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# Nutritional potential of natural and cultivated fodders in Uttarakhand: A comprehensive review paper

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**Abstract**
Livestock are integral to Uttarakhand's rural socio-economy, providing income, food security, and employment across its diverse Himalayan landscape. Fodder availability and quality are crucial for animal productivity and the socio-economic stability of the large population engaged in mixed crop-livestock farming. This paper reviews the diverse natural and cultivated fodder resources available across Uttarakhand's distinct physiographic regions and forest types. Natural fodder, predominantly from forests, is vital, especially in hilly regions and lean seasons, including diverse tree leaves, shrubs, and grasses, offering varied nutritional profiles. Fodder availability varies significantly with forest type and altitude, from seasonal flushes in lower deciduous forests to crucial winter lopped fodder in temperate forests and summer alpine grazing. Cultivated fodder is indispensable, particularly in the Tarai plains and as hill supplementation, encompassing seasonal crops (Kharif, Rabi, Zaid) like maize, berseem, and cowpea, alongside perennial options such as Hybrid Napier and Lucerne for continuous, high-yielding production. Crop residues (wheat, paddy straw, millet residues) provide essential dry roughage during scarcity. Altitudinal variations define fodder availability, from intensive cultivated systems in the Tarai plains (e.g., "Hybrid Napier + Berseem" sequences) to mixed forest and agricultural reliance in the Foothills. Effectively integrating diverse fodder varieties with sustainable management practices is vital for enhancing livestock productivity and ensuring rural socio-economic stability in Uttarakhand.

**Keywords:** Livestock, fodder resources, natural fodder, cultivated fodder, regional variation

## Introduction
Uttarakhand, a northern Indian state nestled in the Himalayas, boasts a diverse landscape and rich biodiversity, stretching from the snow-capped peaks of the higher Himalayas to the fertile Tarai plains. Livestock plays a crucial role in the socio-economic fabric of Uttarakhand, providing a significant source of income, ensuring food security, offering employment, and diversifying farm activities for rural communities. The state supports a substantial livestock population, including approximately 0.4 million non-descript cattle, 0.5 million buffaloes in milk (collectively contributing 1.2 million tons of milk annually, with buffaloes providing the larger share), and 1.2 million goats (Department of Animal Husbandry, Uttarakhand, 2023) [3]. This deep integration of livestock into the rural economy, coupled with the small-scale nature of farming, underscores how fodder availability and quality directly influence not just animal productivity but also the socio-economic stability and food security of a large segment of Uttarakhand's rural population.

Approximately 70% of Uttarakhand's population relies on agriculture and livestock production for their livelihood, with a significant portion engaged in mixed crop-livestock farming, particularly in the hilly regions. While about 47.4% of the state's working population is primarily engaged in agriculture, forestry, and fishing (NITI Aayog, 2023) [22], feed shortages remain a chronic issue. The state's annual livestock fodder deficit is approximately 109 million tonnes; only 143 MT are produced against an estimated demand of 252 MT, resulting in a substantial 43% gap (Livestock Census, 2019). Regions across the state, especially the Garhwal and Kumaun divisions (including districts like Tehri Garhwal, Chamoli, Nainital, Bageshwar, Pithoragarh, Almora, Dehradun, and Pauri Garhwal), are involved in fodder production, utilizing common lands, private plots, and natural grasslands, encompassing subtropical, intermediate, and temperate ranges (Himmotthan, n.d.; Singh & Singh, 2017) [10, 31].

**Types of Fodder Available in Uttarakhand**

**(A) General Fodder Types across the State**

**Forest-Based Fodder**

Forests in Uttarakhand are not just ecological treasures but also a vital source of fodder for livestock, especially in hilly and remote areas where cultivated land is scarce. This "forest-based fodder" provides essential nutrition, particularly during lean seasons when conventional feed sources are limited. The diversity of forest types in Uttarakhand, ranging from tropical moist deciduous to subalpine and alpine forests, contributes to a wide array of fodder species.

**1. Tree Leaves (Tree Fodder/Lopping):** Tree leaves form a significant part of the diet for various livestock, particularly goats, sheep, and even cattle, due to their year-round availability and generally good nutritional profile.

- ***Quercus leucotrichophora* (Banj Oak):** One of the most widespread oak species in the Himalayan region and a very common fodder source. While traditionally used, research indicates that banj oak leaves have a relatively low protein content (9-13% DM) and a very high fiber content (NDF 60-70% DM, ADF 38-60% DM). A significant concern with banj oak is its high tannin content (3-4% or more), particularly condensed tannins, which can bind to proteins and reduce their digestibility and overall palatability for ruminants. Despite its limitations, it is widely utilized, especially when other fodder is scarce, and can serve as a protein supplement in low-quality diets (Joshi *et al.*, 2016; Feedipedia, 2011) [12, 6].
- ***Grewia optiva* (Bhimal):** Bhimal is a highly valued fodder tree, especially during the lean winter months when green fodder is scarce. Its leaves are known for their good palatability and nutritional quality. Studies indicate satisfactory digestibility coefficients for crude protein and nitrogen-free extract. It provides digestible crude protein and total digestible nutrients, making it a crucial supplement for livestock diets in the region (Deshmukh *et al*., 1990; Joshi *et al*., 2023) [4, 14].
- ***Celtis australis* (Khirak/Kharik):** This agroforestry tree is another important fodder source in the Himalayas. Its foliage is known to contain crude proteins, phosphorus, and crude fiber. The nutritional content can vary seasonally and with altitude, with higher altitudes often yielding more nutrient-rich foliage. Chemical analysis reveals typical values of ~15% crude protein, ~17% crude fiber, and substantial amounts of ash and minerals (Mahajan *et al.*, 2023) [19].
- ***Ficus spp.* (Fig species, e.g., *Ficus palmata, Ficus roxburghii*):** Various *Ficus* species are commonly used as fodder. Their leaves are generally palatable and provide a good source of moisture, carbohydrates, and minerals. Some *Ficus* species leaves contain moderate protein content (around 6-8%) and a range of vitamins and minerals like calcium, magnesium, and potassium. They are often preferred due to their high moisture content and digestibility, making them a good option, especially during dry periods.
- ***Morus alba* (White Mulberry):** Mulberry leaves are exceptionally nutritious and are considered a premium fodder. They are rich in crude protein (14-34%) and carbohydrates (9-39%) and have high *in vivo* dry matter digestibility (75-85%). They also lack significant anti-nutritional factors, making them highly beneficial for livestock, especially for milk production. Mulberry leaves are a good source of essential amino acids, calcium, and phosphorus (Hassan *et al.*, 2020; Al-Kirshi *et al*., 2009) [9, 20].

**2. Shrubs:** Shrubs found in forest undergrowth provide supplementary nutrition, especially for Browse animals like goats and sheep. They contribute to a diverse diet, offering micronutrients and often bioactive compounds.

- ***Carissa spinarum* (Karonda):** This thorny shrub is commonly browsed. Studies on *Carissa spinarum* indicate the presence of various phytochemicals like tannins, alkaloids, and flavonoids, which can have medicinal properties (e.g., anthelmintic effects for parasite control) in addition to nutritional value. The leaves contain protein, carbohydrates, and dietary fiber, along with minerals like calcium, iron, and phosphorus (Chauhan *et al*., 2015) [2].
- ***Berberis aristata* (Kingora/Indian Barberry):** This shrub is also commonly browsed. Its leaves and particularly its berries are known for their medicinal properties due to the presence of alkaloids like berberine. While the primary use is medicinal, its leaves are part of the browse diet. The berries are a source of minerals, total phenols, and total flavonoids. The leaves would contribute fiber and some micronutrients, and the tannins present might assist in parasite management, as mentioned by Rawat and Singh (2017) [26].
- ***Indigofera pulchella* (Wild Indigo):** Various *Indigofera* species are recognized for their high-quality nutrients and are utilized as pasture legumes. They are known for their high crude protein content (around 20-27%) and total digestible nutrients. Some species of *Indigofera* also contain condensed tannins, saponins, and flavonoids, which can have beneficial effects on animal health, including parasite control and improved nutrient utilization, especially for ruminants (Rawat & Singh, 2017; Evitayani *et al.*, 2021) [26, 5].
- ***Rubus spp.* (Raspberry/Blackberry species):** Wild *Rubus* species are often found in forest clearings and edges. While their fruits are well-known, the leaves and young shoots are sometimes browsed. These plants are generally low in protein and fats but provide carbohydrates, dietary fiber, and notable levels of vitamin C, potassium, and folate. They are rich in phenolic compounds, including anthocyanins, which are potent antioxidants.

**3. Grasses:** Grasses form the basal diet for many grazing animals. Forest floors, especially in areas with open canopies or along forest edges, provide various grass species.

- ***Themeda anathera* (Red Oat Grass):** This perennial grass is common in open grasslands and forest fringes. Its nutritional content varies significantly with maturity; while it can have 8-9% crude protein at the vegetative stage, this drops to 2-3% when mature. It has a high NDF content, increasing with maturity. While not as rich as some legumes, it provides bulk and energy, especially when young (Feedipedia, 2011) [7].
- ***Cynodon dactylon* (Bermuda Grass/Doob Grass):** A highly adaptable and widespread grass found in open areas, *Cynodon dactylon* is a very palatable fodder

when kept short and fertilized. Its crude protein content can range from 3% in old grass to about 20% in young, well-fertilized grass. It is known for its tolerance to heavy grazing and drought.

- ***Setaria spp.* (Foxtail Millet/Bristlegrass):** Various *Setaria* species are found in wild or semi-cultivated forms. These grasses provide substantial amounts of carbohydrates (60-65%), protein (around 12%), fiber (around 6%), and essential minerals (Phosphorus, calcium, iron, zinc, magnesium, and sodium). They are also noted for various phytochemicals with antioxidant properties.

**Forest Types of Uttarakhand and Fodder Availability:**

The diverse forest types in Uttarakhand directly influence the availability and type of fodder:

- **Tropical Moist Deciduous Forests:** Found in the lower Tarai and Bhabar regions. These forests, characterized by trees that shed leaves seasonally, offer a flush of green fodder (grasses, young leaves) during the monsoon and post-monsoon periods but may have limited green browse in dry seasons.
- **Tropical Dry Forest:** Also in lower altitudes, these are more sparse and drought-resistant. Fodder availability here is highly seasonal, relying heavily on dry grasses and tougher browse species during the long dry spell.
- **Subtropical Pine Forest:** Dominated by Chir Pine (*Pinus roxburghii*), these forests often have a less dense understory due to the acidic nature of pine needles and thick litter. While pine needles themselves are generally not preferred fodder, some grasses and specific shrubs can thrive in the open patches, contributing to seasonal grazing.
- **Himalayan Moist Temperate Forest (e.g., Oak-dominated forests):** These are prime areas for quality tree fodder. Species like *Quercus leucotrichophora* (Banj Oak), *Grewia optiva*, and *Celtis australis* are abundant here, providing crucial lopped fodder, especially in winter.
- **Subalpine & Alpine Forest:** At higher altitudes, these forests and meadows are characterized by coniferous trees and vast grasslands. During the summer months, the alpine meadows burst with a variety of nutritious grasses and herbaceous plants, offering excellent grazing grounds for transhumant livestock. However, they are inaccessible and snow-covered during winter.

The utilization of forest-based fodder is a traditional and indispensable practice for livestock rearing in Uttarakhand. It represents a complex ecological interaction between forests, livestock, and local communities, highlighting the importance of sustainable forest management practices to ensure the continued availability of these vital resources.

| Forest Type | Characteristic Altitudinal Range (m) | Area (State Level) | Dominant Flora |
|---|---|---|---|
| Tropical Moist Deciduous Forests | Below 1000m (specifically 500-1000m) | ~2,826 km² (part of 26.25% of total area under tree species for tropical dry & moist deciduous forests) | Sal (*Shorea robusta*), Shisham (*Dalbergia sissoo*), Teak, Khair, Semal (*Bombax cobia*), Haldu (*Haldina cordifolia*), Kanju, Sissoo, Sain, Bakli (*Anogeissus latifolia*), Jhingan (*Lannea coromandelica*), Sandhan, Rohini (*Mallotus philippinensis*), Amaltas (*Cassia fistula*), Mulberry |
| Tropical Dry Forests | Below 1200m (dry southern Shiwaliks, foothills) | Part of 26.25% of total area under tree species for tropical dry & moist deciduous forests | Kuri, Kemela, Jhingan, Mandar, Dhaula, Binda, Basingha, Gandela. Thorn forests: Khair, Babul, Semal |
| Subtropical Pine Forests | 1000m-2000m | 10,024 km² (29.61% of total area under tree species) | Chir pine (*Pinus roxburghii*)<br>**Understory:** *Arundinella setosa*, cogon grass (*Imperata cylindrica), and Themeda anathera*.<br>**Bushes:** bayberry, Bengal currant, barberry, blackberry, Himalayan raspberry, wild strawberry |
| Himalayan Moist Temperate Forests | 1500m-3300m (specifically 2000-3000m) | 39.02% of total area under tree species (23.18% of total forest area for 2000-3000m altitude) | **Conifers:** pines, cedars, silver firs (*Abies pindrow*), Spruce (*Picea smithiana), and* Deodar (*Cedrus deodara*).<br>**Broad-leaved:** Oak species (*Quercus leucotrichophora, Q. floribunda, Q. dilatata, Q. semecarpifolia*), Rhododendron (*Rhododendron arboreum*), Maple, Chestnut, Laurel, Bamboo |
| Subalpine & Alpine Forests | Sub-alpine: 2900m-3500m (or 3400-4000m); Alpine: Above 4000m (or 3000-3800m) | 4.98% of the total area under tree species (alpine dry & moist scrub). 7.14% of total forest area for 3000-4000m altitude, 0.08% for >4000m | **Sub-alpine trees:** *Pinus wallichiana, Abies pindrow, Prunus cornuta, Acer caesium, Betula utilis* (Bhoj Patra), *Salix sp.*<br>**Alpine:** small shrubs, rhododendron, grasses, mosses, lichen, wildflowers (Blue Poppies, Edelweiss).<br>**Shrubs:** *Cotoneaster, Rosa, Berberis, Ribes, Junipers, Rhododendron anthropogenic, Rhododendron campanulas*.<br>**Herbs:** *Potentilla, Primula, Aster, Saxifrage, Meconopsis, Saussurea, Rheum* |

**Cultivated Fodder Resources in Uttarakhand**

In Uttarakhand, especially in the fertile Tarai plains and as supplementary feed in the hills, cultivated fodder crops are indispensable for sustaining livestock. The selection of specific varieties, considering their yield potential, nutritional quality, and adaptability to local conditions, is crucial for optimizing fodder production.

**1. Seasonal Fodder Crops: Popular Varieties and Their Role**

**Kharif Season Fodder Crops (June-September/October)**

The monsoon-fed Kharif season is characterized by warm temperatures and ample moisture, ideal for robust, fast-growing fodder crops.

- **Maize (*Zea mays*):** A dominant non-leguminous fodder crop, offering high biomass and energy.
- **Varieties**
  - **African Tall:** Known for its tall stature, high green fodder yield, and good palatability. It's a popular choice for ensiling.
  - **Ganga Safed-2:** Another high-yielding variety suitable for green fodder.
  - Hybrid varieties (e.g., HQPM series, certain private hybrids) Often offer superior yields and disease resistance.

**Feeding Period:** Typically fed fresh from July to October

- **Cowpea (*Vigna unguiculata*):** A versatile, protein-rich leguminous fodder that also enriches soil.
- **Varieties**
  - **EC-4216:** A dual-purpose variety suitable for both fodder and grain.
  - **UPC-5286:** Known for good fodder yield and palatability.
  - **Bundel Lobia-1 (BL-1) and Bundel Lobia-2 (BL-2):** Released varieties with good performance for fodder.

**Feeding Period:** Available from July to October and often extended into summer as a Zaid crop.

- **Sorghum (*Sorghum bicolor*):** A robust non-leguminous cereal, tolerant to drier conditions.
- **Varieties**
  - **MP Chari:** A very popular multi-cut variety known for high green fodder yield and good regeneration capacity.
  - **SSG-59-3:** Another widely adopted dual-purpose (fodder and grain) sorghum.
  - Hybrid varieties (e.g., Jawahar Fodder Sorghum 29 (JFS-29)): Offer enhanced yield and quality.

**Feeding Period:** From August to October

- **Bajra (*Pennisetum glaucum*, Pearl Millet):** A drought-resilient non-leguminous cereal.
- **Recommended Varieties**
  - **Giant Bajra:** A tall, high-yielding variety specifically bred for fodder.
  - **Raj Bajra Chari-2 (RBC-2):** A good fodder variety.

**Feeding Period:** From July to October.

**Rabi Season Fodder Crops (October/November-March/April)**

The cooler, post-monsoon months are crucial for high-protein legumes and winter cereals, providing vital green fodder during a lean period.

- **Berseem (*Trifolium alexandrinum*, Egyptian Clover):** The most critical leguminous fodder, highly valued for its high protein content and multiple cuttings.
- **Varieties**
  - **Mescavi:** A classic multi-cut variety known for its rapid growth and high yields.
  - **Pusa Giant:** A well-established variety with good performance.
  - **Wardan:** Another popular multi-cut variety, widely adopted for its productivity.
  - **JHB-146:** A promising variety for higher fodder yield.

**Feeding Period:** Predominantly fed from December to April, providing fresh green fodder during a critical period.

- **Oats (*Avena sativa*):** A prominent non-leguminous cereal fodder for its high yield and palatability.
- **Varieties**
  - **Kent:** A widely grown, high-yielding variety.
  - **JHO-822:** Known for good green fodder yield.
  - **Pusa Oat-5:** A recommended variety for fodder purposes.
  - **OL-1258:** High-yielding and resistant to rust.

**Feeding Period:** Typically fed from January to April.

- **Barley (*Hordeum vulgare*):** While primarily a grain crop, certain varieties are suitable for green fodder.
- **Varieties**
  - **RD-2035 (Rajkiran):** A dual-purpose barley suitable for green fodder at early stages.

**Feeding Period:** Can be fed in December-January as green fodder.

**Zaid (Summer) Fodder Crops (April-June)**

The hot and dry summer months demand quick-growing and relatively drought-tolerant options to bridge the gap between Rabi and Kharif crops.

- **Cowpea (*Vigna unguiculata*):** A versatile leguminous crop that excels in both Kharif and Zaid seasons.
  - **Recommended Varieties:** Same as Kharif season: EC-4216, UPC-5286, Bundel Lobia-1 (BL-1), Bundel Lobia-2 (BL-2).
  - **Feeding Period:** Typically fed from **April to July**.

**2. Perennial Fodder Crops: Long-Term Solutions**

Perennial fodders offer sustained production over several years from a single planting, optimizing resource use and labor.

- **Hybrid Napier (*Pennisetum purpureum x Pennisetum glaucum*):** A cornerstone for continuous green fodder supply.
- **Varieties**
  - **Pusa Napier-1:** High-yielding and widely adopted.
  - **NB-21:** Another very popular hybrid, known for its rapid growth and multiple cuttings.
  - **CO-3, CO-4, and CO-5:** Highly productive varieties developed in India, known for their superior yield and quality. CO-5 is particularly noted for its high biomass and digestibility.

**Feeding Period:** Provides continuous green fodder from April/May to November, making it crucial for year-round availability in the Tarai plains.

- **Lucerne (*Medicago sativa*, Alfalfa):** The "Queen of Fodders," a highly nutritious, protein-rich legume.
- **Varieties**
  - **Anand-2 (LL-Composite-3):** A popular variety for general cultivation.
  - **SS-627:** Known for good performance in various conditions.
  - **Cheftal:** Often used for its perennial nature and multiple cuts.

**Feeding Period:** Offers multiple cuts throughout the year in irrigated conditions, particularly productive from November to June.

**3. Crop Residues and Other Supplementary Sources**

These form the bulk of dry fodder and roughage, especially when green fodder is scarce.

- **Wheat Straw:** Abundant after Rabi wheat harvest (**April/May**). Low in protein and digestibility.
- **Paddy Straw:** Plentiful after the Kharif rice harvest (**October/November**). Also low in nutritional value.
- **Millet Residues:** From hill-grown millets like Finger Millet (Ragi/Mandua), Barnyard Millet (Jhangora/Sawa), Proso Millet (Cheena), and Foxtail Millet (Kangni/Kauni). Generally available after their respective harvests (September-November for Kharif millets).

**General Feeding Practices in Uttarakhand**

- **Summer (June):** Livestock would be transitioning from the last of the Zaid (Summer) fodders like Cowpea. The early plantings of Kharif fodder crops like Maize and Bajra would be in their initial growth stages. Perennial Hybrid Napier would be growing rapidly, providing substantial green fodder. Dry roughage (Wheat Straw, some remaining Paddy Straw from last year) would still be a significant part of the diet, often mixed with available green fodder.
- **Monsoon (July-October):** This period will bring an abundance of Maize, Sorghum, Bajra, and Cowpea. Hybrid Napier will be at its peak production, providing multiple cuts. Natural pastures and forest grasslands will also be lush in the hills, offering excellent grazing opportunities. Paddy straw will become available from October onwards.
- **Winter (December-March):** This period is highly reliant on Berseem and Oats from cultivated fields, providing high-quality green fodder. Stored wheat and paddy straw will form the primary dry roughage component. In the hills, lopped tree fodder (Banj oak, Bhimal, Khirak) becomes absolutely vital as green grasses become scarce.
- **Spring/Early Summer (April-June):** As Rabi fodder finishes, attention shifts to early Hybrid Napier cuts and Zaid season Cowpea. Leftover wheat straw from the recent harvest is a key dry fodder. This is often a lean period requiring careful management of available resources.

By integrating specific, well-adapted varieties into the cropping system, farmers in Uttarakhand can significantly enhance the quantity and quality of fodder, supporting healthier and more productive livestock throughout the year.

**(B) Physiographic Regions and Fodder Availability in Uttarakhand**

Uttarakhand comprises five main physiographic regions: Tarai, Foothills, and Hills, each contributing distinctively to fodder availability.

**Tarai Region**

The Tarai is a low-lying region situated immediately south of the Sivalik Hills and extending north of the Indo-Gangetic Plain. In Uttarakhand, a significant portion of this belt covers the lower areas of the Nainital district, Udham Singh Nagar, and parts of Haridwar. The region's soil is predominantly alluvial, exhibiting a fine to medium texture derived from both older and more recent alluvial deposits (Kumar & Sharma, 2020) [17]. This landscape is naturally characterized by tall grasslands, scrub savannah, sal forests, and clay-rich swamps, often featuring marshy plains formed by re-emerging subsurface streams. For fodder, key cultivated crops include *Avena sativa* (oats), a versatile cereal widely used for feed and fodder. Other significant cultivated fodder crops are *Trifolium alexandrinum* (berseem), *Zea mays* (maize), *Pennisetum purpureum* (Napier grass), sorghum, and *Vigna unguiculata* (cowpea). Research has highlighted the effectiveness of specific cropping sequences, such as "Hybrid Napier + Berseem," which have demonstrated superior yields in both green and dry fodder, higher crude protein content, and enhanced economic efficiency (Verma *et al.*, 2022) [33].

The natural forage in this region primarily consists of the characteristic tall grasslands, scrub savannah, and sal forests. The seasonal availability of fodder crops is well-defined: during the Kharif season (June to September), crops such as cowpea, cluster bean, field bean, bajra, sorghum, and maize are cultivated. The Rabi season (October to January) sees the growth of berseem, lucerne, and barley. In the summer months (April to June), oats and cowpeas become available. The "Hybrid Napier + Berseem" cropping sequence has shown remarkable productivity, yielding 185.8% higher green fodder and 306.7% higher dry fodder compared to conventional cropping sequences (Verma *et al.*, 2022) [33]. This underscores the substantial potential for intensive fodder production in this region.

**Foothills (Sivalik Range)**

The Sivalik Range comprises the outer foothills of the Himalayas, situated south of the Lesser Himalayas and gradually transitioning into the Indo-Gangetic Plain. While not defined by a single, narrow altitude, it covers Dehradun, parts of the Nainital district, and Champawat of Uttarakhand. The foothills are characterized by mixed vegetation, with a mix of cultivated land and forest cover, including species such as *Shorea robusta* (sal), *Dalbergia sissoo* (shisham), *Acacia catechu* (khair), *Bambusa spp.* (bamboo), *Mangifera indica* (mango), and *Syzygium cumini* (jamun) trees. The natural forage in the Sivalik hills includes grasses found below the snow line, as well as evergreen and deciduous dense forests. Major grasses include *Cynodon dactylon*, *Setaria spp.*, and leaves of *Grewia optiva*, *Ficus spp.*, and *Morus alba*. While specific cultivated fodder crops for the Sivalik range are not extensively detailed, the broader "Northern Zone" (which includes Uttarakhand) cultivates major crops like maize + cowpea, sorghum + cowpea, berseem + mustard, and Sudan grass + cowpea.

**Lower Hills**

The lower hills represent a transitional zone with altitudes generally ranging from approximately 365 to 914 meters above mean sea level based on similar agro-climatic categorizations in the broader Himalayan region (FSI 2019) [8]. Specific forest types found here include tropical dry deciduous forests characterized by species such as Kuri, Kemela, Jhingan, and Mandar, and sal forests, which thrive up to an altitude of 1066 meters (Champion & Seth 1968; Negi *et al.* 2018) [1, 21]. In the lower Himalayan region, agricultural practices are often constrained by small farm holdings and limited irrigation, leading farmers to rely heavily on nearby forests for fuel and fodder (Pandey 2010) [23].

The contribution of leaves from forest trees, bushes, and herbaceous plants is significant. Common non-cultivated fodder plants include species from the Poaceae, Moraceae, and Caesalpiniaceae families (Joshi *et al.* 2016) [12, 13]. Fodder trees and shrubs are particularly important, providing essential nutrients that grasses may lack during dry seasons (Rawat & Singh 2017) [26]. Cultivated fodder in subtropical areas (600-1200 m) includes frost-tolerant winter grasses like Napier (*Pennisetum purpureum*) and broom grass (*Thysanolaena maxima*) (Kumar *et al.* 2021) [18].

Traditional mixed cropping systems such as Barahnaja, which integrate cereals, pulses, oilseeds, and vegetables,

also contribute to fodder availability through nutrient-rich crop residues (Negi *et al.* 2018) [21]. These systems support both nutritional security and palatable dry-season fodder for livestock. The availability of green fodder is not uniform throughout the year, with significant reliance on forests and pasture grasslands during fodder-scarce months (FSI 2019) [8]. During the rainy season (June-September), stall-fed crossbred cattle primarily consume green grasses supplemented with concentrates. However, during the lean period (October-March), cereal straw and dry grasses are supplemented with nutrient-rich leaves from fodder trees (Pandey 2010) [23]. The increasing pressure on forests due to rising human and cattle populations has led to reduced fodder availability and growing concerns about the sustainability of forest ecosystems (Sati & Bandooni 2019) [28, 29].

**Mid Hills**

The mid-hill regions of Uttarakhand, encompassing areas like Nainital, Almora, and Ranikhet, experience a temperate climate. The average elevation in this region ranges between 915 and 1523 meters, though Western Himalayan broadleaf forests typically occur between 1500 and 2600 meters (Champion & Seth, 1968; FSI, 2019) [1, 8]. Rainfall is received from both the southwest monsoon (June-September) and western disturbances (December-March), contributing to lush vegetation and fertile soils (Sati & Bandooni, 2019) [28, 29].

The forests and uncultivated lands in this zone play a crucial role in fodder availability, particularly during the dry season when grasses are dormant and nutritionally poor. In such periods, fodder trees and shrubs provide essential nutrients to ruminant diets. Commonly used species include oak, fig, poplar, holly, and rhododendron, whose leaves have been shown to contain 10% to over 25% crude protein on a dry matter basis (Joshi *et al.*, 2016; Rawat & Singh, 2017) [12, 13, 26].

Cultivated fodder in temperate and intermediate elevations (1200-1800 m) includes improved grasses such as cocksfoot (*Dactylis glomerata*), tall fescue (*Festuca arundinacea*), and brome (*Bromus inermis*), which perform well under cool conditions (Kumar *et al*., 2021) [18]. In addition, traditional mixed cropping systems like Barahnaja, practiced across the central Himalayas, integrate millets (e.g., finger millet), amaranth (ramdana), buckwheat, maize, sorghum, and various pulses and oilseeds on terraced fields (Negi *et al.*, 2018) [21]. These systems are agroecologically sustainable and contribute to fodder supply through nutritious crop residues. Similar to other zones, green fodder availability is seasonal. During the monsoon (June-September), green grasses are abundant and used for stall-fed cattle, along with concentrate supplements. However, during the lean winter months (October-March), cereal straw and dry grasses are complemented with nutrient-rich leaves from fodder trees (Pandey, 2010; FSI, 2019) [23, 8].

**Higher Hills**

The higher hills of Uttarakhand are situated at greater altitudes, typically ranging from approximately 1524 to 2742 meters, and include zones such as the Himalayan Moist Temperate Forest (2000-3000 m) and Western Himalayan Subalpine Conifer Forests (2600-3000 m) (Champion & Seth, 1968; FSI, 2019) [1, 8]. Forests at these altitudes are dominated by species such as Himalayan cypress, deodar, blue pine, fir, and longleaf pine (Rawat, 2005) [24, 25].

Natural grasslands and pastures in this region are vital ecological resources that directly support a large livestock population, especially transhumant systems. Fodder trees and shrubs gain critical importance during lean periods, providing nutrient-rich green biomass when herbaceous resources are depleted (Negi *et al*., 2018) [21]. Common trees used for fodder include wild cherry, wild apple, spindle wood, oak, fig, poplar, holly, rhododendron, and various fruit trees.

In oak-dominated zones of the Garhwal Himalaya, the main fodder species include *Quercus floribunda* (Moru), *Q. semecarpifolia* (Kharsu), and *Q. leucotrichophora* (Banj), along with domesticated multipurpose trees like *Grewia oppositifolia* (Bhimal) and *Ficus spp*. In pine-dominated areas, Bhimal and Ficus are also widely used due to their adaptability and regrowth potential (Joshi *et al*., 2016; Pandey, 2010) [12, 13, 23].

Grasses like *Themeda arundinacea* (Ula) and *Brachiaria villosa* (Malchu) are highly valued in both oak and pine belts due to their nutrient density and ability to enhance milk production (Kumar *et al.*, 2021) [18]. However, fodder scarcity during the winter and dry periods remains a major challenge in the Himalayan region, often leading to economic losses among smallholder farmers (FSI, 2019) [8]. Fodder trees play a key role in bridging this deficit due to their deep roots, which allow them to access water and nutrients in dry conditions and remain green longer. Their leaves are rich in proteins (10-30% of dry matter) and can serve as an effective substitute for commercial concentrates (Joshi *et al*., 2016) [12, 13]. Additionally, the nutrient content of such fodder, especially calcium and phosphorus, is often elevated due to the mineral-rich rocky mountain soils (Rawat, 2005) [24, 25]. However, the productivity of natural forage remains highly variable, depending on ecological and seasonal factors (Pandey, 2010) [23].

**Alpine Region**

The Alpine region of Uttarakhand represents the highest altitudinal zone, typically lying between the tree line and the permanent snowline, at elevations ranging from approximately 3,000 to 5,000 meters above mean sea level (Champion & Seth, 1968; Rawat, 2005) [1, 24, 25]. At altitudes exceeding 4,880 meters, the climate is bitterly cold, with temperatures consistently below freezing, and the area remains perennially snowbound (FSI, 2019) [8]. This ecozone is characterized by a cold alpine climate with short, cool summers and long, harsh winters. Alpine zones are snow-free only from May to October, with vegetation emerging for a brief window of 1-2 months, especially near the snowline (Rawat, 2005) [24, 25].

The alpine pastures, locally known as "Bugyals," "Kanda," or "Marg," are treeless high-altitude meadows dominated by alpine grasses, sedges, shrubs, and forbs. The vegetation is typically composed of leaf rosettes, grass tussocks, dense cushions, and succulent alpine forms (Samant *et al.*, 2007) [27]. Lower alpine elevations are dominated by shrubby rhododendrons and birch (*Betula utilis*), while willows (*Salix spp.*) are common along shallow streams and wet patches. Higher up, the vegetation transitions into rich alpine meadows, interspersed with junipers, mosses, and lichens (Kala, 2005) [15, 16]. Many of these species are endemic, and some are classified as endangered due to

overexploitation (Rawat, 2005; Samant *et al.*, 2007) [24, 25, 27]. Due to extreme climatic constraints, cultivated fodder is generally not feasible, and livestock rely almost entirely on natural alpine pastures during the brief snow-free period (Kala, 2005) [15, 16]. The growing season is limited from May to October, and summer grazing is a common practice. However, these pastures are often overgrazed due to increasing livestock pressure and declining forage resources at lower elevations (Rawat, 2005) [24, 25]. These natural grasslands and meadows are vital not only for fodder supply but also for maintaining a diverse assemblage of grasses, legumes, shrubs, and medicinal plants. Despite their ecological and economic value, many alpine species face serious threats from overharvesting and grazing pressure, leading to concerns about their long-term conservation (Samant *et al.*, 2007; Kala, 2005) [27, 15, 16].

| Zone Name | Altitude Range (m) | General Climate | Key Vegetation/Forest Types |
|---|---|---|---|
| Tarai Region | 67 - 300 | Tropical Savanna (Cwa) | Tall grasslands, Scrub savannah, Sal forests, Clay-rich swamps, Alluvial plains |
| Foothills (Sivalik Range) | Below 1500 | Subtropical | Moist deciduous forest (Bhabar), Tall grassland, Scrub savannah, Sal forest, Swamp |
| Lower Hills | 365-914 | Subtropical to Warm Temperate | Tropical Dry Deciduous Forests, Sal Forests, Mixed vegetation (Sal, Shisham, Khair, Bamboo, Mango, Jamun) |
| Mid Hills | 915-1523 | Temperate to Warm Temperate | Temperate broadleaf forests, subtropical pine forests, Oak, Fig, Poplar, Holly, Rhododendron |
| Higher Hills | 1524 - 2742 | Cool Temperate | Conifer forests (Chir, Pine, Burans, Oak, Deodar, Blue pine, fir, and longleaf pine), Temperate broadleaf forests |
| Alpine Region | 3000-5000 (between tree line and snowline) / Over 4880 | Cold Alpine | Alpine meadows (Bugyals), Shrubby rhododendrons, Birch, Juniper scrubs, Mosses, Lichens, Fir, juniper, and Brahma Kamal |

(FSI, 2019; Champion & Seth, 1968; Rawat, 2005; Sati & Bandooni, 2019) [8, 1, 24, 25, 28, 29]

**B) Geographical Influences on Fodder Availability in Uttarakhand**

**Garhwal Region:** Includes districts like Pauri, Chamoli, Rudraprayag, Tehri, Uttarkashi, Dehradun, and Haridwar. More heavily forested, higher reliance on tree leaves (banj, bhimal), shrubs, and alpine grasses from *bugyals*.

| S. No. | Fodder Species | S. No. | Fodder Species | S. No. | Fodder Species |
|---|---|---|---|---|---|
| 1 | Bhimal | 7 | Phalihat | 13 | Dhudi |
| 2 | Baken | 8 | Koiral | 14 | Guriyal |
| 3 | Banjo | 9 | Kuniani | 15 | Timil |
| 4 | Kharik | 10 | Putli | 16 | Satwoot |
| 5 | Moru | 11 | Bhikul | 17 | Siras |
| 6 | Subabul | 12 | Kadam | 18 | Aru |

(ICFRE, 2010) [11]

**Kumaon Region:** Includes districts like Almora, Nainital, Bageshwar, Pithoragarh, Udham Singh Nagar, and Champawat. Includes more diversified landscapes with better integration of leguminous crops like cowpea and fodder grasses in mid-altitudes, along with oak forests and community pasturelands.

| S. No. | Fodder Species | S. No. | Fodder Species | S. No. | Fodder Species |
|---|---|---|---|---|---|
| 1 | Bhimal | 8 | Moru | 15 | Padam |
| 2 | Baanj | 9 | Kuiral | 16 | Kim |
| 3 | Timla | 10 | Kharsu | 17 | Binalu |
| 4 | Kharik | 11 | Payo | 18 | Gohra |
| 5 | Khair | 12 | Bhikva | 19 | Seemal |
| 6 | Phalihat | 13 | Koi | 20 | Soura |
| 7 | Tilonge | 14 | Bindu | 21 | Govava |

(ICFRE, 2010) [11]

**Challenges and Constraints in Fodder Availability**

Despite Uttarakhand's diverse fodder resources, several challenges and constraints impact the consistent availability and quality of feed for its significant livestock population. While the document highlights the variety of natural and cultivated fodder sources across different seasons and regions, the underlying difficulties in meeting year-round demand are evident:

- **Seasonal Scarcity:** The paper implicitly points to seasonal variations in fodder availability, particularly mentioning the "lean seasons" when green fodder is scarce and crop residues become crucial for roughage. This indicates a significant challenge in maintaining consistent nutrition throughout the year, especially during winter and dry summer months.
- **Reliance on Forest-Based Fodder:** While forest-based fodder is vital, especially in hilly and remote areas, it also presents challenges related to sustainable harvesting, forest degradation, and potential overgrazing in common forest lands. The mention of specific tree leaves and grasses as crucial components of the diet suggests a high dependence on these natural resources.
- **Quality of Fodder:** The document touches on the nutritional value of various fodder types, but a deeper dive into the challenges of maintaining optimal nutrient intake for livestock, especially when relying on crop residues (which are generally lower in nutritional value than green fodder), is an implied constraint.
- **Limited Land and Intensive Cultivation:** While the Tarai region shows potential for intensive fodder production, the hilly terrain and small landholdings in other parts of Uttarakhand could limit the expansion of cultivated fodder crops, leading to a continued reliance on traditional or forest sources.

These factors contribute to the ongoing challenge of ensuring a balanced and sufficient diet for livestock in Uttarakhand, hinting at a potential deficit in meeting the overall fodder demand consistently.

**Future Research Directions and Recommendations**

Based on the insights from this review of fodder resources in Uttarakhand, several areas warrant future research and strategic interventions to enhance sustainable livestock nutrition:

- **Quantitative Assessment of Fodder Deficit:** There is a need for detailed studies to precisely quantify the actual fodder demand versus the current supply across different seasons and physiographic regions of Uttarakhand. Such data would be crucial for targeted

policy interventions and resource allocation.

- **Optimization of Cultivated Fodder Systems:** Further research is needed to optimize cropping sequences and introduce high-yielding, climatically resilient, and nutritionally superior fodder varieties, especially in the Tarai and other agriculturally viable areas. The success of the "Hybrid Napier + Berseem" cropping sequence highlights this potential.
- **Sustainable Management of Natural Fodder Resources:** Research should focus on sustainable harvesting practices for forest-based fodder, methods for regenerating degraded grasslands, and assessing the long-term ecological impact of current grazing practices to ensure the continued availability of these vital resources.
- **Nutritional Enhancement and Supplementation Strategies:** Studies are needed to develop cost-effective strategies for improving the nutritional quality of available fodder, particularly crop residues, through fortification, silage making, or hay production. Research into suitable mineral and vitamin supplementation for livestock based on regional fodder analysis would also be beneficial.
- **Exploration of Underutilized Fodder Species:** Investigating the nutritional potential, palatability, and anti-nutritional factors of lesser-known or underutilized local fodder species could diversify feed options and enhance resilience against seasonal scarcities.
- **Technological Interventions and Farmer Adoption:** Research on the effective transfer of improved fodder production and conservation technologies to farmers, along with studies on factors influencing farmer adoption rates, is essential. This includes promoting improved pasture management, fodder trees on farm boundaries, and community-based fodder initiatives.

## Conclusion

Uttarakhand's diverse landscapes provide a wide array of natural and cultivated fodder crucial for its significant livestock population, which underpins the state's rural economy. Despite this richness, persistent challenges such as seasonal scarcities and the need for sustainable resource management limit consistent fodder availability and quality. Addressing these issues requires a multi-faceted approach, including quantitative assessments of fodder deficits, optimization of cultivated fodder systems, and strategic interventions to enhance both production and utilization. Ultimately, a consolidated effort in research and adoption of sustainable practices is vital to bolster the livestock sector and ensure the continued prosperity of Uttarakhand's agricultural communities.

## References


1. Champion HG, Seth SK. A revised survey of the forest types of India. Government of India Press; 1968.
2. Chauhan M, Kumar M, Kumar R. Influence of processing on physiochemical, nutritional and phytochemical composition of *Carissa spinarum* (Karonda) fruit. Asian Journal of Pharmaceutical and Clinical Research. 2015;8(6):254-257.
3. Department of Animal Husbandry, Uttarakhand. Annual Report 2022-2023. Government of Uttarakhand. 2023. https://ahd.uk.gov.in
4. Deshmukh SV, Pathak NN, Johri SB. Nutritional evaluation of biul (*Grewia optiva*) leaves in rabbits. Indian Journal of Animal Nutrition. 1990;7(1):87-88.
5. Evitayani E, Suparman S, Sari NL. The effect of including Indigofera (*Indigofera zollingeriana*) leaf meal in the ration on the productivity of growing male rabbits. ResearchersLinks. 2021;34(1).
6. Feedipedia. Banj oak (*Quercus leucotrichophora*). 2011. https://www.feedipedia.org/node/108
7. Feedipedia. Red oat grass (*Themeda triandra*). 2011. https://www.feedipedia.org/node/367
8. Forest Survey of India. India State of Forest Report 2019. Dehradun: Forest Survey of India, Ministry of Environment, Forest and Climate Change; 2019.
9. Hassan MR, Islam MS, Begum MS. The nutritive value of mulberry leaves (*Morus alba*) as a feed supplement for sheep. Journal of Applied Animal Research. 2020;48(1):32-38.
10. Himmotthan. Fodder Plantation. https://www.himmotthan.org/livestock/FodderPlantation.aspx
11. ICFRE. Report of Livestock Feed ICFRE - RP: Quantitative Estimation of Livestock Feed from Forest in Uttaranchal Himalayas. Indian Council of Forestry Research and Education; 2010.
12. Joshi A, Pathak NN, Kumar M. Chemical composition and *in vitro* dry matter digestibility of common tree fodders of Kumaun hills, Uttarakhand. Indian Journal of Animal Nutrition. 2016;33(2):241-245.
13. Joshi L, Nautiyal BP, Chauhan DS. Nutritional evaluation of fodder tree leaves in mid-Himalayas. Indian Journal of Animal Nutrition. 2016;33(3):276-281.
14. Joshi P, Kumar V, Singh K. Nutritional, phytochemical and antioxidant activity analysis of *Grewia optiva* during vegetative to reproductive growth stage in winter season. Indian Journal of Agroforestry. 2023;25(2).
15. Kala CP. Current status of traditional knowledge and ethno-medicinal plants in the Indian Himalaya. New York Botanical Garden; 2005.
16. Kala CP. Indigenous uses, population density and conservation of threatened medicinal plants in protected areas of the Indian Himalayas. Conservation Biology. 2005;19(2):368-378.
17. Kumar D, Sharma M. Assessment of soil characteristics in Tarai region of Uttarakhand, India. International Journal of Agricultural Science and Research. 2020;10(1):1-8.
18. Kumar V, Singh KP, Saini P, Dhyani BP, Ram K. Evaluation of different temperate fodder grasses under mid hill conditions of Uttarakhand. Journal of Animal Research. 2021;11(4):675-680.
19. Mahajan S, Sharma R, Sharma S, Bhatia R. *Celtis australis*: A narrative review. Biological and Environmental Sciences Journal for the Tropics. 2023;20(1):600-608.
20. Musa I, Al-Kirshi M. Nutrient digestibility of mulberry leaves (*Morus alba*). International Journal of Animal Science. 2009;4(1).
21. Negi SS, Singh DC, Singh K, Sharma R, Kumar A. Traditional mixed cropping system (Barahnaja) for food security and nutritional diversity in Garhwal Himalayas. Journal of Pharmacognosy and Phytochemistry. 2018;7(5):2320-2323.
22. NITI Aayog. Macro and fiscal landscape of the State of

Uttarakhand. 2023. https://niti.gov.in/sites/default/files/2025-03/Macro-and-Fiscal-Landscape-of-the-State-of-Uttarakhand.pdf
23. Pandey RP. Resource use pattern and management strategies in small holder farming systems in Mid-Himalayan region of Uttarakhand. Journal of Agriculture and Environment. 2010;11(2):1-10.
24. Rawat GS. Alpine ecosystems of the Himalayas: Their ecology, conservation, and future. Bishen Singh Mahendra Pal Singh; 2005.
25. Rawat GS. Alpine meadows of Uttarakhand: Ecology, land use and status of medicinal and aromatic plants. Wildlife Institute of India; 2005.
26. Rawat K, Singh B. A review on medicinal plants used in ethnoveterinary medicine in Uttarakhand, India. International Journal of Herbal Medicine. 2017;5(3):40-45.
27. Samant SS, Lal M, Singh RD. Diversity, distribution and traditional knowledge of economically important alpine plants of Uttarakhand Himalaya. Mountain Research and Development. 2007;27(4):353-360.
28. Sati VP, Bandooni K. Climate change and sustainable development: Perspectives from Uttarakhand Himalaya. Springer Nature; 2019.
29. Sati VP, Bandooni K. Forests of Uttarakhand: Diversity, distribution, use pattern and conservation. Current Science. 2019;117(1):1-15.
30. Singh S, Negi RS, Dhanai R. Fodder plants of Machlad Gad Watershed, District Pauri Garhwal, Uttarakhand. ENVIS Bulletin on Himalayan Ecology. 2017;25:1-7.
31. Singh S, Singh BB. Nutritional evaluation of grasses and top foliages through *in vitro* system of sheep and goat for silvipasture system. Range Management and Agroforestry. 2017;38(2):241-248.
32. Tropical Forages. Cynodon dactylon. https://tropicalforages.info/text/entities/cynodon_dactylon.htm
33. Verma A, Das SK, Kumar S, Saini VP, Meena RK, *et al*. Evaluation of integrated fodder production systems for sustainable livestock production in Tarai region of Uttarakhand. Journal of Crop and Weed. 2022;18(1):22-26.
34. Wani BA, Jan GA. Traditional importance, phytochemistry, pharmacology, and toxicological attributes of the promising medicinal herb *Carissa spinarum* L. Molecules. 2023;10(3):158.