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Revitalizing fodder production: Challenges and opportunities

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Abstract
India supports approximately 20% of the global livestock population and 17.5% of the human population, all within a mere 2.3% of the world's land area. While the human population is increasing by 1.6% annually, the livestock population is growing at a rate of 0.66% per year. These escalating numbers are vying for limited land resources with respect to food and fodder production. Consequently, only 4% of the total cultivable land in the country is utilized for cultivated fodders. Currently, there is a significant deficit in green fodder (35.6%), dry crop leftovers (10.5%), and concentrate feed ingredients (44%). Expanding the land area for fodder cultivation ahead of food and commercial crop cultivation is a challenging task. Therefore, the absolute challenge is to utilize the limited available land judiciously to its maximum potential for fodder production, considering the increasing demand from both human and animal populations. This can be achieved by adopting appropriate cropping systems, integrating fodder crops into food and other cash crop-based rotations, cultivating fodder on degraded lands through agroforestry systems, and exploring alternative green fodder options. Cropping systems incorporating forage crops offer a promising solution to address the fodder scarcity by utilizing resources more efficiently.

Keywords: Fodder, cropping pattern, opportunities, livestock, feed supplements, hydroponics

Introduction
Agriculture and livestock faming are deeply interrelated in the cultural, religious, and economic ways of human society engaged with mixed farming and livestock rearing serving as important source of rural people (Dagar, 2017) [19]. Livestock plays a multifaceted role by providing draught power, supporting rural transportation, yielding manure, serving as a source of fuel, and supplying milk and meat. Often, livestock stands as the primary source of monetary revenue for subsistence farmers and acts as insurance against crop failure. The impact of livestock extends beyond the agricultural sector, directly influencing the livelihoods and food security of billion people globally and affecting the diet and health of many more (Downing *et al*., 2017; Hurst *et al.*, 2005) [23, 34]. Approximately 70% of farmers rely on the combined contributions of the livestock and agriculture sector for their livelihoods (Ghosh *et al*., 2016) [27]. As of the 20th Livestock Census in 2019 [1], India's total livestock population has reached 535.82 million, marking 4.6% increase from the previous Census in 2012. Bovine population accounts for 302.82 million including cattle, buffalo, mithun, and yak. India having 57.3% of the global buffalo population and 14.7% of the world's cattle population. According to 20th Livestock Census (2019) [1], India has approximately 74.26 million sheep and 148.8 million goats.
India is the leading milk producer in the world; however, the animal productivity is comparatively low at 1538 kg/year, while the global average is 2238 kg/year. This difference is attributed to significant deficit in animal feed (Vijay *et al*., 2018) [83]. Addressing the challenges of fodder and feed resource development is necessary for sustaining cattle husbandry in the country. The increasing competition for cultivable land among various uses has rendered further increases in the acreage of fodder crops seems to be impossible nowadays (Kumar, 2012; Agrawal *et al.*, 2012) [51]. Consequently, there is an urgent need to enhance the productivity of cultivated fodder crops on the existing land to meet the growing demand for cattle fodder. In addition, the utilization of non-arable land areas for pastures emerges as a viable option to maintain a balance in meeting the rising demand for fodder (Dahiya & Kharb, 2003; Vijay *et al*., 2018) [21, 83].

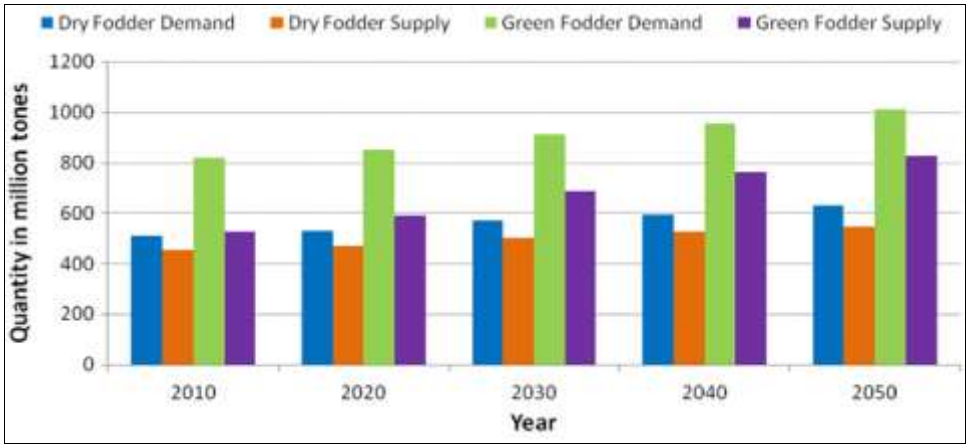


Fig 1: Year wise demadd and supply of green and dry fodder in India (Source: IGFRI Vision. 2020)

Current status of fodder production in India

India currently faces a severe fodder crisis, attempting to meet the demand for livestock feed amidst dwindling land resources. The challenge is compounded by irregular fodder supply during summer and drought, leading to supply chain gaps. Recent estimates indicate an 11.24% deficit in green fodder, a 23.4% shortage in dry fodder, and a 29% deficit in concentrates. To address this, experts recommend dedicating 14-17% of land for fodder cultivation. Presently, 8.4 million hectares (about 4% of the gross cropped area) are allocated to fodder cultivation. India experiences a significant imbalance in fodder production influenced by factors such as cattle type, climate, socioeconomics, and crop patterns. Livestock, particularly cattle and buffalo, predominantly rely on cultivated fodder, supplemented with gathered grasses. Sorghum and Egyptian clover contribute 54% to total fodder during Kharif and Rabi seasons. Various grasses and legumes are cultivated, with farmers resorting to tree-top fodder during scarcity. The area for permanent pastures is diminishing, impacting pasture productivity. Crop residues are expected to contribute 54% to fodder, while rangelands and cultivated fodder crops will provide 18% and 28%, respectively. Examining forage supply across states reveals disparities. States like Uttar Pradesh face a 50% green fodder shortage, while Gujarat shows a surplus. Similarly, dry fodder shortages are observed in states like Assam, Karnataka, and Tamil Nadu, with surplus production in others. These variations highlight challenges in ensuring consistent fodder availability for livestock nationally. Livestock feed, primarily sourced from coarse grains, relies significantly on four key cereals-corn, barley, sorghum, and bajra-contributing to nearly 44% of total cereals. Of these, maize constitutes about three-fourths, while barley makes up 15%. Sorghum and millets account for around 11%, with India producing less than 3% of the global production, approximately 30 million tonnes annually. While coarse grains in affluent nations are mainly used as cattle feed, in India, their primary application is for direct consumption, especially in rural areas. Various millet varieties, such as Kodo, finger millet, little millet, foxtail millet, barnyard millet, proso millet, and savan millet, are crucial for fodder, emphasizing the role of dietary grains in ensuring animal productivity. The surge in livestock population is evident in India, with the cattle population increasing by 0.84% from 190 million in 2010 to 192 million in 2020, and buffalo numbers reaching 109.85 million. Goats have seen a 9.1% increase, totaling 148 million. This growth puts stress on limited land resources needed for green fodder production, posing challenges in ensuring adequate nutrition for animals. Fodder crops, essential for animal feed in forms like hay, silage, and forage, cover 8.3 million acres in India. Sorghum and berseem constitute 54% of the total cultivated fodder area. However, this 8.3 million hectares pales in comparison to the 48 million hectares dedicated to rice cultivation alone in India. The future perspective involves addressing the research gap in neglected crops to meet the escalating demands of the growing livestock population.

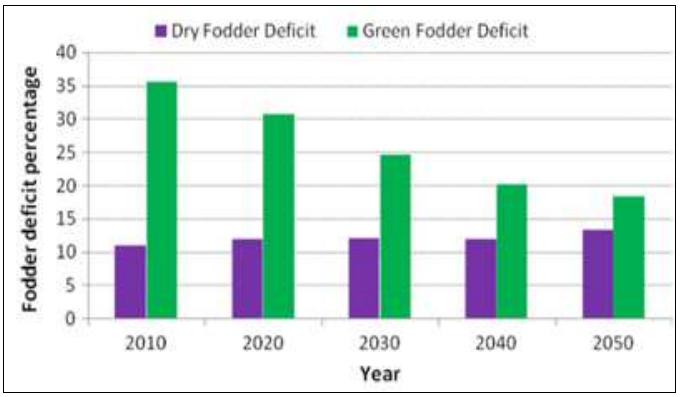


Fig 2: Year wise green and dry fodder deficit (Source: IGFRI vision 2050)

In India, fodder production faces challenges due to diminishing land resources and diverse factors such as climate, cropping patterns, and socioeconomic conditions. The deficit in green, dry, and concentrate fodder is currently at 11.24%, 23.4%, and 29%, respectively. Experts recommend allocating 14-17% of land for fodder cultivation to address the shortage. Currently, fodder is cultivated on 8.4 million hectares, nearly 4% of the gross cropped area. The cultivation of sorghum and Egyptian clover in the Kharif and Rabi seasons contributes to 54% of the total cultivated fodder area. Additionally, various grasses and legumes are grown, such as hybrid Napier, guinea grass, para grass, velvet bean, and stylo. The livestock population in India has increased, putting further pressure on fodder resources. The area dedicated to permanent pastures and grazing land is 10.34 million hectares, gradually decreasing over time, leading to declining pasture productivity due to overgrazing. The projected demand for green and dry feed by 2050 is 1012 and 631 million tons, respectively, creating an anticipated deficit of 18.4% in green fodder and 13.2% in dry fodder. To bridge this gap, the supply of green forage must increase at a rate of 1.69% per annum. Despite government policies, there is a lack of research studies evaluating the on-ground situation. Fodder in India

primarily comes from crop residues, cultivated fodder, and community resources. Challenges include diverse forage crops, non-commercial nature of fodder, and transport cost inefficiencies.

Assessment of dry fodder availability

The assessment of dry fodder availability and requirement in India is based on various factors such as major utilizable crops, harvest index, production, and utilization patterns for each state. The analysis includes crop residues from cereals, pulses, and oilseeds, along with dry forages from sources like forests, wasteland, fallow land, and cultivated fields post-harvest.

- **Small States and Union Territories:** Except for Andaman and Nicobar, there is an overall deficit of 59.1%, with Delhi having the highest deficit of 100%. Primary sources include forests and kitchen/horticultural/top feed/farm waste, but overall demand and supply are low.
- **North East Zone:** There is an overall surplus of 14.0% of dry fodder, with forests being the major source.
- **East Zone (Bihar, Jharkhand, Odisha, West Bengal):** Faces a deficit of 43.9%, with food grains crop residue as the primary source. Except for Odisha, all other states are in deficit.
- **West Zone (Gujarat, Rajasthan, Goa, Maharashtra):** There is a deficit of 43.5%, with food grains crop residue, forests, and other sources being the primary contributors. Except for Goa, all other states are in deficit.
- **Central Zone (Chhattisgarh, Madhya Pradesh, Uttar Pradesh):** Chhattisgarh (9.8%) and Madhya Pradesh (0.8%) are surplus in dry fodder, while Uttar Pradesh (30.4%) is deficit, resulting in an overall deficit of 16.4%. Food grains crop residue is a major source.
- **Hill Zone (H.P., J & K, Uttarakhand):** There is an overall surplus of 55.9%, but practical deficit due to challenging terrains. Major sources include forests, pastureland, and food grains.
- **North Zone:** Punjab and Haryana have a surplus of 31.7%, with food grains crop residue as the major source.
- **South Zone (Andhra Pradesh, Telangana, Karnataka, Kerala, Tamil Nadu):** Faces an overall deficit of 27.00%, with food grains crop residue as the primary source. Except for Kerala, all other states are in deficit.
- **All India Basis:** There is an overall deficit of 23.4% in dry fodder availability. The total availability is 326.4 million tons against a requirement of 426.1 million tons. Major sources include food grains, followed by forests and other sources like groundnut and sugarcane.

Green Fodder Availability Estimates

Estimates were based on resources like forage crops, grasses from forests, pastures, grazing lands, and cultivable wastelands.

- Green fodder availability was estimated considering cultivated areas, cropping intensity, productivity, etc.
- Results showed that among Union Territories (UTs) and Delhi, all UTs were in deficit, with an overall deficit of 76.20%. Chandigarh had the highest deficit of 97.9%.
- In the North East Zone, there was an overall deficit of 23.1%. Some states like Mizoram and Arunachal Pradesh had surplus green fodder, while Tripura, Sikkim, and Meghalaya faced deficits.
- The Hill Zone (H.P., J & K, Uttrakhand) had an overall deficit of 24.9%. Himachal Pradesh was surplus, but J&K and Uttrakhand faced deficits.
- In the North Zone, Punjab and Haryana were surplus, with an overall surplus of 133.05%. These states had well-developed dairies and high levels of technology adoption.
- The West Zone had an overall deficit of 6.3%, with Gujarat and Maharashtra being surplus while Rajasthan and Goa were in deficit.
- In the Central Zone, Chhattisgarh and Uttar Pradesh faced deficits, while Madhya Pradesh was surplus, with an overall deficit of 4.8%.
- The East Zone had an overall deficit of 41.2%, with Jharkhand having the maximum deficit of 67.7%. There was a need for new technologies and increased allocation of areas for forage.
- On an all India basis, there was an overall deficit of 11.24% in green fodder availability.
- Total green fodder availability was 734.2 million tonnes against a requirement of 827.19 million tonnes.
- Major sources of green fodder in India were cultivated land, followed by pasture land and forests.

Challenges of fodder production

1. Increasing livestock population: India's livestock population has increased from 512.06 million in 2012 to 535.82 million in 2019, marking a 4.6% growth with an annual rate of 0.66%. This growth is accompanied by a shift in composition, with a 6% decrease in indigenous cattle and a 26.9% increase in exotic/crossbred cattle. Poultry numbers have risen significantly to 851.81 million, attributed to a 46.8% increase in backyard poultry birds. Buffaloes increased to 109.85 million, goats to 148.88 million, and sheep to 74.26 million. Uttar Pradesh leads in livestock with 67.8 million. This surge puts additional pressure on limited land resources for green fodder, posing a significant challenge in effective management and productivity optimization.

Table 1: Livestock population in India

S. No	Species	2012 (in millions)	2019 (in millions)	Percent change	Present ranking in the world
01	Cattle	190.9	192.52	0.8	Second
02	Buffaloes	108.7	109.85	1.1	First
	Total Bovine (including Mithun and Yak)	299.82	302.82	1.0	First
03	Sheep	65.07	74.26	14.1	Third
04	Goats	135.17	148.88	10.1	Second
05	Pigs	10.29	9.06	−12.03	—
06	Camel	0.40	0.25	−37.05	Tenth
	Total livestock	512.06	535.82	4.64	First
	Total poultry	729.21	851.81	16.8	Seventh

2. Resource constraints: In India, limited land and water resources, comprising only 2.4% of the world's land and 4% of freshwater, face challenges in fodder production. Constraints include threats from animals, pests, diseases, low prices, poor-quality seeds, and insufficient high-quality seeds. Successful fodder cultivation demands fertile land, quality water, increased fertilization, and proper management. Frequent harvesting leads to substantial expenses, and the scarcity of timely inputs, along with limited cultivable land, hinders fodder yield improvement. Inefficient preservation and storage techniques elevate the risk of wastage, discouraging substantial investments in fodder production (Dagar, 2017; Biemond *et al*., 2012; Meena *et al*., 2018; FAO, 2011) [19, 14, 55].

3. **Climate change on fodder production:** Climate change in recent decades has adversely affected the production and quality

of fodder crops for livestock. The International Plant Protection Convention (IPPC) reports a global average surface temperature increase of 0.3 °C to 4.8 °C over the 20th century. This change presents significant challenges to fodder production, impacting both quantity and quality. Even slight variations in environmental conditions, especially temperature, substantially affect the dry matter (DM) content and nutritive value of fodder. Rising temperatures, heatwaves, and increased extreme weather events induce heat stress in plants. Altered precipitation patterns and heightened drought frequency associated with climate change lead to reduced fodder yields and poor forage quality. Shifts in climate patterns disrupt traditional growing seasons for fodder crops, affecting established agricultural practices and causing shortages and nutritional imbalances during critical times for livestock. Climate change also fosters favorable conditions for the proliferation of pests and diseases, resulting in reduced yields and quality. Changes in temperature and precipitation patterns impact nutrient availability and soil structure, influencing fodder crop growth. Intense storms, floods, or cyclones linked to climate change cause physical damage to crops, disrupting agricultural practices and leading to direct losses in fodder production. Adapting to these challenges necessitates sustainable and climate-resilient agricultural practices, including the development and promotion of climate-resistant fodder varieties, improved water management, and the adoption of conservation and sustainable land management practices. Policymakers should also focus on supporting farmers in mitigating and adapting to the impacts of climate change on fodder production.

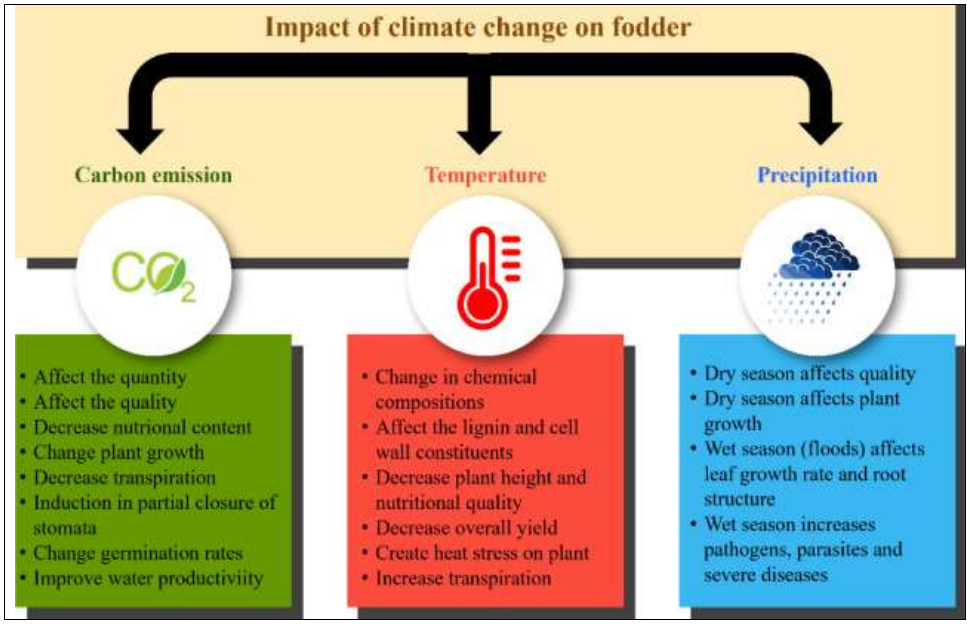


Fig 3: Possible impact of climate change on fodder production

4. Unavailability of quality seed of improved varieties

The availability of good-quality seeds or planting material is a significant limitation contributing to the reduced area and production of forage crops (Parihar, 2010) [64]. Productivity and seed availability are crucial considerations, since forage crops are primarily perennial and cultivated by vegetative propagation for enhanced vegetative potential, resulting in low seed productivity (Vijay *et al*., 2018) [83]. Indeterminate growth, uneven maturity, seed shattering, ill filled seeds, seed dormancy, and climatic factors such as photoperiod, thermos-period, and humidity, among others, are considered physiological limitations for fodder seed production. Weather extremes represent a climatic constraint, while factors like low density of ear-bearing tillers, susceptible to lodging, poor harvest index, lack of seed production technology fall under management factors for fodder seed production. The absence of an exclusive forage seed market further adds to these challenges, collectively limiting the availability of quality seeds for fodder crops (Vijay *et al*., 2013) [54].

Opportunities in fodder production

The livestock sector is a crucial component of Indian agriculture, contributing around 28.63% to the total value of output and accounting for approximately 4.19% of the country's GDP in the fiscal year 2018–19. India has experienced substantial growth in milk production over the past few decades, becoming the world's largest milk producer, with 187.7 million tonnes produced in 2018–19. This surge in milk production is mainly attributed to the increase in the cattle population. Despite this growth, the productivity of Indian livestock, particularly in terms of milk yield, remains low compared to major milk-producing countries. The average milk yield per lactation for cattle in India is approximately 1538 kg, significantly lower than the global average of 2238 kg and the European average of 4250 kg. This indicates a 31% lower productivity globally and a 63% lower productivity compared to Europe. One of the primary reasons for this low productivity is malnutrition or under-nutrition among livestock, stemming from a significant gap between the demand and supply of feed and fodder in the country. The shortage of green fodder, especially during the summer months, forces farmers to rely disproportionately on concentrate supplements to maintain milk production.

Forages are recognized as the most nutritious and cost-effective feed for dairy animals. Green fodder, in particular, is crucial for animal health and sustainable milk production. It provides essential vitamins, minerals, and energy, enhancing digestion and reducing the overall cost of milk production. Forages are also significantly more economical, being 5–14 times cheaper as a source of key feed ingredients like digestible crude protein and total digestible nutrients compared to concentrates. There is a

substantial opportunity for improvement in the livestock sector through increased fodder production in India. Growing fodder crops, especially in combination with legumes, has the potential to enhance palatability and digestibility, contributing to improved animal health and productivity. Addressing the gap between demand and supply of green fodder can play a pivotal role in boosting the overall productivity of the livestock sector in the country.

The way forward

Strategies to augment the supply of green fodder encompass several approaches:

1. **Expanding Cultivated Fodder Crops:** Increasing the acreage alloted to cultivated fodder crops.
2. **Enhancing Productivity:** Adopting improved cultivation technologies to boost the productivity of existing fodder crops. Promoting innovative farming practices. Facilitating access to high-quality seeds and planting material for fodder crops.
3. **Integrating Fodder Crops in Cropping Systems:** Including fodder crops in crop rotations to optimize land use.
4. **Utilizing Marginal Lands:** Exploring the cultivation of fodder crops on marginal lands.
5. **Hydroponic Fodder Production:** Embracing hydroponic techniques for efficient and controlled fodder cultivation.
6. Exploring Alternative Fodder Sources: Investigating alternative fodder sources such as *Azolla*.
7. **Optimizing Crop Residues:** Efficiently utilizing crop residues, such as rice and wheat straw, to overcome shortages in dry fodder.

Despite these strategies, the potential for further expanding cultivated fodder areas is constrained by demographic pressure on land resources especially due to food crops. As a result, a balance between food and fodder production becomes essential, emphasizing the need for sustainable and resource-efficient practices in agriculture.

Increasing Fodder Productivity

- Implementing Integrated Nutrient Management (INM) practices is crucial for sustaining soil fertility and achieving higher forage crop productivity. Prioritizing nutrient management in fodder-based cropping systems, especially for nutrient-demanding Poaceae family crops, is essential (Palsaniya and Ahlawat, 2009) [66].
- Crop + livestock integrated farming systems have proven successful in improving fodder productivity, emphasizing the need for holistic approaches to enhance overall system productivity (Antil & Raj, 2020; Babu *et al*., 2020; Yadav *et al*., 2007) [6, 8, 85].

Enhancing Availability of Good-Quality Seed

- The shortage of quality seeds for forage crops in India is a significant constraint.
- Only 25%–30% of the required quantity of quality seeds is available for cultivated fodders, and this figure drops to less than 10% for rangeland grasses and legumes.
- Strategies include developing superior varieties of forage crops characterized by high yield and quality, creating awareness about the importance of using high-quality seeds, increasing seed replacement rates, establishing an efficient seed chain, and improving the seed chain network (Thomas & Thomas, 2019) [82].
- Specific measures involve promoting seed production through a participatory approach, enhancing marketing facilities, utilizing forest waste lands for seed production, and applying innovative research methods (Palsaniya *et al*., 2010; Vijay *et al*., 2018) [83, 62].

Seed Quality Control in Forage Crops

- Seed quality is a critical factor influencing forage crop productivity, and effective seed quality control is necessary.
- Quality seeds exhibit genetic purity, physical purity, high germination percentage, vigor, and freedom from weed seeds, inert matter, and seed-borne pests and diseases (Elias, 2006) [25].
- Seed health is crucial, and seed quality control involves checks, certification, and adherence to official regulations, ensuring genetic purity, freedom from contaminants, and disease-free status (Bradbeer, 2013) [16].
- Encouraging private sector involvement in fodder seed production and implementing standardized seed quality control measures are vital to address existing challenges in perennial grasses and legumes (Rahman & Cho, 2016) [71].

Methods for Developing Planting Material in Perennial Grasses

- Traditional methods of producing planting material like rooted slips for perennial grasses such as Bajra Napier Hybrid (BN Hybrid) are costly and labor-intensive.
- High-density nursery techniques, involving growing seeds in a nursery before transplanting into the field, offer benefits like reduced labor, lower costs, and efficient production of rooted slips for grass varieties like BN Hybrid (Vijay *et al*., 2018) [83].
- Methods like slant basal cutting and single-budded tray nurseries are employed for quick production of rooted slips and seedlings, respectively, offering practical and cost-effective alternatives.

Fodder Crops in Cropping Systems

- Diversifying traditional rice-wheat cropping systems by integrating fodder crops on a rotational basis addresses challenges of soil health degradation and year-round green fodder availability.
- Sudan grass is recommended for high biomass production in summer and rainy seasons, while berseem, multi-cut oats, and dual-purpose barley are suitable for subsequent rabi seasons.
- Napier grass, known for quick re-growth after cutting, serves as a perennial option, and the choice of crops depends on regional conditions and composition of crop + livestock integrated farming systems (Banjara *et al*., 2021) [10].

Fodder Production from Marginal Lands

- Utilizing degraded and marginal lands through agroforestry systems presents an opportunity to meet fuelwood and fodder demands in India.
- Agroforestry practices involving stress-tolerant tree species, shrubs, and grasses can be successful in challenging conditions, aiding in sand stabilization and fodder production.
- Approximately 29 million hectares of open forests can be used for growing fodder on partially shaded terrain, contributing to year-round fodder availability (Dagar &

Minhas, 2016; Parmar & Misra, 2020) [20, 65].

Alternate Sources of Fodder Production (*Azolla*)

- *Azolla*, an aquatic fern forming a symbiotic association with blue-green algae, is recognized for its high nutritional value, serving as a protein-rich supplement for various livestock.
- With high protein content, low lignin, and minimal carbohydrates and oil, *Azolla* offers a sustainable and economical feed substitute, contributing to increased milk yield and improved weight in livestock (Jain *et al*., 2019; Katole *et al*., 2017) [38, 44].

Overcoming the Dry Fodder Shortage

- Roughages like hay and straw, particularly from rice and wheat residues, fulfill a significant portion of the dry fodder demand in India.
- Addressing the challenges of low-quality feedstuffs, the 'complete feed system' is introduced, involving a balanced mixture of all dietary elements to provide a nutritionally sufficient diet, improving livestock health and productivity.

Hydroponic fodder production

Hydroponics is an innovative method for cultivating fodder, offering several advantages over traditional methods. This soil-less technique involves growing plants in a controlled environment, typically a greenhouse or polyhouse, using a water- or nutrient-rich solution. Hydroponic fodder production addresses various challenges associated with conventional cultivation, providing a sustainable and efficient alternative. Hydroponic fodder is grown in a controlled environment without soil. Seeds are germinated and grown in trays using a water- or nutrient-rich solution for about 6-8 days. Various cereals (barley, oat, wheat, sorghum, maize) and legumes (alfalfa, cowpea) are successfully cultivated. Essential inputs include seeds, water, sunlight, and supplementary nutrients. Hydroponic systems require a smaller land area compared to traditional farming. Green fodder is ready for consumption in a short period, typically around 7 days. Hydroponic fodder appears as a dense mat of 20–30 cm tall green plants, including roots and seeds. Traditional agricultural methods demand substantial water usage for fodder production. Controlled Environment (CE) hydroponic fodder production is gaining attention for its water-saving benefits. Water consumption is significantly reduced in hydroponics, with CE systems using only 2-3 liters to produce 1.0 kg of green fodder. The cost of seeds constitutes a significant portion of the overall expense in hydroponic fodder production, accounting for around 90%. Despite higher seed costs, the benefits of enhanced palatability, digestibility, and nutrition make hydroponic fodder an attractive option. Hydroponic fodder is considered more palatable, digestible, and nutritious compared to traditionally grown fodder. Animals fed with hydroponic fodder may experience additional health benefits.

Hydroponic fodder, especially in Controlled Environment systems, addresses water scarcity concerns by using water more efficiently. As a feed supplement, it is recommended to provide 5–10 kg of fresh hydroponic fodder per cow per day. Hydroponically grown crops exhibit faster growth—up to 50% faster—and yield higher quantities of better-quality fodder. This method of fodder production is considered eco-friendly and helps alleviate pressure on land, cope with water scarcity, and mitigate the impact of irregular rainfall and frequent droughts on traditional fodder crops. Hydroponics is being increasingly adopted in many countries to produce green fodder for cattle, poultry, and other livestock in response to agricultural challenges. There are various hydroponic systems, and they can be broadly categorized into open and closed systems. In open systems, the nutrient solution or water is not recycled, while in closed systems, excess water is recycled. Open hydroponic systems, where the nutrient solution or water is not recycled, are not considered practical due to water and nutrient wastage. Hydroponic fodder grown in closed systems eliminates the need for fertilizers and chemicals, making it a sustainable solution for livestock production.

There are six main hydroponic techniques based on the solution/water feeding methods:

- Nutrient Film System (NFS)
- Deep Water Culture System (DWCS)
- Aeroponics System (AS)
- Ebb and Flow System (EFS)
- Wick System (WS)
- Drip Hydroponic System (DHS)

A. Standard Technique

1. **Advantages:** This involves spraying a nutrient solution at intervals and draining excess water back for recycling.
2. **Disadvantages:** Energy-intensive, but effective for certain crops.

B. Wick System

1. **Advantages:** Simple and requires no energy for water movement.
2. **Disadvantages:** May not be suitable for large-scale production.

C. Deep Water Culture System

1. **Advantages:** Simple and less energy-intensive.
2. **Disadvantages:** Requires a large volume of water and is susceptible to water-borne diseases.

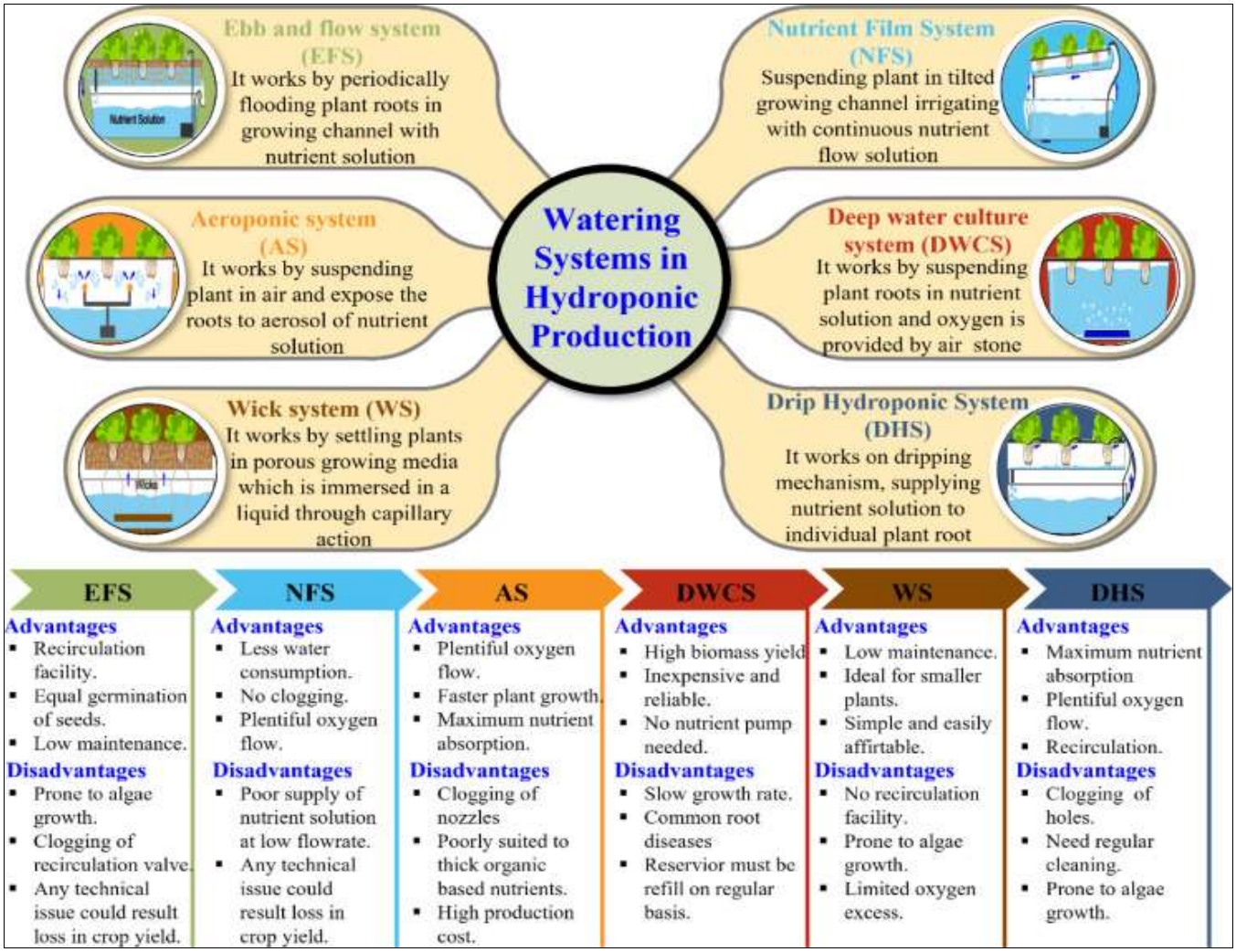
D. Nutrient Film System (NFS)

1. **Advantages:** Growing trays are positioned at a slope for drainage and recirculation.
2. **Disadvantages:** The slope needs to be optimized; water-saving potential.

E. Controlled Environment Fodder Production (CEFP):

1. **Advantages:** Innovative approaches for water-saving.
2. **Disadvantages:** Requires further research to minimize the risk of molds and waterborne diseases, crucial for fodder production.

For hydroponic fodder production, the Nutrient Film System (NFS) is considered promising. Studies on green wheat fodder in NFS have reported that the highest yield can be achieved with trays sloped at a specific angle, such as 6.5%. The water-saving potential in Controlled Environment Fodder Production (CEFP) is an area that requires additional research to minimize the risk of molds and waterborne diseases, which are critical factors in fodder production. Choosing the right hydroponic system depends on the specific goals, resources, and constraints of the farm or facility. Each system has its own set of trade-offs, and optimizing for factors like water efficiency, energy use, and disease control is essential for successful hydroponic fodder production.



Conclusion

The production of livestock relies heavily on a consistent and healthy supply of fodder. However, during the summer season, there is often a shortage in the supply of fodder. This can be achieved through strategies such as adopting suitable cropping systems that integrate forage crops, incorporating fodder crops into existing food and cash crop rotations, utilizing degraded lands for fodder production via agroforestry systems, and exploring alternative green fodder options. These approaches aim to optimize land use, striking a balance between food and fodder production to meet the rising demands of both human and animal populations. To address this challenge, alternative methods like hydroponic fodder production can be considered. Hydroponic fodder systems offer a viable solution, requiring only a fraction of the water used in conventional agriculture while providing high-quality feed for livestock.

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