The necessity to develop a comprehensive feed library for livestock production in south Asia

D. B. V. Ramana, Abu Sadeque Md. Selim and Luis O. Tedeschi*

Regional feed library contains information in regional languages for available feeds/fodders and by-products that are being fed to the livestock. The lack of dynamic feed quality information containing complete nutrient profile, anti-nutritional factors, and digestibility information at the regional level for current varieties of feed and fodder species and their by-products leads to the misuse of valuable crop residues and supplements. The problem is more rampant in Southern Asian countries, like India and Bangladesh. This causes low per animal productivity, more green house gas (GHG) emissions, and wastage of valuable feed material. Modern feed libraries are dynamic and inlcude latest varieties/cultivars/genotypes of feed and fodder along with the most common feeds/fodders available in that region. This assists the small scale and commercial livestock producers in selecting the best locally available fodders/feeds combinations to meet the nutrient requirement of their livestock depending on the physiological stage and productivity. This allows efficient use of available feed resources, low-cost ration formulations and enhance the income of livestock farmers while contributing lower GHG emission from ruminant animals.

Keywords: Feed library, green house gas, livestock, nutrient profile, ration formulation.

SOUTH Asia, also known as the Indian subcontinent, comprises Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. Together, Bangladesh and India have the largest ruminant population in the region. At the beginning of the twentieth century, livestock in South Asia was responsible for 10–45% of the agriculture gross domestic product (GDP) and research technologies emphasizing chemical treatment of crop residues were common on farming systems[1]. Small-scale crop–animal systems in Asia show great diversity and complexity in the type of crops grown, and the cropping patterns used to raise diverse livestock species[2]. Livestock, more particularly ruminants, primarily utilize crop residues and other industrial by-products as their basal diet and added-value feed to convert inedible feeds into high-quality animal products (mainly milk, meat and fibre). Crop–animal systems constitute the backbone of agriculture in this region. The synergistic interactions between system components have a significant positive effect, greater than the sum of their individual effects[3]. In South Asia, particularly in India and Pakistan[4], the native grasses and shrubs are an important feed resource for ruminants, but other feedstocks are equally important in feeding livestock in this region.

Southern Asia has 4.9% and 6.5% of global land and agricultural area, whereas India and Bangladesh have only 2.3% and 0.14% of global land and 3.7% and 0.2% of agricultural area respectively. However, they hold 13.1% and 1.4% of livestock units (LSU) of the world. This creates pressure on land for natural resources along with feed resources in both India (0.9 LSU/ha) and Bangladesh (2.0 LSU/ha) compared to Asia (0.3 LSU/ha) and the world (0.3 LSU/ha). Further, the availability of crop residues was also low in these countries (8.5% and 1.4%) compared to South Asia (12.1%). Milk productivity per animal is 1592.6 and 205.8 kg in India and Bangladesh respectively (Figure 1). This is lower than the average world and Asian production (2407.6 and 1784.5 kg respectively).

Similarly, the average carcass weight of goat is 35 kg for India and 7 kg in Bangladesh, which is lower than the world and Asian average (79.9 and 74.8 kg respectively). In most cases feed and fodder scarcity is regarded a general problem for low livestock productivity in these countries. However, adequate objective information about feed quality in terms of crude protein, digestibility and presence of anti-nutritional factors is lacking. Without such information, appropriate long-term strategies for addressing low productivity cannot be developed and implemented. Alongside research on feed technology, quality assessment of available feed and fodder in

D. B. V. Ramana is in the ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad 500 059, India; Abu Sadeque Md. Selim is in the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur 1706, Bangladesh; Luis O. Tedeschi is in the Texas A&M University, Department of Animal Science, College Station, TX 77843-2471, USA.
*For correspondence. (e-mail: ramana.dbv@icar.gov.in)

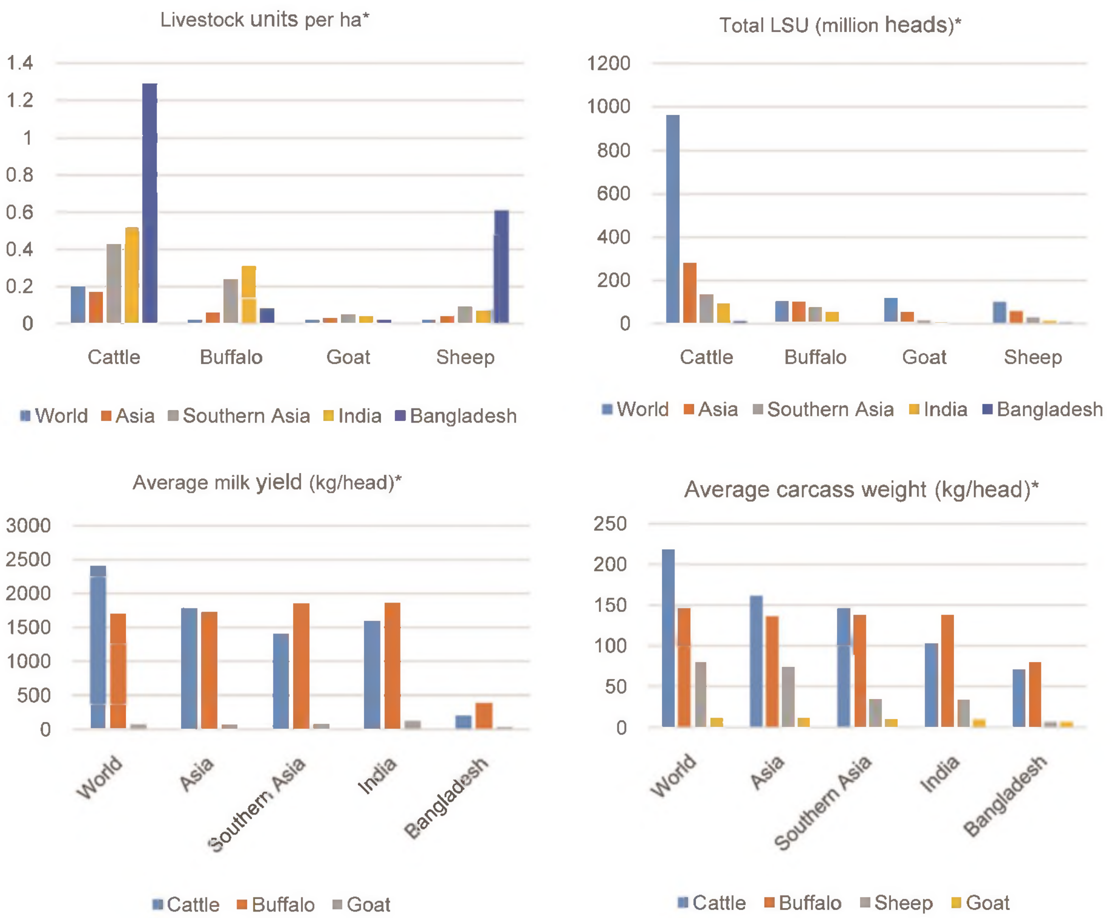

Figure 1. Livestock population and productivity in India and Bangladesh in comparison to the world, Asia and Southern Asia. *Source: FAOSTAT, 2018

different agro-climatic regions can not only aid in understanding key problems of low milk yield and lower carcass weights, but also in developing ruminant production technology dissemination strategies targeting potential adopters and in identifying investment options for viable small scale and or intensive feed production systems.

Livestock population and contribution to economy

According to the 68th round (July 2011–June 2012) National Sample Survey (NSS) estimate on Employment and Unemployment, 16.44 million workers were engaged in animal farming, mixed farming, fishing and aquaculture in India. The country has a vast resource of livestock and poultry, which play a vital role in improving the socio-economic conditions of rural masses. India has 190.9 million cattle, 108.7 million buffaloes, 135.2 million goats, 65.1 million sheep, 10.3 million pigs and 729.2 million poultry. Livestock production and agriculture are intrinsically linked, each being dependent on the other, and both crucial for overall food security. The country produced milk (155.2 million tonnes/year), eggs (83 million/year), meat (7 million tonnes/year) and wool (43.6 million kg/year) in 2014–15. The value of output from livestock sector (milk, meat, eggs, dung and increment in stock) was 7,261,540 million rupees[5] (about US$ 1.1 million).

Similar to India, livestock is a key component of agricultural economy in Bangladesh, and 83.9% of households own livestock (animals or poultry or both). About 45.9% households possess bovine stock and 76.3% possess poultry. On average, each household owns 1.52 bovine animals, 0.9 goat and sheep and 6.8 chicken and ducks. Bangladesh has 25.7 million cattle, 0.83 million buffaloes, 14.8 million goats, 1.9 million sheep and 118.7 million chicken which contributes about US$ 2,309 million[6]. The country produced 3.46 million tonnes milk, 2.33 million tonnes meat and 7304 million tonnes eggs in 2011–12. The contribution of livestock to overall GDP was provisionally estimated at 1.78% for 2013–14. Its share of agricultural GDP in 2013–14 was 14.08% (provisionally estimated). Despite its modest share of overall GDP, livestock serves an essential role as a source of protein, employment generation, export earning and provision of food security. It supports per capita intake of 14.3 kg milk, 8.90 kg meat and 115 eggs in 2011. The supply of milk and meat is only 15–20% of their annual requirement, and they are far below the average of developing countries (55 kg and 32 kg respectively)[7].

Agro-climatic zones and feed resources

India has about 20 ecological regions with 127 agro-climatic zones with different agro-ecological conditions and cropping patterns that yield many natural resources, crops, farming systems, production constraints and socio-economic conditions. Livestock depends primarily on crop residues along with other sources of fodder. The cultivated area under fodder crops amounts to 5.0% (9.72 million hectares) of the total cultivated area, whereas permanent pastures and grasslands constitute about 12.8 million hectares[8]. An area of 15.6 million hectares, classified as wasteland, is also used for grazing. Forests and their associated grasslands and fodder trees are another major source of grazing and fodder collection[9,10]. Trees and shrubs play an important role in ruminant feeding systems especially during lean season and studies on some fodder shrubs in these regions have shown a positive effect on animal performance[11]. Fodder cultivation is not practised by smallholders due to land constraints. However, private dairy farmers grow fodder either on their own land or lands leased from others. As most of the poor families do not have adequate land to grow fodder, they depend on grasses alongside roads, embankments and polders, and on aquatic plants. The smallholders suffer from a shortage of fodder during cropping seasons. Dairy farmers cultivate maize and other crops as fodder for their animals. Some of these are perennial plants, such as Napier, Para, German, Sudan grass, and Jumbo. However, fodder cultivation in arable lands depends on opportunity costs with another crop.

In the same fashion, Bangladesh has 30 agroecological zones and 88 agroecological sub-regions, which have been further subdivided into 535 agroecological units having similar agro-ecology, soil physiographic and climatic factors. Crop residues from field crops, fodders and feed grown in the different zones are the most important input of livestock rearing. Crop residues and grasses alongside roads, river bank, and char lands are the main feed for livestock. Seasonal variation is experienced in the availability of forages. Crop residues and a small amount of green forages are given to animals throughout the year. Shortage of fodder and high price of feed ingredients affect smallholders. Dairy units are closing due to shortage of fodder or grazing land/high price of feed ingredients.

Domestic feed production and availability to livestock

In India, the availability of feed resources regarding dry matter through crop residues, concentrates and greens for the period 1980–81 to 2011–12 increased from 341 to 574 million tonnes. This was chiefly due to the increase in the crop residues and to a limited extent by an increase in concentrates. Availability of greens more or less remained static over the years. Availability of crop residues, 176.69 million tonnes in 1980–81, increased by 167% in 36 years to 471.3 million tonnes in 2016–17 (Table 1). At the national level, out of the total 574.3 million tonnes of dry matter, 62.5% is accounted by crop residues. The availability of dry matter from coarse straws decreased by 29.1% (from 62.46 million tonnes in 1980–81 to 44.26 million tonnes in 2011–12) primarily due to decrease in cropped area under jowar, bajra and small millets. Sorghum, maize, rice, wheat, other cereals, millets and pulses contributed to the majority of crop residue with production estimates of 17.6 Mt, 78.8 Mt, 206.4 Mt, 12.16 Mt, 2.1 Mt, 41.1 Mt and 3.7 Mt respectively, in 2016 (ref. 12).

Sources of green fodder in India are cultivated agricultural land, forests and fallow lands. About 534.6 Mt of green fodder is available from 9.72 M Ha of cropped area under fodder production. Green fodder from forest land is 119.13 Mt from 79.42 million hectares of forest and tree cover[13] as 50% is only available for livestock. Green fodder availability from fallow land is 11 Mt from 11 million ha. Hence, the total green fodder availability from all three sources is around 664.73 Mt (ref. 14). Assuming that cattle, buffalo, sheep and goat grow at 1.46, 1.47, 3.09 and 2.48% respectively, based on the projected crop production and livestock population data, the deficit of crop residues, greens and concentrates would be 21.3%, 40.0% and 38.1% respectively, by 2025 while the requirement would increase as against availability. The availability and requirement of dry fodder, green fodder and concentrates are 433 versus 550, 600 versus 1000 and 65 versus 105 Mt respectively[15]. The fodder and feed deficit varies across states and found more acute and chronic in arid and semi-arid states where farming is dependent on rainfall and farmers have large livestock population.

Ruminant animals in Bangladesh are mostly raised on fibrous crop-residues and cereal milling by-products. The total roughage production in the country is estimated to be $51,056 \times 10^3$ tonnes in 2012, of which $5,781 \times 10^3$ tonnes come from cut-and-carry and roadside grazing (considering a daily availability of green grass per head). This results in a ratio of 89 : 11 for fibrous residues of the crop to green biomass. About $27,316 \times 10^3$ tonnes (53.5%) of fibrous biomass produced in the country is available to animals as feedstock, and the rest is used elsewhere. Cereal milling by-products, grains and oilcakes are the three major types of ingredients constituting concentrate feeds in Bangladesh. Bangladesh would require $73,800 \times 10^3$ tonnes of dry matter (DM) annually to feed the existing ruminant animals. An average ruminant diet sharing roughage and concentrate (DM) at a ratio of 2 : 1 will make a demand of

Table 1. Crop residues production (million tonnes)*

	Residues production (million tonnes)							
	Sorghum	Maize	Rice	Wheat	Other cereals	Millets	Pulses	Total
World	255.7	3180.3	963.2	974.3	20.8	113.4	15.9	5523.7
Asia	31.8	972.3	868.3	424.8	2.5	53.7	7.6	2360.9
Southern Asia	18.2	115.9	302.9	179.7	0.0	43.8	5.3	665.8
India	17.6	78.8	206.4	121.6	2.1	41.1	3.7	471.3
Bangladesh	0.0001	7.3	68.4	1.8	0.4	0.02	0.4	78.3

*Estimates based on the grain production, FAOSTAT, 2018.

49,200 × 10^3 tonnes DM and 24,608 × 10^3 tonnes DM respectively. The total annual roughage DM production is 51,000 × 10^3 tonnes, surpassing 3.8% of its total annual demand[16]. However, unfortunately, current annual availability to an animal is only 27,316 × 10^3 tonnes DM with a deficiency of 56.2% of the total demand. The most limiting factor is the mismatch of biomass production and supply. Most fibrous residues are produced during monsoon when sun drying, the lone system for preservation of crop residues, is difficult. So, they cannot be used for feeding animals during dry seasons. Collection, processing, and preservation of fibrous crop residues may increase their availability to animals.

Significance of fodder quality information

Efficient use of animal feed resources is a high-stake priority for sustainable livestock farming, especially in emerging markets where animal protein consumption is rapidly increasing. India holds a wide variety of plants, starchy tubers, and fruits, protein-rich plants, grasses and pulses that can be used as animal feed. To make optimal use of these local resources at each agro-climatic zone, livestock farmers need precise information about their nutritional value to develop balanced rations. While many feed libraries have been developed and are regularly updated for temperate and tropical countries[17], data for the Indian continent are inexistent or hard to find, and stakeholders often rely on data collected in temperate countries or other tropical countries. These feeds may not be representative of those that are used in India or the data may be out-of-date[17]. Further, the population of Indian subcontinent is 1,324.2 million and a steady increase of 1.2% per year is expected in the next ten years[18]. Therefore, adequate animal nutrition, especially ruminants, is necessary to continue providing animal products to the population. Nutrition models exist to assist producers in formulating and balancing diets for ruminants, but these decision support systems require correct and meaningful characterization of the feed[19].

Ruminant animal depends on diverse feed and fodder resources available in a region to meet the nutrient requirements for maintenance and production. The available feed resources vary across regions and seasons. Crops also vary from one agro-climatic region to another in terms of genotype or cultivar. Within the same plant, the quality in terms of feed value is entirely different from leaf to stem. Nitrogen content together with the contents of cell wall is the most important factor[20] in the supply of required quantity of nutrients. Animal performance, whether growth or milk production, depends upon two forage-related factors: (1) forage intake and (2) forage nutritive value. Collectively, these factors determine the quality of forage.

The chemical composition and nutritive value of fodder and feed available at one zone are entirely different from another because of the variation in soil, climate and production practices. Forages, grains and crop residues of *kharif* season and *rabi* season, for instance, may not have similar composition and digestibility due to variation in environmental temperature and rainfall. Furthermore, the variety and or cultivar and the days of harvest also differ from zone to zone and influences the availability of nutrients especially carbohydrates, proteins and deposition of anti-nutrients like proanthocyanidins and alkaloids. Further, climate change causes unusual behaviour in temperature, rainfall, and flooding pattern that affect either the natural growth or damage the pasture grasses. The development of accurate feed composition information is extremely important for livestock production and feeding systems that optimize the use of locally available feed resources. Improved nutrition is the most important and most feasible way to increase animal productivity to meet anticipated demand.

Climatic factors such as temperature, humidity, precipitation, light intensity and altitude may be dominant in controlling the nutritive value of plants. Although plants depend on the soil for their mineral nutrients, climatic factors affect respiration, assimilation, photosynthesis and metabolism to the extent that the mineral and organic matter content of plants may be strongly modified by climatic factors even when grown in the same soil[21]. Further, factors like cultivars, harvest frequency, fertilization, stage of maturity, pre- and post-harvest management influence forage yield and quality. Physical and chemical quality of soils exerts almost unlimited influence on the nutrient content of plants[22]. Significant differences in forage quality have been reported among different feed and fodder resources and within a feed of genotypes and cultivar grown under different agro-climatic conditions. Studies on eleven brown midrib and nine white midrib genotypes of sorghum germplasm revealed that these genotypes have different levels of crude protein, fibre composition, *in-sacco* dry matter, organic matter, cell wall components disappearance/digestibility besides the fodder yield, total phenolic content and availability index values[23]. Similarly, significant differences were noted for crude protein content and *in vitro* digestibility between sorghum stover types that were traded as fodder[24]. Nutritive value of fodder crop especially protein content decreases and fibre content increases with advancing crop stage.

Application and usage

A localized feed library can provide the latest scientific information to the extension and development workers, planners, project formulators, livestock farmers, science managers, policymakers, students and researchers and help them identify, characterize and properly use feed resources for the sustainable development of livestock sector. It will aid feed industry in the formulation of zonal specific complete feeds/feed blocks for livestock with varying production levels. For researchers, a comprehensive feed library can help in the identification of knowledge gaps and foster improvement in livestock nutrition, productivity and welfare.

The primary stakeholders of this exercise will be the livestock keepers. The available data would enable farmers in selecting efficient low-cost feed resources, which will help sustainable and profitable livestock production. It will lead to nutritional security at household level and food security at the country level. It will also increase the availability of animal products throughout the year at realistic prices and efficient utilization of available feed resources. The industry will also benefit as information will hasten ration formulations according to the season and availability of feed resources.

The prerequisite for establishment of feed media/library is strengthening of the existing quality control/assurance approaches that will help generate quality data by feed analysis laboratories, which is essential for formulating diets for optimum animal production. Proper feed formulation will also enhance animal productivity, animal product quality, and animal welfare. It will also decrease emissions from livestock and help in the containment of global warming. An additional effect of implementing these quality control approaches will be the strengthening of research and education capabilities of students graduating from R&D institutions. This will have long-term benefits and promote investment in both feed industries and R&D institutions. The implementation of quality control/assurance approach will promote better trading environment between developing and developed economies. Identification and incorporation of appropriate feeds having plant secondary compounds (condensed tannins and saponins) as supplements would help in reduction of GHG emissions from livestock. Feed library from local feed resources of South Asia may help in further development of compound feed industry.

Development and dissemination

Information for the most traditional feeds (e.g., paddy straw, wheat straw, sorghum kutty, rice bran, maize, soya) to lesser-known feed sources (sheanut, thorn less cactus, hydroponic fodder) should be included in the feed library. Available resources are extremely variable; however, for instance, despite its hardness, the redgram stalks is one of the alternative crop residues for drought conditions in rainfed arid areas. Blood collected in slaughterhouses, when heated and dried, is used as a supplement (blood meal) for chickens and even silkworms[25]. The feed library should contain a summary of useful information about feed sources, such as description, distribution, preparation and nutritional value in a table form in national and or local language. Detailed proximate analysis of the feed source: crude protein (CP), crude fibre (CF), soluble and non-soluble carbohydrates and protein, their fractionation for rumen degradability, and its overall digestibility (percentage ingested and retained by the animal) for different ruminants (e.g., cattle, sheep, goats) should be mentioned. The data sheets will also indicate the environmental impact of cultivation, whether positive or negative, potential constraints (presence of toxic substances and anti-nutritional factors) and precautions for use. It will become a ready reckoner for selecting feed ingredients with high digestibility and low emission value. This information should be updated and evaluated regularly to provide the complete feed assessment based on multiple criteria.

While there are many documented methodologies for developing a feed library, the true development is a continuous process that never ends. The feed library database requires updating of information on existing feeds, inclusion of new cultivars/varieties, and a constant evaluation of additional descriptions and characterizations (either chemical or physical) that are needed by evolving nutrition models to improve diet formulation and balancing. However, some standard steps in developing a feed library include: (1) selection of available forages, grains, feeds and grain by-products in each agro-climatic zone, (2) determination of chemical composition, digestibility and *in vitro* methane emission of existing and new feed resources, and (3) development of total mixed rations and feed blocks by various combinations of low methane emission and high digestibility feed ingredients to meet nutritional requirement of livestock as per Indian Council of Agriculture Research (ICAR) nutritional standards.

As discussed by Tedeschi and Fox[19], the publication of tabular feed libraries in the early 1910s helped disseminate scientific knowledge of feed composition and quality, as well as how to improve formulation and balance rations for livestock. But their adoption had many limitations. These included high cost for development, difficulties associated with their deployment and continuous updating. Online feed libraries, enabled by the advancement of the internet, could overcome some of these limitations. Feedipedia (https://feedipedia.org/), is an open access information system on animal feed resources that provides information on the nature (e.g., forage, haylage, grain, byproduct, treated versus untreated), occurrence (agro-ecological region of origin and availability), chemical composition (e.g., dry matter, oragnic matter, ether extract, CP, and CF, neutral and acid detergent fibres, cellulose, hemicellulose, lignin, minerals, vitamins, amino acids, and anti-nutritional factors), nutritive value (e.g., gross energy, net energy, total digestible nutrients, and digestible CP) and feed usability. Such usability includes any treatment for the use of available forages, feeds, and feed ingredients. There are other online platforms that can also be used for developing a comprehensive feed library, such as the information contained in the National Animal Nutrition Program (NANP; https://animalnutrition.org).

Expected outcomes

- Documentation of chemical composition, digestibility and *in vitro* methane emission of all the collected feed resources.
- Development of low methane and high digestible forage mixed rations or blocks.
- Awareness of farmers about green animal production systems.
- Productivity improvement in livestock.
- Long-term benefit of decreasing methane footprints.

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