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Feed Resources and their Development for Raising Buffaloes in Arid Regions of India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

India possesses about 2.27 % of the World's 13062 million hectares of total land area. About 10 % of the total land area of the country is arid and 30 % semi-arid. The arid zone is mostly confined to the States of Rajasthan and Gujarat while the semi-arid zone is spread over the States of Maharashtra, Karnataka, Andhra Pradesh, Rajasthan, Tamilnadu, Gujarat and Uttar Pradesh. Rajasthan has the maximum (73.60%) of the total arid and semi-arid area followed by Gujarat (29.50 %) and Andhra Pradesh (21.50 %). The annual rainfall in the arid region varies from 10 to 40

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cm, quite often erratic, so much so that the entire rainfall of the year may fall on a single day and rest of the year may go dry. The summer temperatures may be as high as 49^0 C during day and fall to less than 20^0 C during night. In winters, the day temperatures are higher but the night temperatures may be near freezing point. The buffalo population that had been 22 % in 1951 is now more than 30 % of the total bovine population. Rajasthan state with 53.17 million has about 11.50 % of the country's total livestock population. This includes about 12.16 million cattle, 9.76 million buffaloes, 14.31 million sheep and 16.94 million goats. The total land area of the country is around 304 million hectares. Of the total area, about 22.5 % is under forest cover, 3.6 % is under permanent pasture, 1.2 % is under tree crops and groves, 6.2 5 % is barren and uncultivable land, 4.5 % is under waste lands and 8.0 % is under fallow lands. Buffaloes in arid and semi-arid areas are reared under three main feeding management systems, extensive, semi-intensive and intensive. The advance pregnant buffaloes are supplemented with green fodder of Lucerne, Barseem, and/or Oats during winter season, while green Sorghum or Pearl millet during summer. In rainy season, the advance pregnant buffaloes are fed with *ad libitum* green fodder. The areas in arid and semi-arid regions that cannot support crop production may be identified, developed through reseeding with perennial grasses and legumes and plantation of fodder trees and utilized for buffalo production with low investment.

Keywords: Buffaloes; milk production; arid regions; livestock production; feed and fodder resources.

1. INTRODUCTION

India today, stands first in the area of milk production at the world level, with an annual growth rate of about 4%. Milk production amounted to over 2300 million metric tons in fiscal year 2023 in India (FAOSTAT 2023). A large quantity of milk produced in the country amounting to over 46% is being consumed as liquid milk. The production and use of animal products in the use of human diet is receiving tremendous attention. With this object in view the need for developing Animal Husbandry is recognized very well. The other objects are to provide animal power for farming and adoption of better land use pattern (Singh et al. 2012).

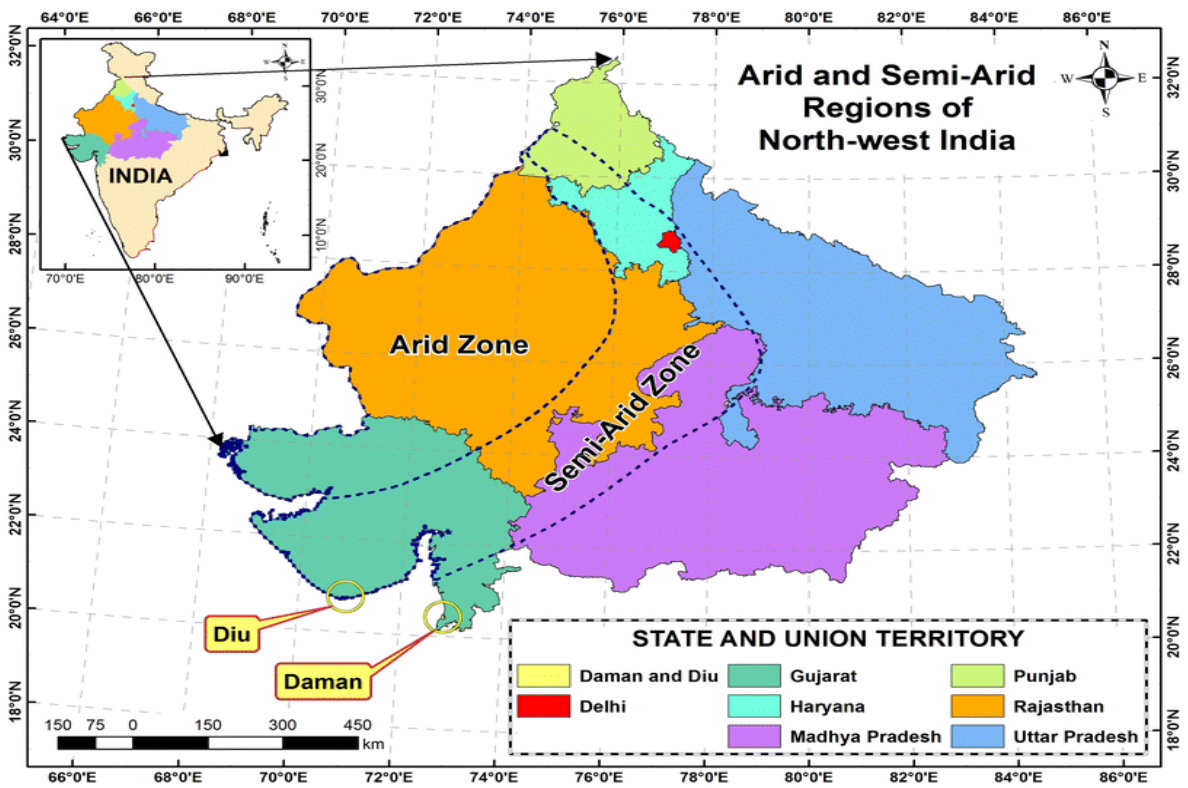

Fig. 1. Map of arid region and semi arid region in India

The annual rainfall in the semi-arid region varies from 50 to 60 cm (GOI, 2001). In semi-arid regions, the summer and winter temperatures are not as extreme as in the arid region but may reach 45^0C during summers and 8 ^{0}C during winters. The crop production in these regions is a gamble mainly due to low and erratic rainfall. The farmers of these areas have, therefore, diversified from crop production to livestock production to counter the risks of crop failures as the livestock in general are more tolerant to harsh climatic conditions as compared to the crops. Cattle, sheep and goats are the preferred ruminant livestock and buffalo rearing is not very popular in most of the arid and semi-arid regions except a few districts in Rajasthan where rainfall is comparatively higher or irrigation facilities have been developed. There are adverse ecological and physiological constraints in the Indian system of goat farming. Goat population of our country increased from 47.14 million in the year 1951 to 124.5 million during 2005 (Singh and Sharma, 2013).

Goats are integral part of livestock production and play a vital role in the socio-economic structure of rural poor. There are adverse ecological and physiological constraints in the Indian system of goat farming. Goat population of our country increased from 47.14 million in the year 1951 to 124.5 million during 2005 (Singh and Sharma, 2014).

2. LIVESTOCK POPULATION

World's current population of cattle, buffaloes, sheep and goats is around 1368.0, 170.5, 1028.5 and 764.5 million respectively (Table 3). Asian region possesses about 35.49, 97.06, 40.38 % and 63.78 % and India 16.53, 56.85, 5.74 and 16.28 % of the total world population of the four respective livestock species (FAO, 2003). India ranked first in cattle, buffalo and goat population in the world. Although the population of all the four livestock species has shown increasing trend since 1951 the buffalo and goat population has increased at a much faster rate than cattle and sheep in India.

The buffalo population that had been 22 % in 1951 is now more than 30 % of the total bovine population. Rajasthan state with 53.17 million has about 11.50 % of the country's total livestock population. This includes about 12.16 million cattle, 9.76 million buffaloes, 14.31 million sheep and 16.94 million goats. Rajasthan state has about 10 % of the total buffaloes of the country. The semi-arid region has significantly higher population of buffaloes as compared to the arid region. Jaipur district has the highest (7.75 lakhs) population of buffaloes followed by Alwar (7.64 lakhs), Ganganagar (7.50 lakhs), Bharatpur (5.25 lakhs), Sawai madhopur (5.10 lakhs), Udaipur (4.75 lakhs) and so on indicating positive correlation with the amount of rainfall received and feed resource availability (GOI, 2001). Major population of India is primarily depends on agricultural based system for their daily life including goat keeping that constitute an important rural business of small marginal farmers and landless labours (Singh et al. 2014). The global goat population currently stands at 921 million, of which over 90% are found in developing countries. Asia is home to about 60% of the total world goat population and has the largest goat breed share of 26%. Goats play a vital socioeconomic role in Asian agriculture, particularly for resource-poor people living in harsh environments. Non-cattle milk accounts for approximately 15% of the total milk consumption by humans worldwide (Singh et al. 2014). Goat meat being high quality protein source is the choicest meat in domestic market. It is leaner than other red meats and its fat has desirable fatty acids. The goat was domesticated as early as 6-7 BC, as evidenced by archaeological remains collected in western Asia. It has since played a significant socioeconomic role in the evolvement of human civilization around the world (Singh and Sharma, 2015).

3. LIVESTOCK PRODUCTION

The total annual World production of milk is 599.71 MMT (Table 3). Asian region contributes 30.82 % and India with 14.50 % of the total milk production ranks first. Total buffalo milk production in the World, Asia and India is 72.62, 70.39 and 47.85 MMT, respectively. Buffaloes provide more than 55 % of the total milk produced in our country. The milk productivity of cattle and buffaloes in Rajasthan is low owing to their poor nutrition and feeding management. They provide less than 10 % of the total milk produced in the country. World's annual production of total meat is around 73.74 MMT. Asian countries contribute about 29.14 % and India about 4.96 % of the World meat production. The buffaloes contribute 4.31 % to the World, 13.36 % to Asia and 40.16 % to India of the total annual meat production. Buffaloes also provide 7.96 % in the world, 17.26 % in Asia and 44.07 % in India of the total skins and hides produced (FAO, 2003). Thus buffaloes are the most

important livestock species in Asian countries in general and in India in particular. Although the buffaloes are more suitable for humid, damp and high rainfall areas, however, they are becoming popular and important in arid and semi-arid areas also with the improving irrigation facilities and advancing crop production. Reproductive management of an animal is governed through a number of parameters, viz. age at first conception, age at first calving and first gestation length etc. However this study is limited to study the reproductive management in terms of age of animal at first calving (Singh et al. 2014). The goat, known as “wet nurse of infant” in the United Kingdom and “poor man`s cow” in India was the first animal to be domesticated. Goat milk contains less lactose than cow’s milk, so is less likely to trigger lactose intolerance (Singh and Sharma, 2015). The productive improvements among dairying animals can be made through proper management, feeding and handling, etc. which may influence expression of productive characters as per its heritability nature. Before identifying the animals for breeding and production purpose screening of animals shall be performed on the basis of physical traits (Singh et al. 2013). Poultry farming has been a traditional practice in India for centuries but the adoption of scientific methods and modern management techniques in poultry farming is a relatively recent development. Poultry farming hold significant, economic, nutritional, industrial, recreational and research values. It also plays an important role in enhancing the livelihood and economic stability of poultry owners. Various government and non-government organization have also recognized the importance of poultry farming as employment generating enterprise and are engaged in motivating more and more entrepreneurs to take up this enterprise (Singh et al. 2014). Goats play a vital socio-economic role in Asian agriculture, particularly for resource poor communities living in harsh environments (Singh et al. 2014). Despite their importance, goats are often poorly managed, primarily due to their remarkable to survieve under challenging conditions. Additionally many rural households rear goats for subsistence purposes to support their families. However the contributuion the of goat to rural livelihood often go unrecorded in national statistics due to the prevalence of informal trading and slaughtering practices (Singh et al. 2014).

4. LAND HOLDINGS AND UTILIZATION PATTERN

The total land area of the country is around 304 million hectares. Of the total area, about 22.5 % is under forest cover, 3.6 % is under permanent pasture, 1.2 % is under tree crops and groves, 6.2 5 % is barren and uncultivable land, 4.5 % is under waste lands and 8.0 % is under fallow lands. The total area available for livestock grazing works out to be about 46 % of the total land in the country. About 40 % of the total area in Rajasthan is available for livestock grazing (Pathak and Gupta, 2003). Almost all the states

Table 1. Treatment methods for low quality roughages

S. No.	Treatment Method	Description
1.	Soaking	The straw is soaked in water or boiling water for 6 or 12 hrs and fed as such or after sun drying
2.	Urea	The 4 kg urea is dissolved in 55 litre of water and sprayed on 100 kg straw. The urea sprayed straw is mixed thoroughly and air tightly stacked with polythene sheet for 21 days.
3.	NaOH	The straw is soaked in 2 % (w/v) NaOH solution for 6 hr. The excess of NaOH solution is drained overnight, sun dried and fed to sheep.
4.	AHP (*activity-related heat production)*	The straw is soaked in 2 % (w/v) NaOH and 1.5 % (v/v) H_2O_2 solution for 6 hr. The excess of NaOH and H_2O_2 solution is drained overnight, sun dried and fed to sheep.
5.	Fungal	The straw is treated with urea as above and inoculated with *Coprinus fimetarius* fungus for 7 days and fed to sheep.
6.	Densification	The 5 kg molasses and 1 kg urea is dissolved in 5 litre of water and thoroughly mixed with 65 kg of mustard straw and 29 kg of concentrate mixture. This premix is fed into CFB making Machine and feed blocks prepared at 4000 PSI. These blocks are fed to sheep.

Table 2. Enrichment levels of low-grade roughages by different methods

Treatment	Improvement		Advantages
	CP %	DMD (unit)	
Soaking	-	24 to 16	Soaking of straw in water or boiling water strengthens its structure and reduces digestibility.
Urea	2.6 to 9.7	21.8 to 27.6	*Adlib* feeding of UTS with 200g of conc. Mix. Or all UTS and Khejri leaves (75:25) can maintain the animals during scarcity period.
NaOH	2.6 to 3.2	21.8 to 31.0	Animals consumed 33% more DM from CFB based on 2% NaOH treated straw.
AHP	2.6 to 3.2	21.8 to 26.0	Improved dry matter intake, decreased N excretion in urine, improved nitrogen balance.
Fungal	2.6 to 7.7	21.7 to 28.0	Fungal treated straw with 200g of concentrate mixture can maintain the animals during scarcity period.
Densification in to complete feed blocks (CFB)	-	46.0 to 52.0	Increased density (g/cm^3) 1.8 to 2.3 times on straw based CFB, improved DMI by 25% in sheep, also improved gain in body weights.

in Central and Peninsular India and part of Rajasthan, Gujarat, Punjab and Haryana come under semi-arid region. Permanent pastures occupy over 5.0 %, forest cover over 14 % and wastelands over 12 % in the semi-arid areas of the country. A survey conducted in the semi-arid region of Rajasthan revealed that the average land holdings of the marginal, small, medium and large farmers were 0.37 and 0.21, 3.60 acres respectively. The percentage distribution of these land holdings categories was 5.05%, 6.80%, 19.06% 20.77% and 75.68%, respectively (Table 4). The proportion of irrigated land with marginal, small, medium and large farmers was 0.0, 21.25, 47.90 and 17.74 % respectively. The overall irrigated land in the survey area was 27.19 % (Chaturvedi et al., 2002). The proportion of irrigated land was slightly lower in the area as compared to the national figure (35%) because the area is typically semi-arid and mostly rain fed. The average family size in the area was 9.67. It was higher in case of large farmers followed by marginal, small and medium farmers (Table 5). The (number of persons engaged and dependent on agriculture was higher in case of large farmers followed by medium, small and marginal farmers. However, due to limited resources such as land and agricultural inputs, marginal and small farmers were found to supplements their livelihoods by taking on other jobs including working as hired agricultural labourers. Crop production and animal husbandry served as the primary livelihood for 89.5% of the population in the semi-arid region of Rajasthan. The overall human-to-land ratio in the region was 1.37, with the highest ratio observed among marginal farmers, followed by small, medium, and large farmers (Chaturvedi et al., 2002). Similarly, Saran et al. (2000) reported that the human-to-land ratio in the Bundelkhand region of Uttar Pradesh, another semi-arid area, closely mirrored that of Rajasthan.

Khejri **Adu** **Lead Tree** **Hyacinth Bean**

Fig. 2. Tree and grasses

Arable land allocated for fodder cultivation accounted for only 2.4%, with most of it utilized for growing crops such as maize (*Zea mays L*), sorghum (*Sorghum bicolour*), pearl millet (*Pennisetum glaucum L*.), cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum L*.), pigeon pea (*Cajanus cajan*), green gram (*Vigna radiata*), and black gram (*Vigna mungo L. Hepper*.) during the kharif season, and mustard (*Brassica juncea*), chickpea (*Cicer arietinum*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), and vegetables during the rabi season. Major fodder crops included M.P. chari, sorghum, pearl millet, and cowpea in the kharif season, and lucerne (*Medicago sativa*), berseem (*Trifolium alexandrinum*), kasni (*Cichorium intybus Linn*.), senji (*Melilotus indicus*), and oats (*Avena sativa*) in the rabi season.

5. LIVESTOCK HOLDINGS

The average livestock holding and Adult Cattle Unit (ACU) in the region were 39.23 and 12.67, respectively (Table 5). Marginal farmers had the highest average livestock holdings, followed by medium, large, and small farmers. However, the average number of ACUs was highest among large farmers, followed by marginal, medium, and small farmers (Chaturvedi et al., 2002).

The livestock-to-land ratio (ACU/acre) was highest among marginal farmers, followed by medium, small, and large farmers. Larger family sizes among large farmers enabled them to manage more livestock due to increased manpower availability. An acre of land owned by marginal farmers, however, supported more livestock and human lives than land owned by large farmers. This pattern of ACU holdings and livestock-to-land ratios closely resembles that of the Bundelkhand region of Uttar Pradesh, as reported by Saran et al. (2000).

The livestock population comprised 22.47% cattle, 17.10% buffaloes, 31.39% sheep, and 29.04% goats (Table 6). Large ruminants (cattle and buffaloes) constituted 39.6% of the livestock, while small ruminants (sheep and goats) made up 60.4%. Sheep and goats, particularly, play a significant role in the economy of farmers in arid regions. Sheep husbandry, in particular, is better suited to the economic and climatic conditions of Rajasthan (Sirohi and Rawat, 2000). The proportion of small ruminants was highest among marginal farmers, followed by medium, large, and small farmers (Chaturvedi et al., 2002).

Goat milk contains less lactose than cow's milk, making it less likely to trigger lactose intolerance. Additionally, it is naturally homogenized due to the absence of the protein agglutinin, and its composition, including fat percentages, is more similar to human milk than cow's milk. These characteristics make goat milk a preferred choice for infants and individuals with difficulty digesting cow's milk (Singh et al., 2014).

Goat meat is a high-quality protein source and is highly favored in the domestic market. It is leaner than other red meats and contains desirable fatty acids. Goats were domesticated as early as 6,000–7,000 BC, as evidenced by archaeological remains in Western Asia (Singh et al., 2014).

The Gir breed, recognized as one of the better milk producers among indigenous breeds, requires further exploration to assess its production potential. Improvement in productivity can be achieved through proper management, feeding, handling, and environmental conditions. However, the limits of these improvements are ultimately determined by the genetic potential of the individual animal (Singh et al., 2013).

6. FEED AND FODDER RESOURCES

The major feed resources in our country are grasses, grazing, crop residues, cultivated fodders, edible weeds, tree leaves and agro-industrial by-products. Kumar and Mathur (1996). Crop residues and by-products constitute the main feeds accounting for 40 % of the total consumption of different livestock. Green fodders contribute 26 %, the concentrates 3 % and the rest is coming from grazing (Mathur, 2004). Pearl millet was recognized as a main source of energy for livestock and is fed at critical times, such as during lactation, illness, and for weight gain. Farmers felt that grass is more useful to fill the animals' stomachs and would therefore come before crop stover as a feed. Farmers preferred Deda over Kona because it has more biomass (Singhand Sharma, 2015).

7. FEEDING SYSTEMS FOR BUFFALOES

Buffaloes in arid and semi-arid areas are reared under three main feeding management systems, extensive, semi-intensive and intensive. Buffaloes in arid regions are mostly reared under extensive system and play only a secondary role to crop as well as other livestock production. Thus the grazing intensity works out to 6.63 ACU per hectare and the grazing area per ACU to less

than 0.15 hectare (Roy, 2003). Sheep, goats, idle bullocks and non-producing cattle were primarily grazes together in mixed herds on community or public rangelands for approximately 8-10 hours per day. The livestock were grazed from 0600-1800, 0700-1700 and 0800-1600 hr during summer, rainy and winter season, respectively. Buffaloes are either stall-fed or supplemented with dry roughage after grazing. Soaked oilseeds and their cakes as well as concentrates mixed with wheat straw, sorghum or pearl millet kadbi were also offered to the lactating animals during green fodder scarcity. The rate of concentrate feeding to lactating cattle and buffaloes was 2.5-3.0 kg per animal per day. similar quantity of concentrate was also provide to working bullocks. The extensive system is principally one of low resource use and a low level of productivity emerges from poor nutritional availability. There are significant functions in feed availability and its nutritive value across different regions, years and seasons. The greatest limitation of our rangelands and natural pastures is the sufficient availability of energy throughout the year and inadequate protein supply for more than half the year. From January to June the energy deficiency is particularly sever and the with intake levels falling well below maintenance requirements. While grazing on the rangelands is regard as the most economical method of buffalo production, over grazing of these lands has led to significant issues including, vegetation losses, soil erosion and land degradation. Due to long dry summers, erratic rains and light textured soils deficient in organic matter content having tendency to salinity, the natural potential of these lands caused short of the nutritional requirements of the buffaloes. The adult body weights, reproduction rates and milk production are very lower and morbidity and mortality rates are very higher. There are great prospects of improving these natural rangelands. Reseeding with Sewan grass (*Lasiurus sindicus*) in arid areas, with Buffelo grass (*Cenchrus ciliaris*) in semiarid areas and marvel grass (*Dicanthium annulatum*) perennial grasses in higher rainfall areas increased the grass yield from 0.5 ton to 2.0 ton per hectare per year. Intercropping of Cowpea in Buffalo grass (*Cenchrus ciliaris*) pasture improved the nutritive value and increased the dry matter yield of the pasture by three times. Introduction of hyacinth bean (*Dolichos lablab*) legume improved the nutritive value and increased the dry matter yield from 1-1.5 ton to 2.5-3.0 ton per hectare. Plantation of 50 fodder trees of Khejri (*Prosopis cineraria*), Aralu, Adu (*Ailanthus excelsa*) and *white lead tree* (*Leucaena leucocephala*) in a hectare had no adverse effect on the pasture growth and provided an additional yield of one ton dry matter when fully grown and lopped twice a year. Areas in arid and semi-arid regions may be identified and utilized for buffalo production with low investment. Rural common grazing lands should be improved through reseeding with nutritious perennial and high yielding grasses and legumes. Fodder tree plantation should be taken up on pasturelands, wastelands, riverbanks and roadsides and bunds of ponds, canals and agriculture fields on large scale.

A kind of compromise between extensive and intensive systems is referred to as the semi-intensive system of buffalo feeding management. This system is mostly followed in semi-arid regions of the country. It is a combination of limited free-range grazing on available pasturelands and feeding in the stalls with feed and fodder supplements. Integration of buffalo rearing with arable cropping and tree cropping is also included and cut and carry system of available fodders is employed. The buffaloes are grazed for 4-6 hours and supplemented with varying amounts of natural and cultivated green and dry grasses, fodders, crop residues, straws, grains, oil seeds, oil cakes and agro-industrial by-products etc. The buffaloes utilize all available feed resources under this system. The level of nutrition is just optimum or little low but surely far better than that of extensive system. Production performance of the buffaloes depends on the quantity and quality of the grazing pastures and supplementary feeding. The dry grasses, fodders, crop residues and straws are mostly fed to cattle and buffaloes as whole without chaffing in most of the arid region. It was interesting to note that there were in general no chaff cutters, mangers and tying chains available in the area for even large ruminants for providing supplementary feeding. Under such circumstances, there was a great scope for improving the productivity of buffaloes through increasing feeding values of the poor-quality roughages available in the arid and semi-arid areas by adopting simpler, cheaper and feasible feed and fodder processing, enrichment and conservation technologies.

8. ENRICHMENT OF LOW-QUALITY ROUGHAGES

Some of the improved technologies developed and recommended for improving the feeding and nutritive value of low-grade roughages and

available for adoption by the livestock owners are Table 1. Poor quality straws like Bajra kadbi, Jawar kadbi, Mustard straw and Wheat straw are available in sufficient quantity in arid and semi-arid regions of the country. These straws are nutritionally poor and can be enriched by different treatments and utilized in the dietary of buffaloes.

8.1 Utilization of Mustard Straw

Approximately 1.7-2.0 MMT of mustard straw is annually available in the country. It is not being used in feeding of animals and is normally burnt in the fields. It contains 3-4% crude protein and its *dry matter digestibility* (DMD) is 25-30%. This straw can serve as maintenance feed for ruminant animals during scarcity period when fed as follows-

- *Ad libitum* straw supplemented with little quantity of concentrate mixture
- Urea-NH_3 treated straw
- Complete Feed Block having 60 kg of mustard straw, 35 kg of concentrate mixture and 5 kg of molasses

The intensive system of buffalo rearing includes complete feeding in the stalls totally on cultivated fresh or conserved fodders, crop residues and concentrates. This system requires significnt labor and capital investment and is particularly well suitable for both milk and meat production from buffaloes. In addition to providing higher body weights, reproduction rates, survival rates, milk yield and quality, this system also removes pressure from the grazing lands. Studies conducted in the semi-arid regions of Rajasthan revealed that stall-fed lactating buffaloes producing 6-8 kg of milk per day were provided with 15-20 kg green lucerne, barseem or oats per head per day during winter, along with *ad libitum* Wheat straw or Bajra kadbi. During summer, they were offered 8-10 kg of green sorghum fodder per head per day supplemented with *ad libitum* Wheat straw or Bajra*/* Jowar kadbi in the monsoon season, the quantity of sorghum and /or Pearl millet green fodder was increased to free choice.

The grazing or stall-fed lactating buffaloes are daily supplemented with 1.0 to 1.5 kg per head boiled cottonseed in the morning and 1.0 to 2.0 kg per head-soaked concentrate ingredients viz. crushed cereal grains, guar *churi*, cottonseed cake and/or mustard cake in the afternoon just before milking. The lactating buffaloes grazing on community pastures are also offered with dry roughage during winter and summer seasons. Like lactating buffaloes, the pregnant buffaloes are also either grazed or stall-fed in arid and semi-arid regions. The advance pregnant buffaloes are supplemented with green fodder of Lucerne, Barseem, and/or Oats during winter season, while green Sorghum or Pearl millet during summer. In rainy season, the advance pregnant buffaloes are fed with *ad libitum* green fodder. The buffaloes are supplemented with the 2.0-3.0 kg concentrate ingredients viz. crushed cereal grains, oilseeds, cakes and grain by-products during later part of pregnancy. The dry buffaloes are not generally supplemented with concentrates. The buffalo calves and heifers are supplemented with concentrates at the rate of 0.5-1.0 kg per head per day. Depending upon the availability, the straws of leguminous crops like black gram, green gram, guar, groundnut, moth, cowpea etc. are also fed to various classes of buffaloes.

8.2 Feed Resource Development for Buffaloes

Feed and fodder resources for buffaloes may be developed through renovation of degraded rangelands, establishment of perennial grass, grass legume and silvi-horti-pastures, introduction of fodder crops, intercropping of fodder legumes in cereal crops, fodder tree plantation and enrichment, improvement and utilization of crop residues, agro-industrial by-products and unconventional feed resources.

Fig. 3. Different feeding methods for buffaloes

Table 3. Livestock population and production

Attributes	World	Asia	India
Population (Million)			
Cattle	1,368.05	485.49	226.10
Buffalo	170.46	165.45	96.90
Sheep	1,028.59	415.35	59.00
Goat	764.51	487.59	124.50
Milk Production (MMT)			
Cow	507.38	104.78	36.50
Buffalo	72.62	70.39	47.85
Sheep	7.89	3.40	_
Goat	11.82	6.29	2.61
Meat Production (MMT)			
Beef and veal	58.74	11.84	1.49
Buffalo meat	3.18	2.87	1.47
Mutton and lamb	7.73	3.78	0.23
Goat meat	4.09	3.00	0.47
Fresh Skin Production (MMT)			
Cattle hides	7.41	2.45	0.48
Buffalo hides	0.86	0.82	0.52
Sheep skins	1.63	0.77	0.05
Goat skins	0.90	0.71	0.13
Greasy Wool Production (MMT)	**2.14**	**0.71**	**0.05**

Source: FAO (2003)

8.3 Pasture Improvement and Management

Lands that are unsuitable for crop production due to edapho-climatic conditions can be utilized by developing perennial pastures and silvipastures. The improvement of pasturelands can be achieved by protecting them from biotic factors, removing unwanted bushes and weeds and preserving beneficial natural grasses and legumes. *Cenchrus ciliaris* pasture can be established by mixing seeds in wet soil in a 1:1 ratio and then putting in open furrows spaced at 50 cm such that the seeds do not go beyond 1-2 cm of soil depth. Increasing the level of nitrogen from 0 to 60 kg/ha linearly increases the fodder yield of *Cenchrus.* Application of sheep manure at 10 ton/ha once in 3 years was most economical for maximization of pasture production under rain fed condition. Sheep manure at 15 ton/ha once in 4 years and 30 kg N/ha in 4th year maintains the production of *Cenchrus* pasture above 50 q dry fodder per hectare on light sandy loam soils. *Cenchrus* pasture in the first year of establishment should be protected from grazing. Intercropping with Cowpea may be adopted during first year to increase DM yield to five times. However, Cowpea should be harvested earlier to avoid suppressing effect of vines.

A mixed pasture of grass and legume, *Cenchrus ciliaris* and *Dolichos lablab* sown in 1:1 ratio as alternate strip of 6 to 8 rows each, provides maximum dry fodder and CP per hectare. Another grass legume mixture of *Cenchrus ciliaris* and *Clitoria ternata* was found suitable. A better method of introducing *Clitoria* in *Cenchrus* pasture is through broadcasting followed by cultivator to mix into soil prior to sowing of *Cenchrus* in lines at a spacing of 50 x 30 cm. Application of sheep manure at the rate of 60 kg N equivalent/ha in a mixed pasture of *Cenchrus* and *Dolichos* or *Clitoria* is most optimum. The grasses and legumes may be harvested at 50% bloom stage to get maximum yield and quality of the forage.

The bur (*Cenchrus biflorus*) due to its thorny inflorescence gets embedded in the fleeces of grazing sheep. Bur infested wool is considered low quality because it complicates wool processing in its early stages; it resembles *Cenchrus ciliaris* or *Cenchrus setigerus* but can be identified later by its distinctive spikelets Additionally, the application of Giberallic acid at 25 ppm on a *Cenchrus- Dolichos* mixed pasture resulted in 62% increase in grass yield, a 29% increase in mixture yield and 42% increase in legume yield.

Table 4. Land holdings of different classes of farmers

Category of farmer	Number of households	Total land holding (Acres)	Average size of holding (Acres)	Proportion of holding (%)	Average irrigated land/farmer (Acre)	Average unirrigated land/farmer (Acre)	Proportion of irrigated land (%)
Marginal (<2.5 Acre)	2	0.75	0.37	0.21	0.00	0.37	0.00
Small (2.5-5 Acre)	5	18.00	3.60	5.05	0.70	2.90	21.25
Medium (5-10 Acre)	10	68.00	6.80	19.06	3.17	3.62	47.90
Large (>10 Acre)	13	270.00	20.77	75.68	3.92	16.85	17.74
Overall	30	356.75	11.89	100.00	2.87	9.02	27.19

Source: Chaturvedi et al. (2002)

Table 5. Family size and proportion of persons engaged and dependent on agriculture

Category of farmer	Average family size	No. of persons engaged in agriculture	No. of persons depend on agriculture	No. of persons engaged in other job	% of persons in agriculture	Human: land (No./Acre)
Marginal (<2.5 Acre)	8.50	1.00	3.50	4.00	57.86	9.33
Small (2.5-5 Acre)	8.00	2.60	4.40	1.00	88.73	2.27
Medium (5-10 Acre)	7.80	3.20	3.90	0.70	92.35	1.10
Large (>10 Acre)	11.92	6.07	4.92	0.92	92.36	0.63
Overall	9.67	4.20	4.40	1.07	89.45	1.37

Source: Chaturvedi et al. (2002)

Table 6. Livestock holdings of different classes of farmers

Category of farmer	Average No. of cattle	Average No. of buffaloes	Average No. of sheep	Average No. of goats	Average No. of total livestock	Average No. of ACU holding	Livestock: land (ACU/ Acre)
Marginal (<2.5 Acre)	2.00	0.00	63.0	0.50	65.50	12.58	2.89
Small (2.5-5 Acre)	1.60	1.00	0.40	7.40	10.40	4.63	1.32
Medium (5-10 Acre)	2.30	2.80	31.5	7.50	44.10	12.53	1.90
Large (>10 Acre)	4.85	4.08	22.85	10.77	42.54	15.87	0.80
Overall	3.27	2.87	24.67	8.43	39.23	12.67	1.34

1 ACU = 1 cow =1 ox =0.75 bull= 0.75 buffalo= 4 calves= 6 sheep =6goats (Chaturvedi et al. 2002)

Table 7. Proportion of different species (%) reared by various classes of farmers

Category of farmer	Cattle	Buffaloes	Sheep	Goats	Sheep		Goats	
					Male	Female	Male	Female
Marginal (<2.5 Acre)	34.11	0.00	49.22	16.67	0.79	99.21	0.00	100.0
Small (2.5-5 Acre)	24.50	18.67	1.43	55.40	0.00	100.0	7.44	92.56
Medium (5-10 Acre)	18.58	19.02	43.61	18.79	3.70	96.30	3.01	96.99
Large (>10 Acre)	22.89	17.65	30.77	28.69	2.59	97.41	16.90	83.10
Overall	22.47	17.10	31.39	29.04	2.76	97.24	10.69	89.31

Source: Chaturvedi et al. (2002)

9. FODDER AND FRUIT TREE PLANTATION

Fodder and Fruit trees provide green fodder and fuel wood, check soil erosion, improve soil texture and fertility and provide shade to the grazing animals. Trees can be planted under silvipasture, agro-forestry, farm forestry and horti-pasture systems.

The dry forage yield increases with increase in the relative distance from various trees. Hence, the choice of suitable tree or bush and their appropriate number per unit area is important to maintain the forage productivity of ground cover and tree leaf fodder. Fodder trees and bushes viz. Khejri (*Prosopis cineraria*), Ardu (*Ailanthus excelsa*), Babool (*Acacia nilotica*), Neem (*Azadirachta indica*), Siris (*Albizia lebbek*), Zinja (*Bauhinia racemosa*), Mulberry (*Morus alba*) and *Dichrostachys nutans* may be planted under 2 or 3 tier silvi-pasture system for maximizing biomass and fodder production. A multi tier silvipastoral system with Ardu + Zinja + Cenchrus can provide 50 q dry grass-legumes- tree leaves/ha in semi-arid areas. Trees should be planted at a distance of 10 x 10 m and the bushes inserted in between two trees along with perennial Cenchrus grass. Arable fodder crops in association with Ardu (*Ailanthus excelsa*), Babool (*Acacia nilotica*) and Khejri (*Prosopis cineraria*) under agro-forestry and farm forestry provides as good yields as without them. Plantation of 50 to 100 trees/ha is recommended under cultivation of Bajra, Sesamum, Guar, Cowpea, Moong, Moth, Dolichos and Clitoria in semi-arid conditions.

Ber (*Zizyphus mauritiana*) was well adapted for hortipastoral or agri-horti systems. Cenchrus, Bajra and Moong under rain fed and Lucerne and Barseem under irrigated conditions can be successfully grown under Ber plantation. 40 kg N and 40 kg P_2O_5 in cereal and grass crops and 25 kg N and 40 kg P_2O_5 in legumes may be applied for higher biomass and fruit yield. Protection from biotic factors and watering at the seedling establishment stage be taken up to increase the survivability and enhance the growth. Jalshakti at 20 g/plant reduces the moisture depletion and promoted the plant growth and can be a practical and economic solution for moisture conservation.

Trees like Ardu, Khejri, Babul and Neem provide quality top feeds and their proper lopping is recommended for higher yields. Ardu trees provide higher dry fodder yield per year when lopped at six months interval. Khejri young trees produce higher dry fodder in annual lopping whereas fully-grown trees give higher yield when lopped at six months interval.

10. INTER CROPPING OF FODDER LEGUMES IN CEREAL CROPS

Inter cropping of legume does not affect the grain yield of cereal crops adversely and gives additional yield of fodder. Inter cropping of Dolichos with Bajra spaced at 45 x 15 cm can be adopted as an ideal combination. Legume may be introduced in line sown cereal crops under rain fed conditions. An erect type of legume like carpet legume (Dolichos) variety IGFRI. S-2214 may be sown between two rows of Bajra spaced at 45 cm. Rhizobium inoculation of Dolichos seeds can increase its fodder production by 20 %. Bajra and Dolichos mixture in 1:2 ratio shown at 30 cm spacing provides higher dry matter in low rain fall year and Maize and Dolichos in high rain fall year. Higher dry fodder was obtained by introducing Cowpea, Dolichos or Cluster Bean with Bajra crop.

11. INTRODUCTION OF FODDER CROPS

*Clitoria ternatea*may be sown at 50 x 30 cm spacing with 20 kg N and 40 kg P_2O_5/ha. The fodder may be harvested at an interval of 50 days for higher yield and better quality. Russian Giant, EC 4216, FOS-I-C-25 and NP3 varieties of Cowpeamay be sown with 15 kg N and 60 kg P_2O_5/ ha for higher fodder production. *Dolichos lablab* may be sown at 20 kg seed/ha at 30 x 30 cm spacing with the application of 20 kg P_2O_5/ha and harvesting at early to late flowering stage for higher production. F0S-277, Durgapura Safed and HFG-128 varieties of Guarmay be sown with20 kg N and 60 kg P_2O_5/ ha for higher fodder production. Other crops like Lucerne (T-9), Oats (Kent), Barseem and Methi + Oats for Rabi and Napier (NB-21), Hybrid Sorghum (Hara Sona), Bajra (Rajko, H-74) and Maize (African-tall) for summer and Kharif seasons are recommended.

12. CONCLUSION

Asian region has the highest and over 165.5 million buffaloes of the World. India possessing more than 56.80 % of the world and more than 58.50 % of the Asian population ranks first both in Asia as well as the world. The buffaloes greatly contribute to the livelihood and economy of Indian farmers. Buffaloes have distinct economical, managerial and biological advantages over other livestock species. Most of the buffaloes in arid and semi-arid regions in India are maintained under extensive system. But the density of livestock per unit grazing area

is increasing due sharp increase in livestock number and shrinkage of grazing lands resulting in vegetative destruction, ecological degradation and desertification. It is not possible to achieve optimum production from buffaloes managed under free range grazing management. The extensive management system should be gradually replaced by semi-intensive or intensive system and new technological innovations should be adopted to improve the productivity of indigenous buffaloes. Appropriate systems of management for different purposes may be identified. Production performance and economics of buffaloes vis-a- vis other livestock species may be studied in arid and semi-arid regions. The biomass production of the common grazing lands may be improved from 2.5-3.5 quintal to 25-30 quintal per hectare through protection, reseeding with perennial grasses and legumes and plantation of fodder trees. The areas in arid and semi-arid regions that cannot support crop production may be identified, developed through reseeding with perennial grasses and legumes and plantation of fodder trees and utilized for buffalo production with low investment. Both the quantity and quality of buffalo milk and meat can be improved through improved nutrition and feeding management. There is also very good scope for commercial meat production from buffaloes through semi-intensive and intensive feeding management. Efforts to identify and utilize the locally available crop residues and agro-industrial by- products for compounding complete rations and supplementary concentrate mixtures in the form of pallets and feed blocks should be intensified. Feed compounding plants capable of incorporating crop residues, tree leaves and natural vegetation in the complete feed mixtures, pallets and blocks should be set up in the rural areas. Packages of practices developed for commercial milk and meat production from buffaloes may be disseminated under field conditions duly supported by the Government, financial Institutions and the non-governmental organizations engaged in development of livestock industry in the country.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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