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# Introduction of domestic buffalo (*Bubalus bubalis*) into Ethiopia would be feasible

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## Abstract

Due to its high agro-ecological variation and favorable production environment, Ethiopia has been endowed with high diversity of animal genetic resources and huge livestock population. However, the per capita consumption of livestock products is among the least in the world. To increase this consumption level, Ethiopia needs to keep livestock species that would be able to thrive under sub-optimal management systems, while providing some amount of products and services. The domestic buffalo (*Bubalus bubalis*) is one of the large ruminants that contribute to the least developed world's food and agriculture production. Therefore, introduction of the riverine-type buffalo would support food and agriculture production in Ethiopia. Moreover, the existing high demand for milk and meat, and the agro-ecological conditions are in favor of introduction of the riverine-type buffalo. More specifically, the riverine buffalo excels over indigenous cattle in its milk yield and quality of milk components. It also has a long productive life, a special ability of converting poor-quality roughage into animal protein, docile temperament and a wide range of adaptation. The presence of wild buffalo also shows Ethiopia's suitability for domestic buffalo rearing. Therefore, even though it seems illogical to make direct comparison between the performance of the Ethiopian indigenous cattle and the domestic buffaloes kept elsewhere; the hardy nature of buffalo and its wide range of adaptation would indicate the adaptation of the riverine-type buffalo in Ethiopia. However, the introduced riverine-type buffalo needs to be handled on experimental stations until management expertise is developed.

**Key words:** domestic buffalo, introduction, Ethiopia, feasibility, indigenous cattle

## Introduction

Ethiopia is one of the eight Vavilovian centers of biodiversity in the world. As a result, it has been well known for its high diversity of animal genetic resources and huge livestock population. According to the Domestic Animal Genetic Resources Information System (DAGRIS)[1], Ethiopia is a home for 32 recognized cattle breeds, 7 sheep breeds, 13 goat breeds and 10 chicken ecotypes. Moreover, there are four donkey breeds, two horse breeds, two mule types and four camel breeds[2]. This is despite the paucity of phenotypic characterization work especially for livestock breeds that are kept by minority ethnic groups and pastoralists inhabiting the very remote areas.

The livestock sector in Ethiopia accounts for 13–16% of the national GDP and 30–35% of the agricultural GDP and constitutes 15% of the total export revenue[3]. This contribution has been made by 43.1 million cattle, 23.6 million sheep, 18.6 million goats, 6.5 million equines (donkeys, horses and mules), 0.62 million camels and 34.2 million chickens mainly kept by subsistence smallholder farmers in the highlands and the pastoralists in the lowland areas[4]. This huge livestock population has placed Ethiopia among the high-ranking countries in Africa and for some of the species at the international level. More specifically, Ethiopia is known to be first in its cattle population and second for its sheep (next to South Africa) and goat population (following Nigeria) in Africa. Ethiopia also constitutes 39.63% of the African equine population[5]. Accordingly, its donkey population is the second in the world following China, and its camel population is the third in the world (next to Somalia and Sudan). Therefore, this indicates that Ethiopia has suitable agro-ecological conditions for rearing different types of livestock species.

This huge livestock population and high genetic diversity have ecological, historical, socio-cultural and economic perspectives. For example, an ancient country, Ethiopia has a long-lasting tradition of farming, it is characterized by

high agro-ecological diversity and, according to Taddese[6], it constitutes 70% of the African highland mass (>1500 m asl), which is considered to be a suitable environment for farming and human settlement. Accordingly, it was estimated that about two-thirds of the total land mass is suitable for agricultural activities[7]. Moreover, diversified uses of livestock species and their multiple socio-economic roles are among the main driving forces behind this diversity. Ethiopia is also the homeland for more than 80 ethnic groups that have at least some degree of variation in their practice of livestock farming. This ethnic diversity could be a source of animal genetic resource diversity, because farmers and pastoralists of a given ethnic group might have specific selective breeding practices dictating their needs.

However, the per capita consumption of livestock products in Ethiopia is among the least in the world. For example, according to FAO[5], the per capita consumption of milk was 22.5 kg and of meat was 8.5 kg. The main reasons for this low level of consumption are low amount of products obtained from indigenous livestock due to production constraints such as feed shortage, disease problems etc., together with the inherently low genetic potential of indigenous breeds. It was also noted that recurrent drought, poor infrastructure and market development, weak policy supports and institutional arrangements have reduced the performance of the livestock industry[7]. Moreover, to feed the fast-growing human population (around 3% annual growth), a considerable portion of the grazing land has been increasingly converted into cropland. This has forced smallholder farmers to rely upon highly fibrous and poor-quality crop residues such as straw, stover and stubble, and marginalized grazing lands to feed their cattle. This type of feeding regime was not able to support, for example, the nutritional requirement of improved temperate cattle breeds and their crosses (attempts have been made for decades to improve the performance of indigenous cattle through cross-breeding with temperate breeds) and as a result these improved breeds usually produce below the expected level[8].

However, Ethiopia has a favorable environment for rearing different types of livestock species, especially those already acclimatized to sub-optimal management and low-input–low-output farming systems. The domestic buffalo is one of these species that have indispensable importance in the least developed countries (LDC) for food and agriculture production. Therefore, the objective of this analysis is to synthesize the existing evidence on domestic buffalo production systems and to analyze the feasibility of introducing the riverine-type buffalo into subsistence-oriented Ethiopian farming systems.

## Ethiopia's Agro-Ecological Diversification

Ethiopia is located in east Africa and is bounded by geographical coordinates 3°24′–14°53′N and 32°42′–48°12′E. It has a total area of 1.1 million km$^2$ and, of this, an area of 7444 km$^2$ is occupied by major lakes. Its altitude ranges from 125 m below sea level in the Denakil depression to 4543 m asl on Mount Ras Dashen[9]. Average annual rainfall varies from < 100 mm in the arid eastern and south-eastern regions to 2400 mm in the southwest highlands, with a national average of 744 mm[10]. This wide variation in altitude and rainfall pattern has resulted in 18 major agro-ecological zones that can be further divided into 49 sub-zones[11]. Ethiopia has major rivers that are 7000 km long, including the famous Blue Nile River that contributes ~85% of the Nile's water source. Ethiopia also shows wide variation in its temperature, which ranges from below 0°C to more than 40°C depending on the altitude and season of the year. However, in the agriculturally important areas, the average daily temperature usually ranges from 10 to 30°C. This is an ideal temperature for buffalo production, because 20°C is the optimal environmental temperature for rearing of buffaloes[12] and this falls well in the temperature range of agriculturally suitable areas in Ethiopia. However, the best milk breeds of buffaloes (the riverine-type) in India and Pakistan are mostly confined to areas where the summer temperature rises above 46°C and the winter temperature falls below 4°C[13].

## The Domestic Buffalo

The domestic buffalo (*Bubalus bubalis*) is one of 40 livestock species used in world food and agriculture production. The domestic buffalo species can be divided into two sub-species or types; the riverine- and swamp-type[14–16]. The diploid set of chromosomes ($2n$) in the riverine-type is 50, whereas it is 48 for the swamp-type[17]. The swamp-type is mainly used for draft and secondarily for meat[14,15,18], therefore, it is considered as a dual-purpose animal[14]; whereas the primary purpose of keeping riverine-type buffaloes is for milk and secondarily for meat[18]. However, the riverine-type was noted by McCool[14] as triple-purpose animal (milk, draught and meat). Therefore, in both types meat production has secondary importance. Similarly, Ranjhan[19] reported the primary use of buffalo for milk and secondarily for meat production in South Asia. However, Sadana[20] reported the use of swamp buffalo to produce small amount of milk and in line with McCool[14]; Sadana[20] has also reported the use of the riverine-type for transport. The swamp buffalo is the most common type in typical South-East Asian rural villages[14]. However, for example, in India, the riverine-type is widespread throughout the country[20]. Generally, the riverine-type is found in South Asia, whereas the swamp-type is distributed across South-East Asia[16]. Swamp buffaloes are typically smaller and less productive compared to their riverine-type counterparts, whereas the riverine-type is characterized by high milk yield because for decades it has been selected for this trait[15].

### *Common buffalo breeds*

India and Pakistan are the home of the best milk breeds of riverine-type buffalo in the world, Murrah and Nili-Ravi;

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whereas swamp buffaloes are not distinguished into breeds[20]. Therefore, breed description and diversity in India are made for riverine-type buffaloes only. Moreover, by virtue of its number and importance, the domestic buffalo in India is synonymous with the riverine-type; however, the majority of buffaloes in Vietnam, Thailand, China and adjoining countries are of the swamp-type[20]. Important buffalo breeds also include the Jaffarabadi and Surti[21]. Jaffarabadi is commonly used in many countries for cross-breeding due to its large size and to exploit its high carcass yield potential[18]. However, the popular Murrah is known as 'black gold' in India and is widespread throughout Asia and the rest of the world[20]. However, Singh and Barwal[22] reported the superiority of the Nili-Ravi breed of Pakistan over Indian Murrah and Egyptian buffaloes. Buffalo breeds can also be classified based on their horn orientation. For example, horns are closed and set close to head and are down swept in Murrah, Nili-Ravi, Mehasana, Jaffarabadi and Sambalpur, whereas horns are sickle-shaped and non-swept in Bhadawari, Kalahandi, Kanara, Manda, Nagpuri, Pandharpuri, Tarai and Toda[22].

### *Population trend*

The world's buffalo population is estimated at 170 million head and approximately 97% are found in Asia, whereas the remaining 2% and 0.3% are found in Africa and Europe, respectively[23]. In Europe and Asia, there is a growing interest in the use of buffaloes for milk and meat production. As a result, the riverine buffaloes have been introduced into many European countries and in swamp buffalo-dominated areas[15]. Murrah buffalo has been the breed of choice for introduction and is followed by Nili-Ravi, Jaffarabadi and Surti. This is because among domestic buffalo breeds Murrah is a well-known milch breed[20]. The importance of buffalo in South Asia is increasing faster than that of cattle, although in some East and South-East Asian countries buffalo population has declined rapidly[19]. This is due to the massive use of farm mechanization which has significantly reduced the swamp buffalo population[18]. Despite this, in the majority of the south Asian countries, a major shift has been taking place from cattle to buffalo dairying. The reasons for this include consumers' preferences for higher butterfat content, persistency of milk production under poor management systems and longer productive life of buffalo[21]. Due to this, for example, buffalo population in the Brazilian Amazon increased at a rate of nearly 13% per annum from 1975 to 2000 compared to cattle with an annual growth rate of 4% only. Therefore, buffalo has steadily gained acceptance as an alternative to cattle, and throughout South America buffalo performs better than cattle both in meat and milk production[24].

### *Behavior*

Buffaloes are probably among the easiest mammals to train and are more rustic animals compared to cattle[15]. Therefore, buffalo is considered a cumbersome and docile large ruminant[14]. Hence buffalo's rusticity and its ability to adapt to different environments are among its important characters[25]. Buffaloes are therefore generally pretty good in their temperament; however, like most animals, the more they are handled the better is their temperament[26]. Buffaloes have inherent docility, therefore they can easily learn upon training and the occurrence of deliberate attacks on people is perhaps much rarer in buffaloes compared to other livestock species[27].

### *Ecological adaptation*

Buffalo rearing has gained importance in recent years due to its innate ability to survive in adverse agro-ecological conditions and due to its special ability of converting poor-quality roughage and crop residues into animal protein[28]. As a result, buffalo rearing is an integral part of the traditional smallholder mixed farming system[25]. Buffaloes also have a special ability to subsist on coarse feeds, straws and crop residues and to convert these feed materials into protein-rich lean meat[29]. Moreover, buffaloes are well known for their disease resistance and special ability to survive and thrive under hot, humid climates[12,18]. This has made buffaloes well recognized for their better adaptation to poor feeding, harsh climate and infectious diseases[30]. Moreover, buffalo is found in more than 50 countries of the world, varying in their ecology, climate, topography and socio-economic conditions. Buffalo adapts well from tropical conditions of the Indo-Pakistan region to the temperate climate of Italy[30]. Therefore, this wide range of adaptation of domestic buffalo[13] indicates its ability to acclimatize to Ethiopia's environment characterized by high agro-ecological diversity. Cattle suffer badly while transiting from dry to wet seasons; however, these conditions bring few problems to buffalo. Due to its ability to adopt and even thrive under difficult conditions of the floodplains, buffalo has now become a popular choice among floodplain ranchers[24]. Moreover, due to long-term natural and artificial selection, buffaloes possess many biological features, including resistance to high temperature and humidity[31]. However, compared to cattle, thermo-regulation is poor in buffalo, therefore, often it requires shade or water for wallowing, although the riverine-type that is proposed for introduction into Ethiopia has better thermo-regulation than the swamp-type[13].

## Utility Pattern

Buffalo is a triple-purpose animal that provides milk, meat and draught[19]. Moreover, buffalo has resistance to common bovine diseases, shows superior weight gain than cattle, produces high-quality milk and meat products and is able to fatten on a wide range of pastures[24]. Buffaloes produce milk that is rich in nutrients and high in quality and provide draft power and dung/urine as organic fertilizer and provide meat that is known for its flavor and marbling, and other products such as mozzarella cheese[20]. Buffaloes contribute

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72 million tonnes of milk and 3 million tonnes of meat annually to world food production and this is mainly produced by smallholder farmers[22]. For example, buffaloes in India account for 30% of the total meat production[19]. Buffaloes represent 12% of the world bovine stock, but its share in the world bovine meat export was estimated at 27% in 2007[32]. However, some buffalo products have a lower price compared to cattle products. For example, buffalo meat is sold at about half the price of beef and buffalo hide is sold at ~40% of cattle hide. The live buffalo is sold at 14% of cattle price. The low export value of buffalo meat could be mainly due to low world market demand for buffalo meat and low export value of buffalo hide could be due to low quality and demand. The low price of live buffalo could be mainly due to export of weaned calves rather than fed bulls or steers and/or low carcass weight of the exported buffalo. Despite the low price of exported buffalo meat, India exports by far more buffalo meat than beef[32]. This might be due to the worship of cows by Hindus, which, in turn, could affect the practice of cattle slaughtering. Generally, buffalo meat is less expensive than cattle beef[24] and is much cheaper than chevon, mutton, pork and poultry. Therefore, it is a cheap source of animal protein for the part of the society with weak purchasing power[19].

However, in the case of milk, the market demand and price show a different picture. For example, in Italy, keeping buffaloes is generally considered more remunerative than keeping cattle. This is because the price of buffalo milk is 2.3–2.5 times more than that of cow's milk and this is about 2.5 times in Asia[33]. Similarly in Pakistan, buffalo milk is sold at Rs. 20 per liter, compared to cow's milk which is sold at Rs. 15[34]. Moreover, Payne and Wilson[13] reported the production of excellent, thick and tough leather articles from buffalo hide, hence leather could be considered an important by-product derived from slaughtered and fallen buffaloes[19]. Moreover, on average, about 5 tonnes of dung are produced annually from an adult buffalo[19]. An adult buffalo therefore voids 3–5 kg dry matter and 50–100 g nitrogen every day, besides potassium and other minerals of high manure value[35]. However, 8.4% and 9.3% of the fuel source in the urban and rural areas of Ethiopia, respectively, constitutes cow dung. Therefore, this type of cow dung use competes directly with the use of dung to improve the soil nutrient levels[36]. The massive horn of buffalo is also used to produce fancy and decorative horn articles[13].

## Milk production

Under rural subsistence farming systems the average milk yield of buffaloes is 1350 liters[37]. Approximately 10.75% of the total milk yield is produced in the first month of lactation, whereas ~12.5% and 11.25% were produced in the second and the third month of lactation, respectively[22]. In Italy, buffalo cows are commonly milked twice a day with an interval of 11–12 h[38]. Buffalo's milk is traditionally preferred over cow's milk by the majority of Pakistanis[37,39,40] due to its aesthetic and creamy characteristics, high milk fat (6–8%), flavor and slightly higher solid not fat (SNF) content (~9–10.5%). Due to this, buffaloes account for 62% of the total milk production in Pakistan[40]. Moreover, the ratio of butter or ghee output from buffalo milk was approximately three times more than that from cow's milk. Buffalo milk is also highly preferred in soft cheese making and the ratio of milk to soft cheese is 5 : 1 kg compared to 8 : 1 for cow's milk[37]. Moreover, Nili-Ravi and Murrah breeds on average complete three lactations in their production lifetime[22], which shows their prolific nature.

Milk fat percentage of buffaloes usually exceeds cattle by 1–3%, depending on the breed type and environmental condition and compared to cow's milk, buffalo milk has a higher percentage of all milk components[41]. The average fat globule size of buffalo milk is larger and its viscosity is higher (2.04) compared to cow's milk (1.86). Due to its higher dry matter content, buffalo milk has a higher cheese yield, however, this does not seem to be due to the difference in milk quality alone. Moreover, for each protein percent point more than 5 cheese yield points are obtained for buffalo, whereas it is about 3 for cows[41]. Buffalo milk also has low cholesterol and high calcium content compared to cow's milk[37]. Moreover, despite its high fat percentage, milk and mozzarella cholesterol content are lower in buffalo's milk than cow's milk (275 mg versus 330 mg and 1562 mg versus 2287 mg, respectively)[41]. Buffalo milk also contains high levels of the natural antioxidant tocopherol peroxidase, having 2–4 times the activity of cow's milk. Furthermore, there are a growing number of people who suffer from cow's milk allergy but this is not the case for buffalo milk[37].

However, according to the findings of Mukasa et al.[42] in the central highlands of Ethiopia lactation milk yield of indigenous cattle was 238 ± 82 liters with associated lactation length of 239 ± 55 days. Payne and Wilson[13] reported that milk of short-horned Zebus in Ethiopia has a fat percentage ranging from 4.7 to 7.1. Therefore, for the majority Ethiopians who prefer to consume a large amount of ghee by adding it as a flavor in a sauce that is consumed together with the traditional bread called '*enjera*', the high-fat percentage of buffalo milk is readily acceptable. A high cheese yield from buffalo milk would be highly demanded by Ethiopians because cheese is among the commonly consumed milk products. Buffaloes are, however, slow and hard milkers due to their slow milk ejection reflex and their hard teat sphincter muscle, although the pressure during milking is higher in buffaloes than in cattle[38].

## Meat production and weight gain

Buffaloes, used as draught animals for centuries, have well-built muscles. However, until recently, little attention was given to their use exclusively for meat production[29]. Despite this, due to its low fat and calorie content, buffalo

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meat has high demand in India and on the international market[28]. This is also due to the lean, tender and juicy nature of buffalo meat[19]. Buffalo meat is also the healthiest among red meats due to its low calorie and cholesterol content. It has about a 2–3-fold cost advantage over mutton and goat meat. Furthermore, its use in meat processing is on the increase due to its high lean meat content and low fat percentage[29]. Therefore, due to buffalo's lean nature[29]; most of the buffalo meat from India was exported for meat processing industries[32]. However, about 86% of the world buffalo meat is produced in Asia and is mainly obtained from old and culled animals. Meat from these types of buffaloes is dark, less tender, has a strong odor and hence it is poorly accepted by consumers[22]. This is indeed true, because meat is mainly produced when buffaloes are retired from their productive lives[19]. However, when young buffaloes are raised under an intensive feeding system their meat is lean, tender and highly palatable and is favorably compared with beef from cattle of similar age and weight[22]. The subcutaneous fat layer of the buffalo carcass is usually thinner than that of comparably fed cattle. Thus, the buffalo carcass has a rounder rib, higher proportion of muscle and lower proportion of bone and fat compared with beef. More pigmentation or less intra-muscular fat (1–2% marbling compared with 3–4% in beef) content makes the buffalo meat darker[29]. However, the dressing percentage of buffaloes is slightly lower than that of cattle[22]; and old and unproductive buffaloes have 43–57% dressing percentage[29]. However, this is higher than the dressing percentage of 42–53% reported for Small East African Zebus[13].

Growth is linear in buffalo from birth up to 36 months. The average daily gain ranges from 548 g (3–6 months) to 404 g (birth to 36 months)[22]. However, the Murrah calves grow at a rate of 900–1000 g a day with feed conversion ratio of 5 : 1[19]. It was also found that buffalo calves gained more and consumed less amount of feed per unit of gain under restricted feeding systems compared with cow calves[30]. Therefore, buffaloes have excellent body weight gain compared with cattle[29].

Ethiopia is a home for wild buffaloes and there had been a tradition of hunting wild buffalo in some areas as a symbol of heroism and to consume bush meat. However, this tradition has been gradually eroded due to change in the socio-economic, cultural and political atmospheres. Therefore, this shows that the consumption of buffalo meat will not face any restrictive social taboos in Ethiopia.

### *Draught work*

Buffaloes are a major source of draught power, and that is why they have been called live tractors of East and South-East Asia[14,22]. This is because buffaloes provide steady but sure-footed draft power in the remote rural areas[20]. Therefore, the draught work of buffalo is among its most important uses in the least developed world[14]. For example, in India 60% of the total farm power is generated from draught animals, of which about 10% is contributed by buffaloes. A buffalo can pull loads of more than six times its body weight, but its common load carrying capacity is 1.5–2.0 tonnes, i.e., 3–4 times its body weight. It can pull this load continuously for 2–3 h and for 6–8 h a day during winter and 5–6 h a day during summer with rest in between[22]. Similarly, it was reported that the usual load carrying capacity of buffalo was 1.5–2 tonnes continuously for 3–4 h during summer and 6–8 h a day during winter[19]. The swamp-type buffalo is especially important for work on paddy fields[20]. Therefore, even though buffaloes are slow movers compared to cattle, they can pull heavier loads[19].

## Management Practices

### *Health care*

Although mastitis is not a common problem in buffalo species, it is a costly disease; therefore, the exposure of teat ends to pathogens should be minimized[38]. However, the hardy nature of buffaloes minimizes disease problems and allows the use of simpler and cheaper housing and equipment[33]. In buffaloes, the incidence of hemorrhagic septicemia and internal parasites were the highest, followed by foot and mouth disease and pneumonia. Other diseases/disorders include tympani, mastitis, dystocia, rabies and lameness[34]. Major infectious diseases that cause significant losses in Bangladeshi buffalo, for example, include foot and mouth, rabies, contagious bovine pleuropneumonia, hemorrhagic septicemia, anthrax, black quarter, bovine tuberculosis, brucellosis, calf scour and calf diphtheria. Brucellosis is the main cause of abortion in buffalo[21]. Therefore, a comparable type of health care practiced by smallholder farmers and the veterinary services in Ethiopia can be adopted to control the risk of disease problems in the riverine buffaloes.

### *Feeds and feeding*

Buffaloes are reared in a mixed cut and carry, tethering and grazing on communal pasturelands and using crop residues and agricultural by-products[18]. Buffaloes also feed on crop leftovers[20] and they can perform better on roughage and marginalized poor pastures[15]. As a result, buffaloes have developed the special ability of converting poor-quality roughage into milk, meat and other services and products[20]. The superiority of domestic buffalo over cattle in digesting and efficient use of feeds is clearly observed when the two species are kept on a low level of nutrition[30]. It was also found that buffalo calves digest larger amounts of dry matter and nitrogen-free extract than cow calves under restricted feeding systems[30]. One of the characteristics that make buffaloes preferable is therefore their extraordinary ability to convert fibrous feed into energy, and this enables them not to compete with humans for scarce resources such as grains[25]. Due to its size, a buffalo's rumen harbors large microbial populations that facilitate better digestion of feed.

Rumen acidosis is also seldom found in buffalo due to a high rate of saliva secretion which helps buffalo to maintain its rumen pH[30]. Therefore, for countries such as Ethiopia that commonly rely upon poor-quality roughage such as straw, stover and stubble to feed their cattle, the high efficiency of domestic buffalo in digesting poor-quality roughage is a reward for resource-poor smallholder farmers.

## Reproduction

Buffalo has low inherent reproductive capacity, resulting in late sexual maturity in heifers followed by longer inter-calving period and fewer calf crops[39]. Domestic buffaloes are generally known for their poor reproductive efficiency. However, this is largely due to the production environment under which the majority of them are maintained, such as harsh climate, poor nutrition and sub-optimal production inputs. Therefore, they would have good fertility if managed well and properly fed[16]. Buffaloes reach sexual maturity at later ages; however, they have extended longevity. As a result, buffalo cows are well grown before their first calving, and this can help them to maintain their body condition while nursing their calf. This extended longevity ensures that buffalo cows produce more calves in their productive lifetime[14]. Therefore, a low replacement rate is required due to their long reproductive life[33]. Moreover, although buffaloes attain puberty at a later age compared to cattle, they have a remunerative longer reproductive lifetime[16].

The average age at first calving (AFC) and calving interval (CI) were 48 and 20 months, respectively, under smallholder buffalo production systems[33]. Specifically, the average calving interval in Surti buffaloes was 462 days[22]. Moreover, according to Younas et al.[25], the average age at maturity and CI were 34.8 and 17.5 months, respectively. Buffalo heifers usually attain puberty when they reach approximately 55–60% of their adult weight, but the age at which this is achieved largely depends on breed, nutrition, management, climate and year (season) of birth[16]. The gestation length of buffaloes is 312–334 days and is longer than that of cattle (285 days)[26]. These reported findings on AFC and CI of domestic buffaloes are comparable with the reproductive performance of indigenous cattle under smallholder farmers' management systems in Ethiopia.

Buffaloes come into heat regularly throughout the year; however, the highest is in October and the lowest is in April[22]. Similarly, buffalo cows and bulls are capable of breeding throughout the year but they often show seasonal variations in fertility due to climatic and nutritional factors that modulate ovarian and testicular activities[16]. Buffaloes usually come into heat in cold months and are sub-fertile during hot months[22]. In spite of this, buffaloes are poly-estrus and are capable of breeding throughout the year[16]. Natural mating is still the most common breeding practice in buffaloes. The use of artificial insemination (AI) both in the swamp and the riverine buffaloes is still marginal and is less efficient. This is due to small herd size, poor heat detection and poor management. This is because buffalo's reproductive function is largely affected by environmental factors and it has physiological features that make it more similar to that of sheep than cattle[15].

**Table 1.** Crude protein (CP) percent content of commonly used crop residues in India and Ethiopia.

| Feed type | Ethiopia[45] | India[46] |
|---|---|---|
| Rice straw | – | 4.0 |
| Wheat straw | 3.9 | 3.5 |
| Teff straw | 5.2 | – |
| Finger millet straw | – | 3.7 |
| Maize stover | – | 4.6 |
| Sorghum stover | – | 4.2 |
| Barley straw | 4.7 | – |
| Natural grass hay | 6.6 | – |
| Faba bean residue | 7.2 | – |
| Field peas residue | 6.7 | – |

**Table 2.** Climatic and agro-ecological setting of India and Ethiopia.

| Variable | India[47] | Ethiopia |
|---|---|---|
| Average temperature (°C) | 12.5–30 | 16–30[48] |
| Average annual rainfall (mm) | 1000–1500 | 744[10] |
| Average humidity (%) | 49.2 | – |
| Elevation (range) | 0–8598 m asl | 125 m bsl–4543 m asl[9] |

m asl, meters above sea level; m bsl, meters below sea level.

## Production Systems of Riverine Buffalo in its Breeding Tract (Mainly India) versus Indigenous Cattle in Ethiopia

An attempt was made to compare the production systems of the riverine buffalo maintained in LDC (with special emphasis on India) with production systems maintaining indigenous cattle in Ethiopia. This comparison is made mainly on feed resource base and climatic and agro-ecological indices. The riverine-type buffalo is mainly kept by resource-poor smallholder farmers in the LDC and the same is true for indigenous cattle management in Ethiopia. Therefore, both the riverine buffalo of the LDC and the indigenous cattle of Ethiopia have evolved under fairly comparable types of management (feeding, health care and housing) systems.

### *The feed resource base*

Buffaloes have subsisted for centuries on low-quality fibrous feeds such as rice and wheat straw, which are low in their protein and energy content, and while grazing

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on natural pasturelands[43]. Moreover, in South-East Asia, buffaloes are mainly fed on cereal straws that are highly lignified and are low both in their fermentable protein and carbohydrate contents[44]. The most limiting nutrient (crude protein, CP) content of these fibrous feeds used in buffalo feed in India is comparable with the commonly used crop residues to feed cattle in Ethiopia (Table 1). It was also noted that majority of the Asian buffaloes are reared in a mixed cut and carry, tethering and grazing system on communal pastureland[44]; which also reflects the feeding systems practiced in Ethiopia. Therefore, this showed that the riverine buffalo can readily acclimatize to the feeding regime of Ethiopia's smallholder farmers who practice a fairly comparable type of feeding system.

### *Climatic condition and agro-ecological setting of India and Ethiopia*

The climatic indices in Ethiopia fall in the range of the extremes of India's climate (Table 2). Therefore the riverine buffalo can adapt to the climatic conditions of Ethiopia as it did in the Indian sub-continent. Moreover, distribution of the riverine buffalo and Zebu cattle usually overlaps in India. Thus, as Zebu has already adapted to the conditions in Ethiopia for millennia following its introduction from its presumed center of domestication (around India), the riverine buffalo is also expected to have a similar type of adaptation in Ethiopia. Ethiopia's agriculture, with the exception of the non-sedentary pastoral areas, is entirely based on a mixed type of crop–livestock farming[49]. This shows that crop production and livestock farming have co-existed as complementary farming activities for millennia[49,50]; however, competitive interaction is observed when the commonly used natural resources, such as land, are limited[50]. As indigenous cattle have been part of this mixed crop–livestock system, it is expected that, unlike deforestation and the practices of inappropriate tillage that are noted as the main causes of soil degradation[51], the proposed introduction of riverine buffalo would fit in this farming system as do cattle, with a relatively small negative effect on the natural resource base. However, improving the grazing land management and the balanced use of crop residues as a source of soil nutrient and feeds would have to be practiced to reduce the depletion of soil nutrients arising from the use of crop residues to feed buffalo and to minimize the outflow of nutrients from the soil[50]. This can be further supported by planting improved pastures and by the use of alternative energy sources such as biogas. This is because the slurry produced from biogas plants can be used as a nutrient source to improve the fertility of the soil. These types of management practices are quite important to make the rearing of riverine buffalo a sustainable farming activity. This is indeed true because sustainable agriculture, among others, must be based on the development of appropriate types of soil management practices[52].

## Performance and Adaptation of Swamp versus Riverine Buffaloes

The swamp buffalo has narrow range of adaptation compared to the riverine buffalo and, due to its very nature, it usually requires unlimited access to water to keep itself cool and is lighter in weight. The riverine buffalo, on the other hand, is heavier and its milk yield is much higher[13]. Therefore, for Ethiopia, where paddy farming is an unimportant practice, introduction of the riverine buffalo would have comparative advantages over the swamp buffalo to increase milk and meat production of the domestic herbivores.

## Conclusions and Recommendations

The diverse agro-ecological zone of Ethiopia and the wide range of adaptation of domestic buffalo showed the feasibility of introducing riverine-type buffalo into Ethiopia. Moreover, the riverine buffalo is hardy, has higher milk yield and fat content compared to indigenous cattle and, more importantly, it can thrive well on low-quality roughage. Therefore, introduction of the riverine-type buffalo has economic advantages besides introducing an additional agriculturally important livestock species. However, the reproductive behavior of buffalo is less intense than that of cattle, therefore, understanding this behavior requires thorough follow-up when buffalo cows are in heat. Moreover, maximum care should be taken before introducing the riverine-type buffalo. Thus, identification of suitable areas to establish experimental farms and training of local experts on husbandry practices by experts from countries that have extensive experience of riverine buffalo rearing are required, as recommended by Taye and Ayalew[53].

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