International Journal of
DATA SCIENCE AND IOT MANAGEMENT SYSTEM
Peer Reviewed, Referred & Indexed Journal
ISSN: 3068-272X www.ijdim.com Original Research Paper

REPRODUCTIVE CHALLENGES IN BUFFALOES: EFFECTS OF NUTRITION, ENVIRONMENT, AND MANAGEMENT

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Abstract

Protein sources for human nutrition are derived from both plant and animal origins. The primary products obtained from buffalo production systems are meat and milk. The success of buffalo production enterprises largely depends on the performance of individual animals, particularly their reproductive efficiency. Reproduction is a key determinant of productivity in buffaloes (*Bubalus bubalis*), as it directly affects meat and milk supply as well as population sustainability in smallholder farming systems, especially in developing countries. However, reproductive performance of buffaloes in developing regions remains suboptimal and requires improvement, particularly in relation to nutritional challenges, environmental stressors, and management practices. Nutritional factors play a crucial role in body condition and physiological readiness for reproduction, while environmental factors especially heat stress can suppress ovarian function and disrupt hormonal indicators essential for estrous cycles and successful pregnancy. Inadequate reproductive management, including poor estrus detection and improper mating strategies, further reduces reproductive efficiency. This article reviews scientific literature on the effects of nutrition, environment, and management on buffalo reproduction and identifies potential intervention strategies to enhance reproductive performance in a sustainable manner.

Keywords: Reproduction, buffalo, nutrition, environment, management

Introduction

Currently, the buffalo population in developing countries continues to decline, estimated at around 7-8% (Prihandini *et al*., 2023) [39]. Buffalo are large ruminants whose primary products are meat and milk. These animals belong to the genus Bubalus and share a similar external body posture. The decline of buffalo in the world, especially in developing countries, is due to the loss of interest in buffalo farming. This is due to farmers no longer needing buffalo labor, the decreasing availability of forage due to increasingly difficult land for cultivation, the impact of global climate change, and inadequate breeding management due to low reproduction. Reproduction is a distinctive characteristic of buffalo farming because it is difficult to detect when silent heat occurs (Petrocchi *et al*., 2023) [35]. Therefore,

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buffalo farming especially the mating process is more often carried out naturally rather than artificially or through artificial insemination techniques. Efficient reproduction is certainly fundamental in the process of increasing population and production, especially at the smallholder farm level (Kolachi *et al*., 2025) [23]. Assessment of buffalo performance can be seen from genetic and environmental factors. Genetic factors can be passed down to offspring, including production, immunity, and reproductive ability. Several environmental factors contribute to this decline, including a combination of feed and nutrition, the surrounding environment, and suboptimal management (Berry *et al*., 2014) [7]. Indicators of successful reproductive performance include age at first mating, age at first calving, gestation length, calving interval, and service per conception (Dhakad *et al*., 2024) [18]. Some regions, particularly tropical and developing regions, are experiencing significant problems due to the recurrence of these events almost annually, necessitating monitoring of feed conditions, maintenance management, and the local climate.

Materials and Methods

This review article was created using a systematic literature review (SLR) approach from peer-reviewed journal articles and other scientific articles related to buffalo reproduction, such as PubMed, Scopus, Science Direct, and Google Scholar, with a discussion of the influence of nutrition, environment, and management. Data collected from journals from the last 15 years (2010-2025) with high and medium reputations were then selected according to the discussion criteria in this article. The analysis focused on the relationship between these factors and the main reproductive parameters of river buffalo and swamp buffalo. Buffalo performance reviewed included age at first mating/calving, gestation period, calving interval, service per conception, pregnancy rate, and also related to milk and meat production. The following is an overview of the systematic arrangement and structure of the work that is directly related to nutrition, management, and the environment.

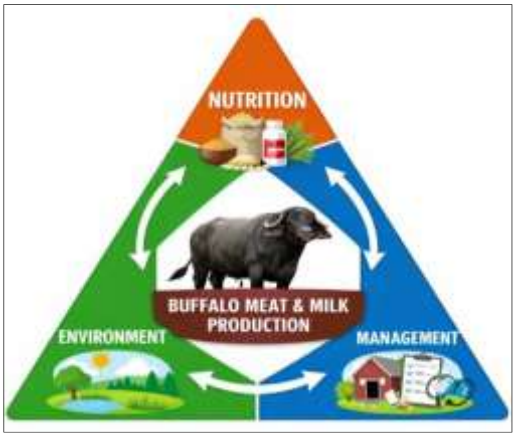

Fig 1: Important Pyramida Triangle of Buffalo

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Results and Discussion

Effect of Nutrition on Buffalo Reproductive Performance

Buffalo is one of the ruminant livestock that can produce the main products in the form of meat and milk (D'Angelo *et al*., 2022) [16]. The component to support the life of a dairy buffalo is the intake of nutrients derived from the feed consumed. Generally, buffalo cattle eat from forage and concentrates (a mixture of grains). Nutrition is the availability and balance of nutrients in feed that are used in the body to support production. In the reproductive performance of buffaloes, supporting nutrients are needed to produce good performance (Singh *et al*., 2024) [45]. If nutritional needs are not met and the quality of feed is low, reproductive efficiency becomes low. These incidents are more prone to occur in developing countries. Lack of nutrients in the body will have a direct impact on hormones that lead to a low pregnancy success rate (Bešlo *et al*., 2022) [8]. The whole nutrient will form an energy which is a primary need that affects the reproductive performance of buffaloes. Lack of energy in the body will have an impact on the negative energy balance (NEB) especially after childbirth (Song *et al*., 2021) [46]. The estrus cycle becomes delayed and the anestrus increases. Low energy intake in buffalo affects the concentration of gonadotropin hormone (GnRH & LH) which plays an important role in ovulation and the formation of the corpus luteum (Iwasa *et al*., 2018) [21]. In addition, nutrient components such as protein hold important in carrying out a buffalo activity such as supporting reproductive performance. Protein is needed for the synthesis of reproductive hormones, reproductive tissues and enzymes (Kumaresan *et al*., 2023) [24]. The protein that is commonly used to meet the needs of buffalo is crude protein. If crude protein is lacking in the ration, it has an impact on ovarian follicle growth, decreased oocyte quality, and high embryo implantation failure (Chaves *et al*., 2024) [11]. In addition to the lack of crude protein, if there is an excess it also has a bad impact on livestock, namely ammonia in the blood becomes toxic. Nutrition is closely related to the development and growth of livestock from birth to adulthood. Body weight is an important factor in the level of livestock performance measures (Costa *et al*., 2021) [15]. There is a relationship between body weight and body condition known as Body Condition Score (BCS) as an indicator that describes the effectiveness of nutrition and is related to the reproductive performance of buffaloes (Alapati *et al*., 2010) [2]. Buffalo has a judgment that is almost similar to other ruminants such as cows. Various results have been obtained that buffaloes with a low BCS of less than 2.5 on a scale of 1-5 will have an impact on delayed puberty, long childbirth intervals, low pregnancy (Anitha *et al*., 2011) [13]. If BCS is optimal, it illustrates that energy reserves are able to meet the needs for reproductive performance activities (Costa *et al*., 2021) [15]. Here is table 1 of nutritional needs for buffalo livestock.

Table 1: Buffalo Nutritional Needs in Various Production Periods

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Period of project	Age	DM (%BW)	TDN (%)	CP (%BW)	Ca (%BW)	P (% BW)	Remarks
Buffalo calf (Pre-weaned)	0-3 months	2.5-3.0	65-70	16-18	0,8-1,0	0,5-0,6	Supports rumen development and growth acceleration
Buffalo calf (Post-weaning)	3–6 months	2.5-3.0	60-65	14-16	0,6–0,8	0,6–0,8	Transition change to fibrous feed
Buffalo Early Heifer	6–12 months	2.0-2.5	58–62	58–62	58–62	58–62	Skeletal and muscular growth
Buffalo Heifer	12–24 months	2.0-2.3	55–60	55–60	55–60	55–60	Preparation for puberty and reproduction
Buffalo Early pregnant	1–6 months of pregnancy	2.0-2.2	55–58	55–58	55–58	55–58	Embryo maintenance
Buffalo final pregnant	7-9 months of pregnancy	2.2.2.5	60–65	60–65	60–65	60–65	Complete fetal growth
Buffalo Early lactation	0-3 months of lactation	2.8-3.2	65–70	65–70	65–70	65–70	High NEB risk
Buffalo Middle lactating	4-6 months of lactation	2.5-3.0	62–65	62–65	62–65	62–65	Stable milk production
Buffalo	>6 months	2.2.2.5	58–60	58–60	58–60	58–60	Restoration of body

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Final lactation	of lactation						condition
Bull buffalo	>24 months	2.0-2.2	55–60	55–60	55–60	55–60	Maintenance and fertility

Table 2: Buffalo Nutritional Needs Based on Physiological Period

Physiological Period	**Energy (TDN/Mcal ME)**	**Crude Protein**	**Mineral**	**Main Description**	**Source**
Maintenance	97.8–188.8 kcal/kg $W^{0.75}$ (ME) / 13–16.3 MCal	1.28–3.48 g/kg $W^{0.75}$	Approx. ~18–24 g; P ~13–17 g	The basis of energy & protein needs for body maintenance	Wahid and Rosnina (2016) [52]
Growing	27.5 - 52 g TDN/kg MBS (ad libitum)	~11–14% DM (ideal) >11 %	-	The need increases with growth and body weight	Paul & Lal (2010) [33],
Early pregnancy	Maintenance + 0.63–0.65 Milk FU/kg DM	~10–11% DM	-	Maintenance + gestation needs; Supplemental concentrate is given in the final 3 months of	Singh *et al.*, 2024 [45]
				pregnancy	
Late pregnancy	Maintenance + additional for fetal gestation	10–14% DM (up from baseline)	-	Increased needs as the fetus grows; Important to support mammary development	Purohit, 2016 [40]
Early lactation	1171–1863 kcal/kg $W^{0.75}$ 4% FCM (ME)	90–126 g CP/100g protein	-	Highest need for milk production; Energy & protein should be	Singh *et al.*, 2024 [45]

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		milk 127 CP/100g protein milk		sufficient	

Nutrients are divided into two parts, namely macronutrients and micronutrients. Macronutrients are the nutritional needs needed by livestock in large quantities such as minerals and vitamins that play a role in the reproductive performance of livestock (Purohit, 2016) [40]. Meanwhile, micronutrients are the nutritional needs needed by the body of livestock in small amounts and generally come from mineral groups (Van Neerven *et al*., 2025) [50]. But minerals can be further classified into two macrominerals and microminerals. Macrominerals are minerals that are needed in large quantities such as calcium (Ca) and phosphorus (P) that play a role in ovarian function and uterine contractions. Microminerals are needed in small amounts such as zinc (Zn), selenium (Se), copper (Cu) and manganese (Mn) (Cena and Calder, 2020). These minerals are important because they are directly related to the need for reproductive nutrition, especially in buffaloes, including the quality of male sperm, hormone regulation and work, and embryo viability. If mineral needs are not met, estrus failure occurs which leads to embryo death (Stathopoulou *et al*., 2012) [47]. On the other hand, the role of vitamins also has the power to support better reproduction such as vitamins A, D, and E. The role of vitamin A for buffalo is embryonic development and differentiation of reproductive epithelial cells (Hodge and Taylor, 2023) [20]. Vitamin D plays a role in immunity for embryos, successful pregnancy, improving muscle function of the reproductive organs, and muscle contractions during childbirth (Zmijewski, 2019) [51]. Meanwhile, vitamin E acts as an antioxidant that plays a role in protecting reproductive cells from oxidative stress (Kemnic and Coleman, 2023) [22]. If the feed is lacking, there will be reproductive disorders, namely placental retention. Not only that, reproductive nutrition has an impact on other things such as the lower the stradion hormone, so the signs of bias are more difficult to determine and less visible. Therefore, low estrus detection and artificial insemination failure have a direct effect on the decline in overall reproductive efficiency (Perry *et al*., 2023) [37].

The gestation period in buffalo averages 10-11 months or the equivalent of 300-340 days (Petrocchi *et al*., 2023) [35].

The nutrition given to buffalo in the pregnancy period is very important to maintain the health of the mother and the development of the fetus until before birth. Nutritional deficiencies in the final phase of pregnancy affect low calf birth weight, decreased postpartum colostrum production and reproductive performance in the next cycle (Redifer *et al*., 2024) [41]. The continuity between nutrition and the environment is very significant to heat stress, especially for buffalo raised in the tropics. Extreme heat stress lowers feed consumption so that protein and energy cannot be fulfilled properly (Bernabucci *et*

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al., 2010) [4]. The combination of unbalanced nutrition and heat stress due to environmental climate change can prolong the vacant period, as well as reduce fertilization rates, causing pregnancy failure (Coudhary and Sirohi., 2019; Galloso *et al*., 2021) [19]. Thus, the influence of balanced nutrition and meeting physiological needs is the key to success in improving the reproductive performance of buffaloes. Improved feed management, attention to vitamin and mineral nutrients, and BCS monitoring of livestock individuals are carried out on a scheduled basis for the evaluation and resolution of reproductive cases such as silent heat, anestrus, and long birth intervals (Montiel-Olguín *et al*., 2019) [29]. An appropriate nutrition strategy is needed to increase productivity and change the business of producing buffalo livestock for the better.

Environmental Influence on Buffalo Performance

The performance of buffalo as a meat and milk producer is highly dependent on the external conditions where they live. This affects the physiological performance of the body, its production and reproduction (Cheng *et al*., 2022) [12]. Buffalo maintenance is mostly carried out in various regional conditions, namely tropical and subtropical. The fundamental difference is the state of temperature and humidity which can change every day and can be measured throughout the year. Monitoring the comfort of buffalo can be measured through the thermoneutral zone so that it will be seen that livestock are in hot environmental conditions, triggering stress (Petrocchi *et al*., 2023) [35]. Stressful conditions will interfere with physiological and metabolic performance and then have an impact on production and reproduction and even be easily exposed to disease-causing parasites. Ruminant livestock are animals that are susceptible to heat stress and cause changes in respiration rate, body temperature, and unusual behaviors such as eating, curling, and finding shelter (Piscopo *et al*., 2024; Costa *et al*., 2020) [36]. Buffaloes when compared to cows have fewer sweat glands so they are less able to withstand sunlight. The sensitivity of buffalo to the temperature humidity index (THI) greatly affects the body's metabolism, reproductive organ dysfunction and energy imbalance in the body (Wang *et al*., 2022) [53].

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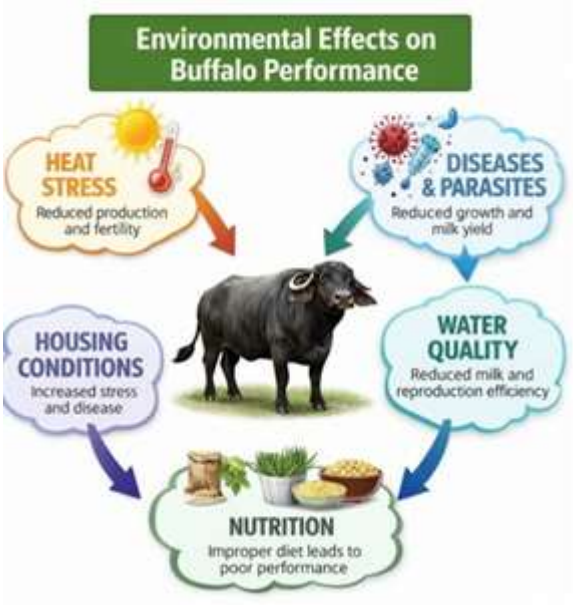

Fig 2: Environmental Effects on Buffalo Performance

There are hormones that are important in the reproductive process because they can be suppressed as a result of environmental stress. Gonadotropin releasing hormone (GnRH) and luteinizing hormone (LH) cannot work when the body temperature is high (Ṭogoe *et al*., 2024) [49]. Such conditions cause the occurrence of unclear silent heat, low pregnancy rates and decreased ovulation. Several factors such as water availability, type and poor quality of cages cause buffalo to fall into the stress category (Szalai *et al*., 2025) [48]. Humans as subjects in a livestock business can regulate and understand livestock to meet their welfare such as the availability of ponds for shelter, shade, and microclimate management regulators. The environment greatly affects its reproductive performance and production (Wang *et al*., 2022) [53]. Therefore, an environmental management strategy that is adaptive to local climatic conditions is an important key in efforts to improve the welfare, reproductive efficiency, and sustainability of buffalo farming businesses.

Challenges of Buffalo Reproductive Management Management

The key to success in a buffalo farming business is reproductive management. The potential for buffalo to be developed is more appropriate because in addition to cattle, these animals also produce good meat and milk (Devkota *et al*., 2023) [17]. Service per conception is low almost in some countries the existence is minimal. The main problems in buffalo breeding are the difficulty in detecting birahi or estrus, mating arrangements, and the lack of modern reproductive technology (Riaz *et al*., 2023) [42]. Buffalo that is approaching adulthood is very weak to know its estrus. The short estrus time and the mating activity at night are difficult to determine the exact time. This condition makes it difficult for

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inseminators who will carry out the artificial insemination process (López-Gatius, 2022) [25]. Therefore, it has an impact on the conception rate. The lower the conception rate, the better, on the other hand, if the conception rate is high, the worse it will be. In addition, it also affects long intervals, and low pregnancy rates (Pehan *et al*., 2025) [34]. Another challenge is that buffalo have not been able to optimally mate through an artificial system but must be natural (Riaz *et al*., 2023) [42]. In addition to the internal factors of buffaloes, they generally still face external obstacles including inseminator knowledge, semen quality, and incorrect insemination time (Pehan *et al*., 2025) [34]. The success rate of buffalo is lower compared to cows. Reproductive management is influenced by monitoring the physiological status and reproductive health of livestock (Devkota *et al*., 2023) [17]. Recording is related to evaluation so it is very good to do so that the livestock raised can be maintained or improve their performance. The recording process usually includes the interval of birth, the age of first marriage, and pregnancy (Nkadimeng *et al*., 2022) [30]. In addition, reproductive disorders such as anestrus, inactive ovaries, and reproductive tract infections are often not detected early due to the lack of regular reproductive examinations by experts (Coman *et al*., 2024) [14]. The challenges ahead of buffalo reproductive management management require an integrated and sustainable approach. Improvement can be done through many activities including training in birahi on buffaloes, simple reproductive recording. Better and planned reproductive management, the reproductive efficiency of buffalo can be significantly improved, thereby supporting the productivity and sustainability of buffalo farming businesses in various production systems (Merkelytė *et al*., 2025) [27].

Multi-Factor Interaction Relationship in Buffalo Livestock

Many factors that affect reproductive performance as well as overall buffalo production are a combination of nutrition, environment and management (Binyameen *et al*., 2022) [9]. Dynamically, these combined factors affect the body's metabolism, physiological, hormonal, as well as other endocrine performance related to reproduction (Lu *et al*., 2025) [26]. If something bad happens, such as an imbalance, it will affect reproduction and other performance. Feed is an important thing to pay attention to in buffalo maintenance because it is related to nutrient intake to meet basic life needs (Mohd Azmi *et al*., 2021) [28]. In addition, the environment is also an aspect that supports buffalo to live comfortably without causing stress that has an impact on the performance of buffalo as a meat and milk producer. Both can be said to be factors that have power for the buffalo rearing system, especially in the tropics (Singh *et al*., 2024) [45]. Body stress due to overheating that results in metabolic imbalances can affect feed consumption patterns so that it has an impact on the body's energy and protein (Prates, 2025) [38]. The amount of feed consumed affects the amount of nutrients as well, thus affecting the Body Condition Score (BCS). In addition, there is an imbalance in the

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performance of reproductive hormones such as estradiol, LH, and GnRH (Petrocchi *et al*., 2023) [35]. Therefore, the influence of nutrients is very important on reproductive performance that cannot be separated from the environment in which the buffalo lives.

Optimizing buffalo performance is highly dependent on the regulation of the maintenance system, including those that focus on feed aspects, in this case nutrition and the environment that are further improved for reproductive performance (Devkota *et al*., 2023) [17]. Management carried out in a buffalo farm must be carried out appropriately and efficiently, such as providing and providing balanced feed, adjusting the microclimate in and around the cage (Simeanu *et al*., 2023) [44]. This application is useful to reduce stress in buffaloes which affects their physiological status and nutrition. The overall interaction of factors can be seen from the performance of buffaloes to environmental resilience and nutrients absorbed in their bodies (Petrocchi *et al*., 2023) [35]. Many factors can affect including physiological status, age, and reproduction, birth, and lactation. Various periods in buffalo will make a difference in whether or not the body imbalance causes stress (Devkota *et al*., 2023) [17]. Buffalo experience a transition period that occurs at the end of pregnancy to the beginning of lactation. During this period, the need for nutrients in feed increases significantly, but stress control sometimes decreases, resulting in a risk of interfering with reproductive performance (Oliveira *et al*., 2025) [32]. Thus, improvements through management need to be made to prevent reproductive disorders in buffaloes. It is necessary to design a strategy in the maintenance of buffalo as meat and milk producers through increasing the understanding of the multifactor relationships that have been described in order to improve sustainable reproductive performance. Nutritional, environmental and directed management aspects provide better results and increase production, reproduction and business sustainability (Coman *et al*., 2024) [14].

Conclusion

The performance of buffalo as a meat and milk producer is influenced by the existence of close and very complex relationships such as nutrition, environment and management. The reproductive performance of buffaloes is influenced by these three factors. Unbalanced and fulfilled nutrition is still one of the main obstacles, as it directly affects the body's condition, metabolic status, and hormonal regulation that are essential for reproductive activity, estrus, and successful conception. Nutritional deficiencies, especially energy, protein, and essential minerals, are closely related to delayed puberty, silent heat, anestrus, and extended childbirth intervals. Environmental factors, especially heat stress in tropical and subtropical regions, further affect reproductive efficiency through disruption of endocrine function, decreased etruss behavior, and increased embryo mortality in early pregnancy. Buffalo have a high sensitivity to thermal stress due to limited sweating ability, so environmental modification and the provision of thermal comfort are crucial aspects in maintaining optimal reproductive function.

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ISSN: 3068-272X www.ijdim.com Original Research Paper

Management practices play an important role in determining reproductive success, where ineffective estrus detection, inappropriate mating strategies, and inadequate reproductive monitoring can significantly reduce fertility rates. The absence of an integrated reproductive management system often magnifies the negative impacts of nutritional and environmental stresses. Overall, improving the reproductive efficiency of buffalo requires an integrated and holistic approach by taking into account nutritional adequacy, mitigation of environmental stress, and the implementation of strategic reproductive management. Sustainable interventions such as balanced feeding programs, the application of heat stress reduction technologies and strategies, as well as improved estrus detection and mating management are essential to improve the reproductive performance, productivity, and sustainability of buffalo populations, particularly in developing countries.

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