UNIVERSIDAD DEL ZULIA
Serbiluz
Sistema de Servicios Bibliotecarios y de Información
Biblioteca Digital
Repositorio Académico

Revista Científica, FCV-LUZ / Vol. XXXIII, Supl. Esp., 31 - 46, 2023, https://doi.org/10.52973/rcfcv-wbc002

SUSTAINABILITY OF BUFFALO FARMING IN DIFFERENT ENVIRONMENTS IN THE WORLD

Sostenibilidad de la cría de búfalos en diferentes entornos del mundo

Antonio Borghese[1], Vittoria Lucia Barile[1,2], Antonella Chiariotti[1,2]

[1]General Secretariat International Buffalo Federation, Monterotondo, Italy
[2]Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA) -Research Centre for Animal Production and Aquaculture, Monterotondo, Italy
**Corresponding author: Borghese, Antonio (antonio.borghese@email.it).*

ABSTRACT

The domestic buffalo (*Bubalus bubalis*) plays a strategic role in the world for the economy and society. 203.9 million heads on the planet represent this species and produce 137 million tons of milk and 4.3 million tons of meat (+18.7% and +8.2% increase from 2015 to 2021, respectively). Buffalo products are essential for the human requirements of proteins of high nutritional value. These requirements will increase rapidly in the future with the growth of the human population. Therefore, the buffalo has and will have more of a strategic role in Governments' economic programs in many countries. The buffalo is a long-living ruminant with a high capacity to convert fiber into energy and adapt in complex areas such as marshlands, Iraq, or Bangladesh, or in hot and humid climates where other ruminants cannot survive. Buffalo is a social and family animal in small villages in Southeast Asia, where it is used mainly in the rice fields as a draught animal producing milk essential for the children's nutrition, meat, leather, manure, horns, and bones. Thanks to its great adaptability, buffalo can be bred both in intensive and extensive systems, as in South American countries where natural pastures are highly available. In this paper, the contributions of local breeds and cosmopolitan dairy breeds to sustain protein production, maintain the land's biodiversity, and sustain the livelihood of populations are reported according to the different farming systems.

Keywords: Buffalo population, milk, meat, farming systems, sustainability.

RESUMEN

El búfalo doméstico (*Bubalus bubalis*) juega un papel estratégico en el mundo para la economía y la sociedad. 203,9 millones de cabezas en el planeta representan esta especie y producen 137 millones de toneladas de leche y 4,3 millones de toneladas de carne (aumento de +18,7% y +8,2% de 2015 a 2021, respectivamente). Los productos de búfalo son esenciales para los requerimientos humanos de proteínas de alto valor nutricional. Estos requisitos aumentarán rápidamente en el futuro con el crecimiento de la población humana. Por lo tanto, el búfalo tiene y tendrá un papel más estratégico en los programas económicos de los gobiernos de muchos países. El búfalo es un rumiante longevo con una alta capacidad para convertir la fibra en energía y adaptarse en zonas complejas como las marismas, Irak o Bangladesh, o en climas cálidos y húmedos donde otros rumiantes no pueden sobrevivir. El búfalo es un animal social y familiar en pequeñas aldeas del Sudeste Asiático, donde se utiliza principalmente en los campos de arroz como animal de tiro, produciendo leche esencial para la nutrición de los niños, carne, cuero, estiércol, cuernos y huesos. Gracias a su gran adaptabilidad, el búfalo puede criarse tanto en sistemas intensivos como extensivos, como en países sudamericanos donde los pastos naturales tienen alta disponibilidad. En este artículo, se informan las contribuciones de las razas locales y las razas lecheras cosmopolitas para sostener la producción de proteínas, mantener la biodiversidad de la tierra y sostener los medios de vida de las poblaciones de acuerdo con los diferentes sistemas agrícolas.

Palabras clave: Población de búfalos, leche, carne, sistemas agrícolas, sostenibilidad.

INTRODUCTION

The buffalo (*Bubalus bubalis*) was domesticated ~6,300 yr Before the Present (BP) in India, probably along the Indo River [1]. The buffalo is a water animal that withstands adverse weather conditions, thrives on rough food, and keeps riverbeds and wetlands clean, conditioned its diffusion in Southeast Asia countries linked to rice cultivation [2]. The buffalo can enter and work in the rice fields, particularly in the terraced areas, where mechanization cannot be applied, or cattle cannot survive.

So, buffalo spread out along the other Asian rivers, Nili and Ravi of Punjab, Gange until its delta marshlands in Bangladesh, Ping River in Thailand, Mekong in Vietnam, and Chang in China, going to East Asia in the first centuries. Buffalo moved also to the West, reaching the rivers Tigris and Euphrates and the Nile in Egypt.

In the Middle Ages, buffalo moved to Europe, South Italy along the Sele and Volturno rivers and Pontine marshlands, and the Balkan region along the Danube River.

In America, buffalo was introduced only two centuries ago in Trinidad and Tobago at the time of the English colonial empire in the wake of the Indian people. The Buffalypso breed was then created by crossing the different Indian breeds as dual-purpose animals (draught power and meat) and spread in the Caribbean area to be used in sugar cane plantation.

The richness of lands and natural pastures of the South American countries created a particular farming environment where buffalo have had an economic role in meat and milk production. Different breeds (Murrah, Italian Mediterranean, Jaffarabadi) imported mainly from Europe and Asia constituted the actual population.

In Australia, the Northern Territory was the original entry point for the Swamp and Riverine buffalo from Asia as a food supplier into the new settlements established by the British in the 1800s. Domesticated buffalo were released free-range and spread to most floodplain areas.

The buffalo population in the Americas is increasing at a 13% rate per year. South America was the first, with Brazil having around 85% of the herd and the most advanced buffalo industry, followed by Venezuela, Colombia, and Argentina as the most representative countries.

Buffalo has been in North America for many years in small numbers, but only in the last 15 years, the dairy industry has expanded.

Now, the buffalo species is represented by 203.9 million heads worldwide, 97% of which is in Asia, and plays a strategic role in the economy and society [2], producing 137 mil T of milk and 4.3 mil T of meat (TABLE I). Productions increased remarkably both for population increase and genetic improvement of herds, leading to a milk yield increase of +18.7% and meat + 8.2% from 2015 to 2021. For this reason, buffalo is part of many governmental development programs to increase the availability of high-value proteins essential for human nutrition, considering that the world population will reach more than 9 billion in 2050 [3].

Compared to other ruminants, buffalo offers advantages such as longevity - with a productive life of often more than eight lactations - a high ability to convert fiber into energy, and adaptation to challenging environments from cold to sweltering and humid climates where other ruminants cannot thrive [4,5].

Moreover, buffalo need water for thermoregulation, and wallowing represents the natural species-specific behavior.

Due to these characteristics, buffaloes can adapt to different farming systems: a) extensive management (natural pastures, i.e., in South American countries, Indonesia, Australia); b) marshlands (i.e., Iraq, Bangladesh, Amazonia); c) family farms (i.e., India, Pakistan, China, and other Asian countries); d) intensive management (i.e., Italy).

Nevertheless, adopting the best sustainable farming systems is often complex as they could result in different outcomes, favoring, in some cases, biodiversity conservation and carbon sequestration, or in some others, privileging production [9]. For example, systems based on grazing may show higher environmental performances because of the lower inputs needed for production, albeit requiring more land. However, when land use options are included in the assessment methodology, results on environmental impacts may change [10].

EXTENSIVE MANAGEMENT

The extensive farming system is based on grazing pasture. A pasture is a system characterized by having a mixed botanical composition, including plant communities in which grasses (Poaceae) are the dominant species, with dicotyledonous herbaceous species (Magnoliopsida) present in various quantities. Moreover, in tropical zones, there are associations with legumes, weeds, trees, and shrubs, in line with the agroecological conditions of the climate, soil fertility, grazing pressure, pests, and livestock needs. Improved pastures are considered to be those that have been sown from selected species [11]. For Casimir and Rao [12], a pasture is sustainable if there is a balance between the first trophic level (pastures), the consumers of the second trophic level (herbivores), and the consumers of the third trophic level (humans), where the populations densities of both plants and herbivores remain relatively constant. The consumption does not exceed the primary productivity of plants. Similarly, [13] states that a sustainable pasture should consider practices that balance production objectives with social values and ecological needs. Therefore, the last two authors approach the concept more holistically and appropriately to sustainability.

Extensive farming practices may reduce both environmental impact and costs while promoting animal welfare and quality product differentiation [14]. These practices may be

TABLE I
BUFFALO POPULATION AND PRODUCTION IN THE MOST REPRESENTATIVE COUNTRIES IN 2021 [6]

	Head (mil)	Meat (T)	Milk (T)
Asia			
India	111.786.188	1.635.507	94.383.692
Pakistan	42.416.000	1.151.000	36.445
China	27.020.479	658.163	2.905.807
Nepal	5.159.931	188.172	1.419.412
Philippines	2.849.006	64.672	36.444.850
Viet Nam	2.264.700	91.223	26.622
Myanmar	1.980.000	26.898	176.137
Bangladesh	1.500.000	6.878	35.714
Laos	1.243.959	21.843	---
Indonesia	1.189.260	20.972	91.426
Thailand	748.484	15.459	6.674
Africa			
Egypt	3.445.172	166.745	1.508.000
Americas			
Brazil	3.000.000*	---	---
Venezuela	2.800.000*	---	---
Colombia	451.783	8.265	23
Europe			
Italy	409.410	---	257.460
Bulgaria	21.690	16.580	---
Romania	18.500	---	---
Germany	11.220	---	---
Oceania			
Australia	180.000**	---	---
World	203.939.158	4.322.190	137.761.643

* Patiño et al. (2023); ** estimated by Casanova (2019)

conveniently used for species well adapted to the environment, such as buffaloes, and non-productive animal categories, such as heifers [9].

The conduction of buffalo farming on natural pasture is possible, and it also allows the reduction of several sources of pollution while reducing the production costs, hence the economic sustainability, both in terms of fixed (the barn becomes unnecessary) and variable costs (part of the feed is directly gathered from natural pasture by the animals). In addition, permanent grasslands have an essential role in climate stability, as they store nearly as much carbon as forests [15], with 0.01 - 0.3 gross tons of volume C/ year [16]. With their manure, grazing animals avoid the risk of desertification, improving soil functionality in terms of structure, organic matter content, and resilience to erosion by wind or water. When deposited directly on pastures and fields, manure does not significantly increase the amount of methane [17].

Although this system requires greater land use, it increases animal welfare and livestock sustainability and promotes landscape ecology and biodiversity conservation.

However, grazing should be streamlined appropriately to avoid excessive ecological damage caused by overgrazing, trampling, soil compaction, and excessive exploitation of water sources [18]. The causes of these impacts can be ascribed to buffalo thermoregulation habits, including wallowing in the mud, especially in periods and areas characterized by hot climates [19]. Sabia et al. [9] found that heifer free-ranging reduced water consumption and most polluting agents in the atmosphere and in water. At the category level, they observed a reduction of the impact of climate change (9%), terrestrial acidification (10%), marine eutrophication (6%), and water depletion (11%), whereas agriculture land occupation was 7% higher.

The availability of excellent land extension, rich in pasture, in some areas in Asia, Australia, and much more in Cen-

tral and South America, represented an excellent opportunity to realize a new economy based on grazing.

The extensive system for meat purposes is a historical priority in South American countries, and the richness of pasture increased the number of buffaloes bred (FIG. 1).

Brazil has the highest numbers (around 85% of the Americas' herd) and the most advanced buffalo industry. The main breeds are Murrah, Italian Mediterranean, Carabao, and Jaffarabadi. Typically, beef production has basic foodstuff from native or cultivated tropical pastures. The nutritional requirements are satisfied with the pasture rotation or through concentrates supplementation.

Silvopastoral systems are also an alternative for tropical agriculture and ranching in Amazonas to optimize land use and integrate livestock, forage species, and trees [20]. When these systems are associated with intensively rotated pastures, they have a higher productive index with a stocking rate of up to 3.2 livestock units/ha/year, providing animal shading. Moreover, the meat from silvopastoral systems tended to have a lower $\omega 6$:$\omega 3$ ratio, which is more beneficial to human health [21].

Buffalo farms in Venezuela are often large properties (from 1,000 to 10,000 hectares). However, it is also expected to observe on a small scale of raising (< 100 hectares) with a different number of animals depending upon the farm size (from 100 or less up to 22,000 heads). The management and feeding are mainly entirely grazing-based. However, it is increasingly common to observe more sophisticated feeding systems with strategic supplementation based on fodder, silage, and specialized feeding according to the animal´s nutritional requirements [22]. The main advantage of producing buffalo meat under tropical conditions is the shorter time to reach the ideal slaughtering weight (425-550 kg at 18-28 months old) compared to cattle.

The four breeds in the country are Italian Mediterranean, Murrah, Nili-Ravi, and Jaffarabadi [23].

FIGURE 1. Extensive system in South America. 1a. Buffaloes on pasture in Paraguay (Moss photo, 2022); 1b. Dairy buffaloes Mediterranean × Murrah grazing in the South Region of Maracaibo Lake, Venezuela (Gutierrez-Anez photo 2015); 1c. Buffalo reared in an extensive system in Vista Hermosa farm, Guanabacoa, Cuba (Chiariotti photo, 2022); 1d. Murrah x Buffalypso on pasture in Puchino farm, Costa Rica (Borghese photo, 2014)

Colombia is South America's second-largest exporter of buffalo dairy products and the third in population. The buffalo producers have found buffalo calf fattening a productive market, slaughtering buffalo at younger ages with an average weight of 450 kg. Buffalo plays a vital role in fruit recollection at oil palm plantations, making the recollection cost only 3% of the production cost. Since 2020, the Group of Rural and Agricultural Planification (UPRA) has found 27 million hectares, representing 71.3% of the national agricultural area, apt to produce grazing buffaloes [24].

The Northeast region of **Argentina** (NEA) concentrates 85% of the total buffalo population due to pasture characteristics, availability, and the convenience of rearing buffalo compared to cattle. They quickly reach 220 kg in 8 months, 480 kg in 24 months, and 550 kg in 27-30 months, reaching the slaughtering weight one year earlier than cattle and improving the carcass quality. The suckling (or baby) buffalo of 11 months with 250 – 300 kg of weight has good market niches in the medium cities of NEA [25].

In **Bolivia**, the buffalo was introduced recently, particularly in the Cochabamba region, to produce food (meat and milk) for the local market [26]. The breed comprises 70% Italian Mediterranean and 30% of its cross with Murrah. The University of San Simon in Cochabamba began a project for conservation and preservation with an agroecological approach to a grass and pasture rotation system. At 18 months, the average live weight for males is 390 kg, and for females is 383 kg. The most docile water buffalo cows are selected for milking. They milk 2 Liters daily with the calf present and leave the rest for the calf. Small farms are encouraged to implement water buffalo projects in areas since this species is adaptable to the rustic environment and natural grassland, producing meat and milk [27].

Mexico started to import buffalo in 1990; most of the Mexican population is found in the tropics and subtropics in the south of the country (Veracruz, Tabasco, Campeche, Chiapas), with almost permanent average temperatures of 34 to 36°C and rainfall of 1,800 to 2,000 mm annual. In this region (in the natural field), an average daily gain of 600 grams in live weight is achieved, reaching 450 kilos at 28 months of age. In addition, an average production of 5-6 liters of milk per day is obtained [28].

In **Paraguay**, buffalo were introduced almost 70 years ago, utilizing large pastures. In extensive conditions, herds often had little human contact without proper management, so the animals became feral, and this explains the relatively small herd despite all its benefits. Of the 267 small, medium, and large producers dedicated to raising buffalo in the country, 80% are doing so, mostly in marginal, challenging low, and wetlands. Their grazing in set-aside areas helps reduce fuel load and fire intensity [29].

In Central American countries such as Costa Rica, Trinidad and Tobago, and Cuba, the buffalo is reared on pastures, and the most representative breed is Buffalypso.

In Cuba, the Cuban Buffalypso performs better than the Carabao and the local cattle. The feeding is based on autochthonous species in natural meadows, such as paraná, jiribilla, perilla, moringa, and small areas of introduced grasses, such as Angola and coastal bermudagrass. In the less rainy season, the buffalo are fed king grass forage. Feeding with unimproved natural pastures and inefficient supplementation cause poor milk and meat production. The future perspective is to increase production volumes by having more milking buffaloes organized in small herds, with better care in all animal husbandry areas and related economic systems [30].

In Asia, particularly in **India** and the **Southeast**, even if the majority is family farming, extensive management can be found (FIG. 2). It is characterized by small farms, with buffaloes maintained on natural grasses on community lands, supplemented with agricultural by-products using family labor and traditional technology. The silvopastoral is the most economical management system, provided adequate fodder resources are available for grazing, and it ensures the possibility for animals to move around and graze on a wide variety of plant species. However, only some of the pastures provide the necessary nutritional requirements. Forage production during the dry season could be low and scarce, causing animal feed competition. Due to a lack of space for adequate grazing, farmers tend to take their small herd of animals to the open farmland or orchard and tie them with a long rope to facilitate spot grazing for a short period [31].

In **Sri Lanka,** more than 70% of the buffaloes are reared in extensive systems in the country's dry and dry intermediate zones. The local Sri Lankan breeds produce 1-2 liters of milk per day in a short lactation period of 3–5 months due to the poor quality of fodder [32]. Buffaloes are primarily used as a source of draught power and to obtain an income from selling fresh and processed milk as curd. A semi-intensive system is practiced in the wet intermediate zone, wet zone, and some parts of the coconut triangle [33].

In Australia, the only native pasture with reasonable carrying capacity in the native state is the coastal floodplain system, where there is a satisfactory phosphorus level in the soil and where there are species, such as Native Hymenachne, with very high protein content. Pasture-feeding livestock in the wet season is usually fine due to the abundant rainfall and good pasture growth. The main requirement is the use of fertilizer and improved pasture species. Besides, native pastures are generally of much lower feed quality and have much lower carrying capacity. Grasses and legumes both have an integral place [34]. Nowadays, the buffalo in southern Australia are Riverine bred for dairy purposes, in 12 dairy and 3000 heads [35]. Australian milk yields are variable; a purebred could produce an average between 5 and 15 liters/day (with twice daily milking) over the entire lactation [34,36]. In the more southern regions of Australia, it is essential to shelter the animals from the cold, particularly for the Swamp buffalo, as they are less

FIGURE 2. Extensive system in Southeast Asia. 2a. Bangladeshi buffaloes in Jamalpur District in an extensive system during the dry season (Borghese photo, 2012); 2b. Swamp buffaloes on pasture in West Sumatra (Borghese photo, 2008); 2c. Local buffalo in the extensive system in Sri Lanka (Borghese photo, 2000); 2d swamp buffalo in Thailand (Chiariotti photo, 2014)

tolerant to cold compared to the Riverine, which has a heavier coat of hair that grows with exposure to cold [34].

According to Motta et al. [11] definition, "a sustainable pasture is an anthropized ecosystem that must provide livelihoods, produce benefits to the soil and plants, as well as well-being to animals and to the family, from the use and rational management of the soil to allow nutrient recycling and avoid its biological degradation, for the supply of plant and animal products in stable volumes over time with appropriate management practices (Voisin rational grazing) and, at the same time, conserve or improve natural resources for present and future generations, ensuring the livelihood and well-being of the family".

BUFFALO FARMING IN MARSHLANDS

The world has an estimated 7 to 9 million km^2 of marshlands which are characterized by their hydrology, physiochemical environment, and biota [37].

They play a key role in the development of life on Earth and have been critical to the survival of human communities throughout history. These ecosystems have important ecological functions such as water supply, flood control, groundwater restoration, sediment retention, climate change mitigation, and water purification [38]. However, large amounts of senescent vegetation and dry biomass accumulate without productive use, causing problems, and the nearby rural population experiences poverty and limited human development.

Thanks to its anatomical and physiological characteristics, the water buffalo can be used for grazing in marshlands and managing vegetation in tropical and subtropical wetlands. It can move easily in humid and muddy terrain, where cows and other livestock will not. It removes the biomass and cleans the riverbeds, allowing the regeneration of plants, seeds, and tiny organisms, food sources for aquatic birds. So, buffalo helps significantly increase biodiversity and species abundance in the wetlands. In these environmental conditions, buffalo may produce milk and meat of high nutritional value, making the

FIGURE 3. Buffalo farming in the marshlands. 3a. Papangan buffaloes in the marshes of South Sumatra (Borghese photo, 2008); 3b 3c. Mesopotamian buffalo in the Iraqi Marshlands (Borghese photo, 2019); 3d. Buffaloes living in Colombia lagoons (Roldan photo, 2006)

marshland farming system an exciting habitat conservation model and a strategy against climate change [39].

This type of buffalo farming is present in different regions of the world. The **Iraqi** marshlands are the most significant wetland ecosystem of Western Eurasia, a rare example of aquatic landscape in the desert, a unique habitat for endemic buffalo, and endangered animal and vegetal species. Buffaloes are bred in the marshes along the Tigris and Euphrates rivers, particularly in the Marshi region up to the confluence with the Persian Gulf. Buffaloes of the Mesopotamian breed have been living there since the second millennium B.C., as testified by archaeological remains discovered in Ur [40]. From that time, Mesopotamian buffaloes swam for feed, eating papyrus, reeds, and other autochthonous plants. When the flood is high, these plants are collected by breeders to feed buffaloes on platforms. Buffalo is the fundament for food security and livelihood for the Maadan population living on the little isles in the Iraqi marshlands in primitive reed huts. Women play a pivotal role in producing, processing, and marketing dairy products.

Another wide marshland area in Asia is located in the Gange River delta in **Bangladesh** in the Bathan saline coastal region. The coastal region covers about 20% of the country, representing over one-third of the cultivable lands. About half of the coastal areas are affected by salinity, which causes unfavorable environments and hydrological situations that restrict normal crop production throughout the year. Agricultural land use in these areas is very poor, much lower than a country's average cropping intensity. Here, Swamp and River buffalo live in the same situation as Iraqi marshlands.

Coastal wetlands in **Indonesia** have a high potential for global climate change mitigation, for they have considerable capacities to store carbon compared to similar ecosystems globally. However, coastal wetlands in Indonesia potentially sustain significant loss due to inundation following the upcoming rapid sea level rise and land use change and conversion following rapid population growth in the coastal areas [41]. Shrimp farms have cleared large tracts of mangroves and coral reefs along the coastal and marine environment. These areas, such as around the North Coast of Java, are vulnerable to storms, tidal waves, and coastal erosion. This vulnerability will only increase with a changing climate, leading to storm surges and sea-level rise. In addition to aquaculture, urban development, pollution, over-harvesting of wood in the coastal forests, and

destructive fishing contribute to the destruction and degradation of mangrove forests [41].

In the province of South Sumatra (Papangan Subdistrict), there is a marshland coastal area with very hot and wet weather, with high dampness during the humid season, where Kerbau Papangan, a local Swamp breed, survives grazing autochthonous grass (kumpai copper, kumpai paddy, bento creep, parum). The dairy buffalo cows come to the islands to be hand-milked once daily.

Another example of marshland farming is in **Amazonia**, a wide area attractive, particularly Brazil, Colombia, and Venezuela, covered by immense rivers: Rio Amazonas, Rio Negro, Orinoco, Japurà, and others.

On Marajo Island of Rio Amazonas, there were about 500,000 buffaloes living free in the marshland area, flooded during the rainy season and very rich in water plants during the dry season, creating a unique resource for feeding. Nowadays, following the progressive decrease of the buffalo population, there is a need for governmental actions to protect the environment, taking into account the socioeconomic impact of this type of buffalo farming system for the indigenous population [42]

In **Colombia,** Buffalypso was the first buffalo breed introduced from Trinidad and Tobago and used mainly for draught power in marshland areas where cattle could not be reared. Buffalo is suitable for work in plantations due to its broad articulation in the hoofs, especially during the rainy period, when the soil becomes muddy, causing difficult mobility for other species. For this characteristic, the buffalo became the best draught power animal option for oil palm harvest in the tropics [43]. Later, numerous Murrah and Italian Mediterranean buffaloes were imported from Venezuela and Brazil for semi-intensive management to exploit the meat and milk production sector [24].

In **Paraguay**, there is about 23% of marshland areas. The largest are the Pantanal Paraguay, the Lagunas del Chaco Central, the Lagunas del Chaco Húmedo, the wetlands at the foot of the Cerrados, those belonging to the Arroyos y Esteros wetlands, those of the Atlantic Forest, the Ñeembucú wetland [38]. Of the 267 small, medium, and large buffalo farms, 80% operate in marginal, challenging wetland areas [44]. Due to the relationship between wetlands and buffalo, the latter can be considered a tool for regenerative and sustainable livestock farming in Paraguay. The remarkable capacity of the buffalo to convert fiber into energy is very important in this area, wherein in the estuaries, there is an abundant supply of crude fiber, such as reeds and grasslands. These forages, which cattle do not consume, allow the buffalo to obtain astonishing rates of daily gain. The buffalo is an exciting alternative for the wetlands of the Paraná Delta [29].

The Lower Paraná Delta in northern **Argentina** is a vast, forested marshland and an estuary with great natural values. Fish and birds have their breeding grounds around the many islands and wetlands. At the same time, deforestation is occurring on a large scale, and urban development is spreading uncontrollably. The buffalo species are adapted to live in wetlands, and by adjusting the loads and managing the receptivity of the environment, it is possible to achieve sustainable buffalo production. Its rusticity, combined with rational management systems, alternating trampling with rest periods, stimulates plant and soil regeneration, promoting biodiversity and carbon sequestration [45]. In the summer, buffaloes are constantly submerged in the estuaries, feeding on water hyacinths and other aquatic plants. During the winter, with the low temperatures, the animals generally seek higher areas, sheltered from the cold and grazing on the natural vegetation of the hills.

In the marshlands, there are livestock management recommendations for the maintenance of water quality that include avoiding the accumulation of excreta and feces in bodies of water and no use of herbicides in bodies of water to eliminate plants. Also, reducing landscape modifications that affect the hydrological regime and water quality, such as the construction of dams or canals, is important, as well as rotating livestock distribution areas to minimize nutrient input and use veterinary products rationally, given their impact on the environment and water quality.

FAMILY FARM

According to the International Steering Committee for the 2014 IYFF, “Family Farming (which includes all family-based agricultural activities) is a means of organizing agricultural, forestry, fisheries, pastoral and aquaculture production which is managed and operated by a family and predominantly reliant on family labor, including both women’s and men’s. The family and the farm are linked, co-evolve, and combine economic, environmental, social, and cultural functions” [46].

Family farms, therefore, affect sustainable development, people, and the planet. An individual or a family runs more than 90% of farms, and women provide almost 50% of farm labor, holding less than 15% of farmland. Family farms produce more than 80% of the food in the world, managing around 70-80% of farmland worldwide. In short, they create employment, help expand rural economies, prevent depopulation and support the area, preserve biodiversity and ecosystems, and help reduce climate change risks [47].

There are some general problems in the family farming husbandry practices in many developing countries, such as no housing system, no artificial insemination system, no routine vaccination program, and no animal identification and recording system. In smallholder production, it is important to integrate genetic improvement programs with other livestock development activities such as health cover, nutrition, management, and access to output markets.

In **Iran** the buffalo farming system is based on smallholders (99%), and most buffaloes are raised in traditional rural farms with a herd size of 10 to 30 buffaloes. In spring and

FIGURE 4. Family farms. 4 a,b. Family buffalo in a rural village in Haryana, India (Chiariotti photo, 2018); 4c. Family buffalo in Chitwan, Nepal (Moioli photo, 2017); 4d Woman preparing buffalo dung cake (Pathee) in a small village in Haryana, India (Chiariotti photo, 2018)

summer, simultaneous with rice cultivation, buffaloes are transferred for their nutrition to fenced and exclusion rangelands and summer grazing areas, which are covered with hircany forests. In autumn and winter, they are kept in closed housing and are hand-fed with roughages such as rice stem, rice bran, and wheat bran [48]. The feeding stuffs are straw, alfalfa, and sugar cane pulp. The desert is irrigated and produces sugar cane and dates.

In **Bangladesh,** 95% of dairy buffaloes are reared under the transhumant system. Production is usually based on a small herd of mixed ages and sexes at the rural level, generally for draught and breeding purposes. Buffaloes are sheltered at night and graze for roughage together with other animals. Grazing and browsing ranges over practically all village lands during the dry season but is restricted to upland non-cropped areas during the rainy season. Sometimes, they graze on roads and other aquatic herbage [33].

In **Nepal**, most households raise at least one buffalo for milk and manure production and sell male calves or mature males for family income. In road-accessible areas, buffaloes are the main contributor to urban milk supply. Nepal's indigenous buffalo River breeds are Terai, Gaddi, Lime, and Parkote, and exotic breeds are Murrah and other Indian breeds. Native breed productions are inferior; however, their adaptability is better [49]. Lime and Parkote live on the country's hills and mountains, producing about 900 kg of milk yield per lactation. These purebreds will be reduced as crossbreeding with Murrah is applied to increase the milk yield, reaching 1500 kg per lactation [50]. Fodder tree leaves in mountains and hills, grasses, legumes, straw, stover, and other agro byproducts are the primary feeding resources in Nepal.

In **Sri Lanka,** the buffalo population is integral to mixed farming enterprises and rural life. More than 90% of the local indigenous breed and their crosses are found in small holdings (0.8 ha in extent). A limited number of Murrah, Surti, and Nili-Ravi breeds are maintained in large farms to serve as breeding stock and improve local animals. The average herd size of the country is approximately 20-25 animals but can

vary with different agroecological zones, feeding resources, climate cropping patterns, and production systems. Buffaloes are allowed to graze on the naturally available forage during the daytime and paddock housed in the nighttime. Buffaloes are primarily used as a source of draught power and to obtain an income from selling fresh or processed milk as curd. In Sri Lanka, raising buffaloes for meat is not practiced [32]

China has the third-largest buffalo population in the world. Chinese buffalo belong to the Swamp type, with 18 local breeds. They are strong animals mainly used for draught in the marshlands, particularly in rice fields, as a family animal, similar to **Thailand**, **Vietnam**, **Laos**, **Malaysia**, and the **Philippines**. They are also a source of meat, but their milk production is deficient (500-700 kg milk yield for lactation on average) and used in family and local economy. Murrah buffalo arrived in China from India in the late 1950s, while Nili-Ravi arrived from Pakistan twenty years later.

In **India** and **Pakistan**, most dairy farms are small holdings practicing subsistence farming; however, several larger farms are expanding and generating growth in the dairy sector, which is highly significant in the country's economy.

Employment generation for rural people, particularly women; nutritional security for the majority vegetarian population with high-quality milk and resistance to the prevalent infectious diseases make buffalo a livestock species of national importance in **India**. The production systems are based, for the most part, on small farms that maintain 1 to 3 buffaloes with crop residues and limited yields and tie their buffaloes at night in small shelters, which are made of mud or thatched walls and thatched or tin roofs for protection from rain and wind [31].

Under the rural subsistence smallholder production system, which is most common in **Pakistan**, milk is produced for the family at minimal cost. The Nili-Ravi produces 1000-3000 kg of milk and swamp-type 600 kg [51]. Grazing provides over 60% of the animals' feed requirements. Some roughages and a small quantity of concentrate are given only to milking animals. This traditional system is heavily labor-consuming.

Egypt is the leading African country with an economy based on buffalo farming of 3.9 million head [52], the highest population in the Mediterranean area. Egyptian buffalo is not only considered a vital genetic resource with great potential for milk and meat production but also the main dairy animal raised by small Egyptian farmers [53]. Buffalo milk represents 45-50% of Egyptian milk, with an average milk yield of up to 2,500 kg in 305 days of lactation [54]. 80% of all farms have less than two feddans (0.420), and small Egyptian farmers prefer buffalo since they can use lower quality and less digestible feeds. The locally available feeds include clover, corn silage, rice straw, clover hay, concentrates feed mixtures, and other plant residues. A notable decrease in the buffalo population in the lower and middle regions was due to the drought and desertification in rural and semi-rural areas [55]. The supply of milk increases in winter due to the availability of green fodders. More than 69% of farms tend to practice meat production along with milk production. Women share important activities such as milking, calf rearing, and interrelated activities [56].

INTENSIVE FARMING

Agricultural intensification is the increased production of agricultural commodities per unit of inputs, such as labor, land use, fertilizer, time, feed, animals, or cash [57]. As land is the ultimate limiting input for agricultural production, agricultural intensification is often defined as increased production per unit of land area [58].

The main drivers for livestock intensification are population growth, an increase in gross domestic product (GDP), urbanization, and the globalization of the markets, which increased demand for animal products. This caused the development of the livestock sector towards product intensification and changes in branch industries and transportation, mainly in developed countries. Intensification per cow was primarily due to a better feed conversion ratio, while intensification per ha was due to increased production per cow, lower culling and replacement rates of cows, and increased forage and crop yields per ha [59]. Dairy system intensification invariably leads to higher impacts per ha of land occupied due to the higher proportion of maize silage and concentrate feed in the diet, which entails increased use of inputs, so combining environmental impacts and productivity is difficult [60].

Buffaloes reared in intensive systems are handled according to the same or comparable management routines of cattle (FIG. 5). However, these conditions cause animals new stressors generated by new technologies such as artificial rearing of calves and reduced space. Space restriction can adversely affect health, social behavior, and heat dissipation, particularly without access to pasture and water for wallowing [14].

For this reason, ensuring the buffalo's welfare in intensive systems is a pivotal goal, providing the possibility to express species-specific behavior and might positively affect product quality. In addition, the sustainability and welfare of the animals may also affect consumer liking [61].

Some advanced techniques are being developed to increase the sustainability of intensive management, such as intelligent farming (FIG. 6). The smart farming system is a new concept in the agricultural field and refers to managing farms using technologies like sensors, software, data analysis, communication systems, that enable farmers to give plants/animals the precise treatment that they need. Regarding livestock, most of these technologies are utilized in the dairy cattle sector, where the use of automated and robotic devices is increasing rapidly. In buffalo ear tags, sensor systems for recording activity, resting, rumination, and temperature at ear level are tested to get information on health, nutrition, and reproduction [62].

FIGURE 5. Intensive systems in Asia. 5a, intensive farm of ICAR, Haryana, India (Chiariotti photo, 2018); 5b. Traditional intensive system in India with tie-stall (Chiariotti photo, 2018); 5c, Intensive system in Egypt (Barile photo, 2019); 5d. Intensive system in CREA Research center, Roma, Italy (Barile photo, 2023))

In **Italy**, buffalo farming has been conducted for centuries in extensive conditions based on marshland environments. In the last forty years, the increasing demand for mozzarella cheese induced a proportional increase in the number of buffaloes, mainly located in central-southern Italy. Therefore, buffalo farming has shifted to a more intensive farming system based on three different feeding regimens corresponding to the three main buffalo productive stages (lactating cows, dry cows, and growing heifers [63] with limited access to pasture and water for wallowing. Such management changes concerned all animal categories (including juvenile and heifers) that do not need milking facilities and feeding supplementation.

Due to the high commercial value of buffalo milk, calves are separated from the dams at birth and reared artificially. Calves are weaned at 90/100 kg, around three months of age. Lactating buffalo cows are housed in paddocks. They are fed a total mixed ration (composed of maize or sorghum silage, concentrates, hay, straw, and sometimes agricultural by-products). The average milk production is over 2,350 kg for lactation up to over 5,600 kg milk/270 days of lactation and 8.32% fat and 4.63% protein [64]. Male buffaloes are reared as young bulls in intensive systems for the meat market. Usually, the live weight at slaughter is 400-440 kg obtained at 15-16 months of age with 800-1000 g of daily gain [5]. According to the Italian market requirements, young bulls have good quality carcasses and medium fattening (57% dressing percentage, 62% meat on carcass) [65]. A good pasture system could be adopted for reared heifers, reducing the production costs (i.e., management and feedstuffs) and increasing the sustainability of the breeding system. In Italy, numerous farms produce renewable energy from manure and sludge in co-digestion with agricultural waste such as cheese whey and tomato pomace in biogas plants (FIG. 7). The process residue, so-called digestate, is used as organic fertilizer.

In **Asia**, an intensive management system is practiced in the urban, peri-urban areas where the demand for milk and

FIGURE 6. Italian Mediterranean buffaloes in an intensive system with modern technologies for animal welfare. 6a. Wide space, rubber mats, and brushes in Vannulo farm, Salerno, Italy (Barile photo, 2023); 6b. Milking robot unit in Vannulo farm, Salerno, Italy (Barile photo,2023); 6 c, d. Calf management in an intensive system in Garofalo Farm, Caserta, Italy (Chiariotti photo, 2023)

dairy products is high and constantly growing due to the increasing urbanization.

Indian rarmers who own high-yielding buffaloes try to grow or buy fodder to ensure higher production. Fodder cultivation can be more remunerative than many cash crops if the cows and buffaloes fed are high yielders. India is highly advanced in buffalo nutrition, production, reproduction, biotechnologies and genetic improvement, and scientific and technological development. The country possesses 13 recognized breeds, plus 20 different River and Swamp types populations. The main River dairy breeds are Nili-Ravi, Bhadawari, Pandharpuri, Surti, Jaffarabadi, and particularly Murrah, which is the most widespread breed in India and the world (2500 kg per lactation on average) [66]

The herd has up to 100 buffaloes in the intensive system, mainly in Haryana, Punjab, Uttar Pradesh, Rajasthan, Gujarat, and peri-urban areas. There is also a semi-intensive system of 3 to 5 buffaloes maintained with fodder produced under irrigation, crop by-products, concentrates, improved housing, and care.

Pakistan is the second country in the world after India for buffalo heads. In Pakistan, only River buffaloes are found, mainly dairy, of the Nili-Ravi breed, with an average milk yield of 2300 and a maximum of 3500 kg/lactation in the rice-wheat zone of Punjab, and the Kundhi breed, having a smaller body size, with an average milk yield of 2100 kg/lactation up to 2600 in the wealthiest areas [67]. Therefore, the buffalo's role in Pakistan's milk production system and food availability is pivotal. Peri-urban commercial dairy farms are around all big cities, the largest being at the Landhi Cattle Colony, located in the suburbs of Karachi, where more than 400,000 milking animals (around 95% are buffaloes) are kept. It has about 1,500 farms spread around 650 ha, with a daily yield of about four million liters of milk and 7,200 T of dung, making it the world's largest

FIGURE 7. Biogas plant for green energy production at Roana farm, Latina, Italy (Photo Barile, 2023)

dairy colony. Individual farmers often own up to 200 animals each [68]

FUTURE PERSPECTIVES

Sustainable livestock farming must consider various economic and social factors, including food security, poverty alleviation, mitigation strategies, and social and cultural value preservation. This could only be achieved through policy initiatives, enabling discussion with all stakeholders involved in the supply chain. Climate change impacts will need special attention through adopting sustainable agricultural practices, better utilization of local feed resources, and enrichment of its nutritional values, considering land and water shortage.

Buffalo, with its genetic diversity and adaptability to different environments, from cold climates to hot, humid ones and wetlands, where other ruminants could not thrive, could help achieve some Agenda 2030 Sustainable Development Goals [69].

Pastures are anthropogenic ecosystems that offer low-cost food resources mainly for feeding ruminants, buffalo in particular, being the ground for production and livelihoods in many rural areas worldwide. More intensive buffalo meat and milk production on pasture has proven to be sustainable if rational grazing is applied. In environmental terms, it can help reduce the pressure of deforestation to increase new areas for cultivation, water depletion, fertilization, and pesticide inputs to fulfill plants' needs. Crop-livestock-forest integration systems, including silvopastoral ones, will gain relevance in the future and help reclaim agricultural areas altered by inappropriate previous use. It could add value to the land, enabling better nutrient cycling or animal welfare due to natural shading or to the environment because the presence of trees also acts as a carbon sink.

Thanks to its anatomical and physiological characteristics, the buffalo is the only ruminant that can be reared in wetlands and produce milk and meat of high nutritional value, making the marshland farming system an exciting model for habitat conservation. So, it helps increase biodiversity and the livelihood of the local population.

The family farming system spread particularly in Southeast Asia, has a pivotal role in sustaining people's livelihood due to the local buffalo breeds, some of which are endangered. Those should be maintained because they are the most adapted to low-input production systems and a specific environment, producing food with unique properties.

Future advancements in smart technologies hold great promise, especially in intensive production systems; adapting to individual animals' needs will help reduce the inputs and improve animal welfare.

The livestock production systems are strictly linked to sustainability, welfare, and quality of products, and new tech-

nologies and education will play a pivotal role in facing the challenges of climate change.

ACKNOWLEDGMENT

We are grateful to Dr Emanuela Rossi for the efforts she provided to complete the editing of the work

REFERENCES

[1] Minervino AHH, Zava M, Vecchio D, Borghese A. Bubalus bubalis: A short story. Frontiers in Veterinary Science. 2020; 7. https://doi.org/10.3389/fvets.2020.570413.

[2] Borghese A, Chiariotti A, Barile VL. Chapter entitled "Buffalo in the World: Situation and Perspectives in: Springer's edited book Manmohan Singh Chauhan and Naresh Selokar (Eds): Biotechnological Applications in Buffalo Research. 2022; 16:978-981. ISBN, 978-981-16-7531-7.

[3] United Nations – Department of Economic and Social Affairs. The Sustainable Development Goals Report 2018.

[4] Borghese A Buffalo Production and Research. FAO Ed. REU, Roma, Italy. Technical Series 2005; 67:1-315.

[5] Borghese A Buffalo Livestock and Products. A. Borghese and CRA (Council of Research in Agriculture) (Eds), Rome, Italy 2013; 1-511

[6] FAOSTAT, 2023. https://www.fao.org/faostat/en/#data.

[7] Patiño EM, Crudeli GA, Coronel Sicairos I. Buffaloes in America: Current Status and Future Challanges of Buffalo Production Post-centenary of its Introduction in Venezuela. Buffalo Newsletter. 2017; 39:16-21.

[8] Casanova S. Top End Buffalo Population estimates. Paper presented to 2019 Territory NRM conference. 2019. https://www.abc.net.au/news/rural/2019-11-21/nt-buffalo-population-on-therise/11713352

[9] Sabia E, Napolitano F, Claps S, De Rosa G, Barile VL, Braghieri A, et al. Environmental impact of dairy buffalo heifers kept on pasture or in confinement. Elsevier Agricultural System. 2018; 159(c):42-49. https://doi.10.1016/j.agsy.2017.10.010.

[10] Thomassen MA, Van Calker K.J, Smits MCJ, Iepema GL, De Boer IJM. Life cycle assessment of conventional and organic milk production in The Netherlands. Agric. Syst 2008; 96(1-3):95-107. https://doi.org/10.1016/j.agsy.2007.06.001.

[11] Motta-Delgado PA, Ocaña Martínez HE, Rojas-Vargas EP. Indicators associated to pastures sustainability: a review. Ciencia y Tecnología Agropecuaria. 2019 August; 20(2):387-430.

[12] Casimir M, Rao A. Sustainable herd management and the tragedy of no Man´s Land: an analysis of west Himalayan pastures using remote sensing techniques. Human Ecology. 1998; 26(1):113-134. doi:10.1023/A:1018701001793.

[13] Sherren K, Fischer J, Clayton H, Schirmer J, Dovers S. Integration by case, place and process: transdisciplinary research for sustainable grazing in the Lachlan River catchment, Australia. Landscape Ecology. 2010; 25(8): 1219-1230. doi:10.1007/s10980-010-9494-x.

[14] Napolitano F, Pacelli C, Grasso F, Braghieri A, De Rosa G, 2013. The behaviour and welfare of buffaloes (Bubalus bubalis) in modern dairy enterprises. Animal. 2013; 7:1704-1713.

[15] EIP-AGRI Focus Group Profitability of permanent grassland. How to manage permanent grassland in a way that combines profitability, carbon sequestration, and biodiversity? Starting Paper Koldo Osoro. 2014 28th May.

[16] Lal R. Soil carbon sequestration impacts on global climate change and food security. Science. 2004; 304:1623-1627.

[17] Bernués A, Ruiz R, Olaizola A, Villalba D, Casasús I. Sustainability of pasture-based livestock farming systems in the European Mediterranean context: Synergies and Trade-offs. Livestock Science. 2011; 139:44-57.

[18] Hoogesteijn R, Hoogesteijn A. Conflicts between cattle ranching and large predators in Venezuela: Could use of water buffalo facilitate felid conservation? Oryx.2008; 42:132-8. https://doi.org/10.1017/S0030605308001105

[19] Mora-Medina P, Napolitano F, Mota-Rojas D, Berdugo Gutiérrez Ruiz-Buitrago J, Guerrero-Legarreta I. Imprinting, sucking and allosucking behaviors in buffalo calves. J Buffalo Sci 2018; 7: 49-57. https://doi.org/10.6000/1927-520X.2018.07.03.3

[20] da Silva JA, Garcia AR, de Almeida AM, Bezerra AS, de Brito Lourenco Junior J. Water buffalo production in the Brazilian Amazon Basin: A review. Tropical Animal Health and Production. 2021 Jul; 53(3):343

[21] Joele MR, Lourenço LF, Lourenço Júnior JB, Araújo GS, Budel JC, Garcia AR. Meat quality of buffaloes finished in traditional or silvopastoral system in the Brazilian Eastern Amazon. Journal of the Science of Food and Agriculture. 2017 Apr; 97(6):1740-5.

[22] Gutiérrez-Añez JC. Current status and future challenges of buffalo production post-centenary of its introduction in Venezuela. Buffalo Newsletter. 2019; 35:29-36.

[23] Cuéllar Yáñez. Buffalo in Venezuela. Buffalo Newletter. 2021; 37:28-30.

[24] Suarez A L. Buffalo in Colombia. Buffalo Newsletter. 2021; 37:27-28.

[25] Zava M. Present situation and future perspective of buffalo production in America. The J of Anim and Plant Sci. 2012; 22(3):262-269. ISSN/ISBN: 1018-7081.

[26] Chacón Condori E. Buffalo´s production in Bolivia. Buffalo Newsletter. 2019; 35:10-13.

[27] Skorc L. Buffalo in Bolivia. Buffalo Newsletter. 2021; 37:24-26.

[28] Zava M. Búfalos: México será sede de un encuentro global de productores. Sitio Argentino de Producción Animal. 2017 https://www.produccion-animal.com.ar/informacion_tecnica/razas_de_bufalos/126-Bufalos-Mexico.pdf

[29] Moss Ferreira R, Patiño EM. Buffaloes in Paraguay: Past, Present and Future. Buffalo Newsletter. 2022; 38:3-9.

[30] Mitat VA. Cuban Buffalo Production. Buffalo Newsletter. 2022; 39:25-32.

[31] Hegde NG. Buffalo husbandry for sustainable development of small farmers in India and other developing countries. Asian Journal of Research in Animal and Veterinary Sciences. 2019 Mar 18; 3(1):1-20.

[32] Seresinhe Thakshala. Buffalo production systems and the role of buffalo in Sri Lanka. Buffalo Newsletter. 2018; 33:13-14.

[33] Habib KA, Kim CG, Oh J, Neogi AK, Lee YH. Aquatic Biodiversity of Sundarbans, Bangladesh. Korea Institute of Ocean Science and Technology (KIOST). 2017; 394.

[34] Lemke B. The Australian water buffalo manual. Department of Primary Industry and Resources. 2017:43-50.

[35] Agrifutures 2021-2025. https://agrifutures.com.au/wp-content/uploads/2021/03/21-004.pdf.

[36] Suarez A L. Buffalo in Colombia. Buffalo Newsletter. 2021; 37:27-28

[37] Mitsch WJ. Applying science to conservation and restoration of the world's wetlands. Water Science and Technology. 2005 Apr 1st; 51(8):13-26.

[38] Secretaría del Ambiente (SEAM) y Programa Marco para la Gestión Sostenible de los Recursos Hídricos de la Cuenca del Plata en relación con los efectos de la variabilidad y el cambio climático (PMCIC-PLATA. Inventario de humedales del Paraguay. OEA Contrato. 2015; 1º Edición Nº 366: 127.

[39] Barboza Jiménez G. El búfalo en la rehabilitación de humedales: finca las delicias en Guanacaste, pacifico norte de Costa Rica." Revista CES Medicina Veterinaria y Zootecnia. 2016; 11(3):124.

[40] Al-Fartosi K, Al-Saedy JK. Mesopotamian buffalo: home-tract and challenges. Proceed. Intern. Buffalo Congress, Lahore, Pakistan. J. Vet. Animal Sci. 2019; 6:1-13.

[41] Hapsari KA, Biagioni S, Jennerjahn TC, Reimer P, Saad A, Sabiham S, Behling H. Resilience of a peatland in Central Sumatra, Indonesia to past anthropogenic disturbance: Improving conservation and restoration designs using palaeoecology. Journal of Ecology. 2018 Nov; 106(6):2473-90.

[42] Vale WG, Ribeiro HFL, Barbosa LAL, Rolim Filho ST, Neves KAL, Silva AOA, Lima WF. Forty years fo buffalo artificial insemination in the Amazon Valley, Brazil – An Historical Retrospective. Buffalo Newsletter. 2022; 38:9-20.

[43] Cortés RH. El uso del búfalo en la cosecha de palma africana. IIIrd American Buffalo Symposium, Medellín, Colombia. 2006 September 6th-8th.

[44] Frutos, L. (2021) Producción de búfalos crece 25% al año (criadores están comercializando carne, hamburguesas, embutidos, quesos y leche). Infonegocioshttps://infonegocios.com.py/infoganaderia/produccion-de-bufalos-crece-25-al-ano-criadores-estan-comercializando-carne-hamburguesas-embutidos-quesos-y-leche

[45] Travaini, A.; Astrada, E.; Cadoppi,A. Búfalos de agua (*Bubalus bubalis*) en el Delta del Rio Paraná. Serie Ganadera en Humedales. Programa Corredor Azul. Fundación Humedales./Wetlands International. Bs. As. Argentina. Rubén D. Quintana Editor.2019:1-28. ISBN 978-987-29811-7-4.

[46] FAO 2013. https://www.fao.org/news/archive/news-by-date/2013/it/.

[47] World Family Forum. 2019. https://www.fao.org/news-room/detail/global-forum-of-the-un-decade-of-family-farming-2019-2028-begins/en

[48] Derisavi F. Introduction of excellent Nikookar Buffalo Farm in Gilan province. Buffalo Newsletter. 2021; 37:9-12.

[49] Devkota B (2018) Overview of Buffalo Development in Nepal. Buffalo Newsletter. 2018; 33:11-13.

[50] Nirmal BK, Devkota B, Shrestha S et al. Nepal country report on buffalo production system. In: Book of abstract 9th Asian Buffalo Congress Hisar, India. 2018 February 1st-4th February.

[51] Farooqi A. Buffalo Farming: Its Significance in Economy of Pakistan. 2022 March 4th.

[52] FAOSTAT, 2019. https://www.fao.org/faostat/en/#data.

[53] Eid L. Insight on the status of Egyptian buffalo. Buffalo Newsletter. 2019; 35:14-19.

[54] Shafik Basant MN, El-Bayomi KMC Abo-Salem MES, et al. Environmental factors affecting some productive and reproductive traits in Egyptian Buffaloes. Benha Veterinary Medical Journal. 2017; 32(1):153-159.

[55] Hassanein MK, Abolmaaty SM, Khalil AA, Taqi MO, Essa YH, Shawki HH. Geographical Distribution and Developmental Pattern of Buffalo in Egypt. World Rural Observations. 2013; 5(4):14-9.

[56] Fahim NH, Abdel-Salam SA, Mekkawy W, Ismael A, Abo Bakr S, El Sayed M, Ibrahim MA. Delta and upper egypt buffalo farming systems: asurvey comparison. Egyptian Journal of Animal Production. 2018 May 1; 55(2):95-106.

[57] Kenmore PE, Stannard C, Thompson PB. The ethics of sustainable agricultural intensification. FAO. 2004; 3.

[58] Donald PF, Green RE, Heath MF. Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London. Series B: Biological Sciences. 2001 Jan 7th; 268(1462):9-25.

[59] Crosson P, Shalloo L, O'Brien D, Lanigan GJ, Foley PA, Boland TM, Kenny DA. A review of whole farm systems models of greenhouse gas emissions from beef and dairy cattle production systems. Animal Feed Sci. Technol. 2011; 166 and 167:29-45.

[60] Salou T, Le Mouël C, Van der Werf HM. Environmental impacts of dairy system intensification: the functional unit matters!. Journal of Cleaner Production. 2017 Jan 1; 140:445-54.

[61] Mota-Rojas D, De Rosa G, Mora-Medina P, Braghieri A, Guerrero-Legarreta I. Napolitano F. Invited review: Dairy buffalo behaviour and welfare from calving to milking. CAB Rev 2019; 14: 1-12. https://doi.org/10.1079/PAVSNNR201914035

[62] Meo Zilio D, Steri R, Iacurto M, Catillo G, Barile VL, Chiariotti A, Cenci F, La Mantia MC, Buttazzoni L. Precision Livestock Farming for Mediterranean Water Buffalo: Some Applications and Opportunities from the Agridigit Project. In: Biocca M., Cavallo E., Cecchini M., Failla S., Romano E. (eds) Safety, Health and Welfare in Agriculture and Agro-food Systems. SHWA 2020. Lecture Notes in Civil Engineering. SpringerNature. 2022; 252:41-50. https://doi.org/10.1007/978-3-030-98092-4_5.

[63] Sabia E, Napolitano F, Claps S, Braghieri A, Piazzolla N, Pacelli C. Feeding, nutrition and sustainability in dairy enterprises: the case of Mediterranean buffaloes (Bubalus bubalis). In: Vastola, A. (Ed.), The Sustainability of Agro-food and Natural Resource Systems in the Mediterranean Basin. Springer Open. 2015a:57-64.

[64] AIA 2023. (available at: https//aia.it).

[65] Failla S et al., see Borghese A. Buffalo Livestock and Products. A. Borghese and CRA (Council of Research in Agriculture) (Eds), Rome, Italy. 2013a:1-511.

[66] Singh I. Buffalo – the harbinger of prosperity in rural India. In: book of abstract 9th Asian Buffalo Congress Hisar, India. 2018 February 1st-4th.

[67] Aujla KM, Hussain A. Economics of milk production of major dairy buffalo breeds by agroecological zones in Pakistan. Pakistan J. Agric. Res. 2015; 28(2):179-191. https://popularinpakistan.com/buffalo-farming/

[68] Afzal M, Naqvi AN. Livestock resources of Pakistan: present status and future trends. Quarterly Science Vision. 2004; 9(1):1-2.

[69] United Nations – Department of Economic and Social Affairs – Sustainable Development. Transforming our World: The 2030 Agenda for Sustainable Development. https://sdgs.un.org/2030agenda