factor seemed to be explaining general size of Buffalo of Kosi Region with respect to their length, height and diameter size. The second factor accounted for 13% of total variability. It had high loading for NL FL and FW and form a group representing the front view of the buffalo. The communality ranged from 0.91 (PG) to 0.11 (FW) and unique factors ranged from 0.087 (PG) to 0.89 (FW) for all these 16 different biometric traits. The lower estimates of communality of different traits indicates that they did not explain the body conformation in Buffalo of Kosi Region.

The first rotated factor after Promax rotation accounted for 45% of the total variance of data taken on 16 body conformation traits of Buffaloes of Kosi region. The second rotated factors accounted for 10% of the total variance while the remaining PCs jointly accounted for 46% of the total variation. The both Promax rotated common factors jointly explain 54% of the total variance of data taken on 16 body conformation traits of Buffaloes of Kosi region with significantly high 0.6 correlation coefficient between factors

First factor represented by significant positive high loading of HG, PG, ND, HW, BL, TLS, TL, DHB, HS, DPB, DHP EL and DBH with First Factor. Out of these, variables PG HG and ND had significant positive very high loading ($r > 0.9$) with First Factor. The NL and FL presents non-significant negative correlation with first common factor. The first factor seemed to be explaining general size of Buffalo of Kosi Region with respect to their length, height and diameter size. The second factor accounted for 10% of total variability. The ND, BL, HG and PG presents non-significant negative correlation with second common factor. It had high loading for NL and FL and form a group representing the front view of the buffalo.

The communality ranged from 0.91 (PG) to 0.11 (FW) and unique factors ranged from 0.087 (PG) to 0.89 (FW) for all these 16 different biometric traits. The lower estimates of communality of few traits indicates that they did not explain the body conformation in Buffalo of Kosi Region. The communalities estimates indicated that FL, FW, EL, DBH, DPB and DHP did not contribute effectively to explain body conformation in Buffalo of Kosi Region

The two extracted common factors determine the source of shared variability to explain body conformation in Buffalo of Kosi Region. These common factors represent general size of Buffalo of Kosi Region with respect to their length, height and diameter size and front view of the buffalo. The communalities estimates indicated that FL, FW, EL, DBH, DPB and DHP did not contribute effectively to explain body conformation in Buffalo of Kosi Region. The remaining traits HW, HS, NL, MD, BL, HG, PG, TL and TLS contributed effectively and may be considered to explain the body conformation of the in Buffalo of Kosi Region. The result suggests that common factor analysis (CFA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

Conclusions

1. Buffaloes of Kosi region are hardy, dual purpose animals reared for both milk and draught purposes.
2. There is need to organise the breeding systems of buffalo of Kosi region by making availability of male germplasm. Buffalo of Kosi region are reared for milk and draught purposes. These buffaloes are able to thrive well in low input systems forming an integral part in the livelihood of farmers in the region.
3. The various age groups of buffalo of Kosi region possess different body dimensions for all the biometric traits taken in study.

4. The sex difference has non-significant effect on all biometric traits except Height at shoulder (HS) and Face Length (FL). This indicate that make buffalo may appear little long in Height and face length in comparison to that of females of respective age groups
5. The two extracted common factors determine the source of shared variability to explain body conformation in Buffalo of Kosi Region. These common factors represent general size of Buffalo of Kosi Region with respect to their length, height and diameter size and front view of the buffalo. The communalities estimates indicated that FL, FW, EL, DBH, DPB and DHP did not contribute effectively to explain body conformation in Buffalo of Kosi Region. The remaining traits HW, HS, NL, MD, BL, HG, PG, TL and TLS contributed effectively and may be considered to explain the body conformation of the in Buffalo of Kosi Region. The result suggests that common factor analysis (CFA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

The significant level of variability in this population reflects that the local buffalo population contains a valuable and substantial amount of genetic diversity among the studied population but the study needs to be extended to include more number of observation to make in a large sample size to further validate the research. The application of Oblique characters (PC1 and PC2) derived from the PCA can be more reliable in predicting body size compared to the use of the original body measurements.

The two extracted factors determine the source of shared variability to explain body conformation in Boffaloes of Kosi region of Bihar. These first two PC could be exploited in the evaluation and comparison of animals and thus provide an opportunity to select the animals based on a small group of traits rather than on isolated traits. Our results suggest that the present PCA provided a means for a reduction in the number of biometric traits to be recorded in Boffaloes of Kosi region of Bihar (PG, HG, HW, NL, ND, and FL) which could be used in ranking programs as a mean to explain the body conformation. The results also suggests that principal component analysis (PCA) could be used in breeding programs with a drastic reduction in the number of biometric traits to be recorded to explain the body conformation.

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