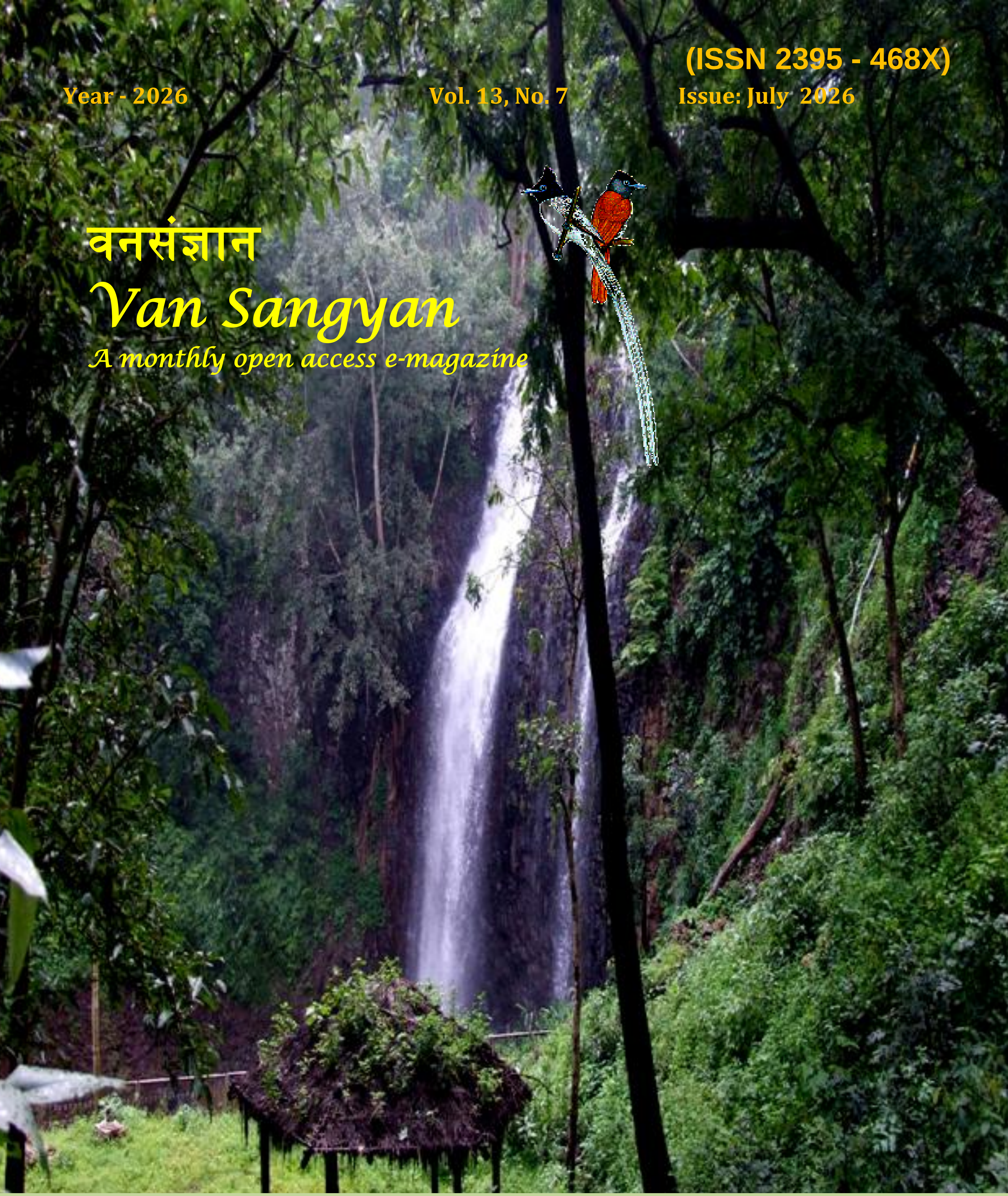
(ISSN 2395 - 468X)
Year - 2026 Vol. 13, No. 7 Issue: July 2026

वनसंज्ञान
Van Sangyan

A monthly open access e-magazine



Indexed in:
COSMOS Foundation (Germany)
International Inst. of Org. Res. (Australia)
IIJIF

ICFRE-Tropical Forest Research Institute
(Indian Council of Forestry Research and Education)
Ministry of Environment, Forests and Climate Change(MoEFCC)
PO RFRC, Mandla Road, Jabalpur – 482021, India

Van Sangyan

Note to Authors:

We welcome the readers of Van Sangyan to write to us about their views and issues in forestry. Those who wish to share their knowledge and experiences can send them:

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TFRI, Jabalpur houses experts from all fields of forestry who would be happy to answer reader's queries on various scientific issues. Your queries may be sent to The Editor, and the expert's reply to the same will be published in the next issue of Van Sangyan.

Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve

From the Editor's desk

The increasing frequency of climatic extremes, shifts in precipitation patterns, rising temperatures, and degradation of traditional agricultural resources are creating significant challenges for livestock-dependent farming systems in the North-Western Himalayas. In this context, Bauhinia variegata L. (Fabaceae), locally valued as a multipurpose tree, deserves greater scientific and policy attention as a potentially climate-resilient component of Himalayan agro-ecosystems. The species is traditionally integrated into rural landscapes for fodder, fuelwood, food, timber, shade, and medicinal applications, while its adaptability to varied environmental conditions makes it particularly relevant to climate-smart agroforestry. Its foliage can contribute to livestock nutrition during periods when herbaceous forage becomes scarce, thereby strengthening the seasonal feed base and reducing pressure on natural grazing resources.

The significance of B. variegata extends beyond its direct fodder value. As a perennial woody component of agroforestry systems, the species can contribute to landscape diversification, soil protection, nutrient cycling, carbon storage, and microclimate regulation. Deep-rooted perennial trees may also improve the functional stability of farming systems by providing biomass under increasingly variable climatic conditions. In the fragmented and topographically complex landscapes of Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and adjoining Himalayan regions, integrating suitable native or traditionally cultivated fodder trees into farms can provide an important buffer against forage shortages and climatic uncertainty. Such tree-based systems are especially relevant for smallholder farmers whose livestock production is closely linked to locally available biomass resources.

In line with the above this issue of Van Sangyan contains an article on Bauhinia variegata: A climate-resilient fodder tree for north-western Himalayan agro-ecosystems. There are also useful articles viz.. Cultivation of sweet orange var.mosambi, From waste to wealth, Vermicompost: Turning Organic Residues into a SoilSaving Resource, Anti-predator crouching behaviour and breeding observations of the Endangered Indian Skimmer Rynchops albicollis on the Chambal River, Rajasthan, India, Traditional Water Storage Structures of Kumaon, Uttarakhand: Indigenous Wisdom for Sustainable Water Security in the Himalaya, Nature-based solutions (NbS) for climate change mitigation, Growth simulation models: Predicting forest development for sustainable forest management, Climate change and trees: Adapt, migrate or perish?, Changing phenology of himalayan trees under climate change and दहीमन (Cordia macleodii): दुर्लभ औषधीय वृक्ष.

Looking forward to meet you allthrough forthcoming issues

Dr. Naseer Mohammad

Chief Editor

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Contents **Page**

Bauhinia variegata: A climate-resilient fodder tree for north-western Himalayan agro-ecosystems

Kamini[1], Sapna Thakur[2], R V Kumar[1], Hari Singh Meena[1] and Harish Sharma[3]
[1]ICAR-Indian Grassland and Fodder Research Institute, Jhansi, U.P.
[2]Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, Punjab
[3]ICAR-Central Agroforestry Research Institute, Jhansi, U.P.
E-mail: kaminigautam1989@gmail.com

Bauhinia variegata Roxb. (Family: Leguminosae), locally known as Kachnar, is a small- to medium-sized tree native to the North-Western Himalayas. It has a long, spreading crown and attains a height of up to 15 m and a girth of about 1.5 m, depending on the locality and edaphic conditions. The species occurs naturally in the sub-Himalayan tracts of the Indian Himalayas, growing in subtropical moist deciduous forests up to an altitude of 2,000 m above mean sea level (amsl). It is widely cultivated or retained on agricultural fields and village community lands for its multiple uses, including fodder, edible flowers, and fuel wood, and soil and water conservation.

In the North-Western Himalayan region, fodder scarcity during lean seasons is a major constraint that leads to substantial economic losses for small and marginal farmers who rely heavily on livestock for their livelihoods. To mitigate this challenge, fodder trees play a vital role as an alternative and supplementary source of feed alongside traditional grasses. Owing to their high nutritional value, excellent palatability, long productive lifespan, and adaptability to diverse agro-climatic and management conditions, these trees form an integral component of ruminant feeding systems in hilly regions. Most importantly, they provide a dependable source of nutritious green fodder during periods of seasonal feed scarcity, when grass and other conventional forage resources are limited or unavailable.

Fodder tree leaves are rich in crude protein and essential macro- and micro-minerals such as calcium and phosphorus, which are necessary for proper animal growth and health. In addition, the nutrients and beneficial secondary metabolites present in the leaves stimulate rumen microbial activity and support a healthy intestinal microflora thereby enhancing feed digestibility and nutrient utilization. Consequently, fodder trees play a vital role in meeting livestock feed requirements, sustaining animal productivity, and improving the resilience and sustainability of North-Western Himalayan agro-ecosystems. Among these, *Bauhinia variegata* is particularly important as it provides nutritious green fodder during the autumn and summer seasons, when the availability of grass and other conventional forage resources is limited.

Distribution in India

B. variegata occurs naturally in the sub-Himalayan tracts of the Indian Himalayas, where it grows in subtropical moist deciduous forests up to an altitude of 2,000 m above mean sea level (amsl). Its natural distribution extends from Jammu and Kashmir, Himachal Pradesh, Punjab, and Uttarakhand to Assam. The species thrives best on well-drained sandy loam soils. Across its distribution range, the annual rainfall varies from 500 to 2,500 mm, while the maximum temperature ranges from 30 to 40 °C and the minimum temperature is from 0 to 15 °C.

Silvicultural characters and phenology

B. variegata is a moderately light-demanding species that can tolerate partial shade. Its seedlings are sensitive to heat and drought, whereas mature trees are both frost and drought-hardy and respond well to lopping. Tree remains leafless from

December to March month and flowers during March-April month while pods ripen during May-June.

Figure 1. *Bauhinia variegata* tree

Utilization

In the Western Himalayas, *B. variegata* is utilized in a variety of ways owing to its nutritional, medicinal, and ecological importance.

Flowers as a nutritionally rich food

The flowers of *B. variegata* are widely relished by local communities because of their high nutritional value and medicinal properties. The flower buds are commonly used to prepare pickles and vegetables and are valued for their rich antioxidant content and essential nutrients, making them an important seasonal food resource.

Fodder

The leaves of *B. variegata* are an excellent source of high-quality fodder and are primarily utilized during the lean fodder periods of October-December and May-June. Their high nutritional value and palatability make them an important feed resource for livestock in the North-Western Himalayan region.

Dining plates and bowls

The leaves of *B. variegata* are traditionally used to prepare biodegradable dining plates (*pattals*) and bowls (*donas*), particularly during social gatherings, religious functions, and festivals. The leaves can be collected, dried, and machine-compressed to produce durable, eco-friendly disposable tableware. Owing to their medicinal properties, these leaf-based products are considered safe and beneficial for human use while offering a sustainable alternative to plastic and other non-biodegradable materials.

Ethnomedicinal uses

B. variegata possesses significant ethno-medicinal value. The bark paste is traditionally used to treat diarrhoea and skin ulcers, while the flower buds are commonly used in the treatment of dysentery, diarrhoea, and haemorrhoids. In addition, the leaves have been reported to possess antidiabetic and anticancer properties.

Fuelwood

The branches and twigs are commonly used as fuelwood for household cooking in the Himalayan region. The wood has a calorific value of approximately 4,791 kcal kg^{-1}, making it a good source of domestic energy.

Timber

The wood is greyish-brown, moderately heavy, and sufficiently strong while remaining relatively lightweight. It is traditionally used for manufacturing animal-drawn wooden land levellers and other agricultural implements.

Tannin

The bark is a valuable source of tannins and is traditionally used for producing various shades of brown dye.

Potential as a fodder tree in north-western Himalayas

The North-Western Himalayas supports a large livestock population that requires a continuous supply of quality fodder throughout the year. In this region, tree leaves, agricultural residues, and dried grasses constitute the major sources of livestock feed. Although green fodder is abundantly available from natural grasses during the rainy season, its availability declines considerably during the autumn, winter, and summer months, resulting in a serious seasonal fodder shortage that affects livestock productivity.

During these lean periods, fodder trees become the primary source of green forage for livestock. Among them, *B. variegata* plays an important role in maintaining fodder availability during seasons of feed scarcity. Its leaves are highly palatable and rich in crude protein and essential minerals, while exhibiting comparatively less seasonal variation in nutrient composition than grasses. Consequently, *B. variegata* is regarded as a valuable and climate-resilient fodder tree species of the North-Western Himalaya. The leaves are widely fed to cattle and goats as green fodder, particularly during the autumn and summer seasons, thereby contributing to sustained livestock productivity and enhancing the resilience of farming systems in the region.

***B. variegata* a promising source of nutritious green fodder:**

1. It provides medium-sized, highly palatable leaves during the autumn and summer seasons.
2. Its leaves have higher dry matter digestibility compared with other locally available fodder tree species.
3. It has high leaf biomass production potential, yielding approximately 15–20 kg of green foliage per mature tree annually.
4. Leaves are rich in crude protein and mineral content (Table 1).

The leaves of *B. variegata* can be harvested during the autumn and summer seasons and mixed with dry fodder to improve the nutritional quality and palatability of livestock feed. In the North-Western Himalayas, trees are typically lopped by about 30–40% during these seasons to ensure a sustainable supply of green fodder while maintaining healthy tree growth.

Table 1. Nutritional composition and mineral content of *B. variegata* leaves

Fodder Quality Traits	Content (Dry Matter Basis)
Crude Protein (CP)	15.25 %
Crude Fibre (CF)	24.36 %
Ether Extract (EE)	3.42 %
Ash	6.72 %
Nitrogen Free Extract (NFE)	50.25 %
Neutral Detergent Fibre (NDF)	59.81 %
Mineral	**Content mg/100g**
Calcium (Ca)	2.13
Phosphorus (P)	0.27
Copper (Cu)	2.80
Zinc (Zn)	3.50

Suitability of *B. variegata* in Agroforestry

B. variegata is a nitrogen-fixing, multipurpose tree species (MPT) that is highly suitable for agroforestry systems. Its root architecture, canopy characteristics, silvicultural attributes, and wide range of economic uses make it compatible with agricultural crops and livestock-based production systems.

Characteristics that make B. variegata suitable for agroforestry

Nitrogen-fixing ability Improves soil fertility by enriching soil nitrogen and enhancing nutrient cycling.

Deep taproot system: Possesses a deep taproot with limited lateral root spread, resulting in minimal competition with understory crops for water and nutrients.

Manageable crown architecture: Develops an elongated crown that can be effectively regulated through pruning and canopy management to reduce shading.

Valuable fodder source: Produces nutritious foliage during the summer and autumn seasons, when green fodder is often scarce, making it an excellent fodder tree.

Amenability to pruning and lopping: Tolerates regular pruning and lopping, allowing sustained fodder production while maintaining compatibility with intercrops.

Multipurpose utility: Provides fuelwood, fodder, timber, wood for agricultural implements, edible flowers, and contributes to soil and water conservation, enhancing the overall productivity and sustainability of agroforestry systems.

Carbon sequestration potential: *Bauhinia variegata* has a high potential for climate change mitigation through carbon sequestration and oxygen release. In an 11-year-old plantation established in 2013 at a spacing of 3 × 3 m (1,111 trees ha^{-1}), the species sequestered 105.93 Mg C ha^{-1} and released 77.04 Mg O_2 ha^{-1}, demonstrating its significant contribution to atmospheric CO_2 mitigation and ecosystem carbon storage (Megha et al., 2025).

Restoration of degraded lands: *Bauhinia variegata* is an important species for the restoration of degraded lands due to its ability to improve soil quality, reduce land degradation, enhance soil stabilization, and promote nutrient cycling. These characteristics support ecosystem recovery and sustainable land management, making it a valuable component of restoration and agro-forestry programmes (Jinger et al., 2023).

Propagation and leaf biomass production potential

B. variegata is primarily propagated through seeds, which is the most common method of multiplication. Seeds are generally sown during March–April in nursery bags, and the seedlings are transplanted in July–August with the onset of the monsoon. To enhance germination, the seeds are soaked in water 24 hours prior to sowing, which helps soften the hard seed coat and improves germination percentage. For maintaining elite or superior genotypes, vegetative propagation through one year or older branch cuttings is practiced during August month using branch cuttings treated with 2000 ppm IBA (Indole-3-butyric acid) using quick dip method. Branch cuttings of about 10-15 cm in length with 3–4 nodes are generally recommended for vegetative propagation. On maturity single tree can provide 15-20 kg fresh yield of fodder per tree on 30-40 % canopy lopping.

Way forward for utilizing B. variegata to sustain fodder supply in the North-Western Himalayas

- Promoting cultivation of *B. variegata* on farm bunds and field boundaries to ensure a sustainable supply of green fodder without affecting crop production.
- Encourage its integration with other fodder tree species on agricultural border lands to provide a continuous supply of high-quality fodder throughout the year.
- Expand plantations on community grazing lands to strengthen local fodder resources and reduce pressure on natural forests.
- Harvest twigs and leaves before natural leaf fall and conserve them as tree hay for feeding livestock during fodder-deficit periods.

- Process leaves into leaf meal by drying them to approximately 20–30% moisture content, grinding them into powder, and compressing the material into nutrient-rich leaf meal blocks for long-term storage and strategic feeding during periods of fodder scarcity.
- Establish quality planting material through nurseries and promote large-scale plantation programmes in suitable agroforestry systems across the North-Western Himalayan region.
- Create awareness among farmers regarding the nutritional value, proper management, and plantation of *B. variegata* through extension programmes and field demonstrations.
- Support further research on fodder quality, biomass production, storage technologies, and economic feasibility to enhance the adoption of *B. variegata* as a climate-resilient fodder tree species.

Conclusion

B. variegata is a valuable multipurpose tree species of the North-Western Himalayas with excellent fodder potential and significant relevance for sustainable livestock production. The region experiences a recurring shortage of quality green fodder, particularly during the summer months when pasture productivity declines. Promoting the cultivation of *B. variegata* in agroforestry systems, on farm bunds, community lands, grazing lands, and other marginal or degraded lands can substantially enhance the year-round availability of nutritious fodder. In addition to supporting fodder security, its nitrogen-fixing ability, high carbon sequestration potential, compatibility with crops, and multiple economic uses make it an ideal component of climate-resilient farming systems. Wider adoption of this species can improve livestock productivity, strengthen rural livelihoods, conserve natural resources, and contribute to the ecological and economic sustainability of the North-Western Himalayan region.

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Cultivation of sweet orange *var.* mosambi

Abdul Majid Ansari
Department of Horticulture
Birsa Agricultural University, Ranchi-834006,
Jharkhand, India

Mosambi is an important variety of sweet orangewhich is a popular citrus fruitin India. Its plants are grown for pulp and juice and yield is good under ideal cultivation practices. Mosambi is the 3rdlargest fruit cropin India. The Mosambi plant can grow up to a plant height of 20 to 25 feet. The major sweet orange (*Citrus sinensis*) growing states in India are Telangana, Andhra Pradesh, Maharashtra, Madhya Pradesh, Karnataka, Punjab, Bihar, Assam, Mizoram and the union territory of Jammu & Kashmir. The branches of these trees are relatively smooth, brownish-grey bark. Mosambi flowers are white and they spread an aromatic fragrance. Usually, fruits are green and they become light yellowish on ripening.

Table 1: Indian Production of Sweet Orange (Malta, Mosambi)

Production (000 Tones) 2017-18			
S. No.	**State**	**Production**	**Share (%)**
1	Andhra Pradesh	2,003.11	61.34
2	Maharashtra	684.80	20.97
3	Telangana	368.60	11.29
4	Madhya Pradesh	111.72	3.42
5	Karnataka	25.77	0.79
6	Punjab	25.09	0.77
7	Tamil Nadu	17.53	0.54
8	Jammu & Kashmir	5.72	0.18
9	Mizoram	4.94	0.15
10	Bihar	4.40	0.13
	Page Total	**3,251.68**	

Source: National Horticulture Board (NHB)

Fruits and vegetables are made available to us by nature with the intention of us being healthy and fit. Most fruits will provide us with the required vitamins and minerals, but each of them has something in abundance compared to other fruits. Just like Mosambi, it is a rich source of vitamin C and consists of different nutrients required for our health.

Mosambia variety of sweet orange is a fruit that is mostly located in south-east Asia. It looks just like a lemon but tastes sweeter when we relish the fruit in our leisure time. We will go around understanding the nutritional value of Mosambi juice and the benefits it offers to our body, internally and externally. It is beneficial to our skin, eyes, internal organs and many more.

Nutritional Composition

If we are looking for something that has low calories and still help us feel full and a feeling to relish, go ahead with the sweet orange. Mosambi fruit consists of minerals like phosphorus, folate, riboflavin, niacin, and magnesium. Also, one sweet orange can cover around 22% of the Vitamin C requirement of our body the Reference Daily Intake (RDI). 2% each of Iron, Calcium, Vitamin B_6, Thiamine and 1% of Potassium of the total daily intake of these minerals.

Healthy Benefits of Mosambi Juice

As good and balanced as the nutritional composition sounds on paper, it is equally good in application and function. There are numerous sweet orange benefits when we have it in different forms, especially in the form of juices. Sweet orange juice is one of the yummiest and healthiest drinks to start or end our day with. Here are the top 10 benefits of drinking Mosambi juice.

Helps digestion

Sweet orange juice helps in regularizing and improving our digestion. If digestion is an issue for us, there are many other issues that we are bound to face and therefore, we suggest taking care of it. A glass of Mosambi juice is all we need to take care of the digestion issue. It is acidic and therefore helps in keeping digestion proper. If indigestion and constipation are problems, Mosambi juice can be a natural way to cure them. It is a recommended solution by experts. It also regulates metabolism and helps in regulating bowel movements.

Prevents gums and teeth issues

Sweet orange fruit juice is a powerhouse of Vitamin C and it provides all the required nutrition to the health of gums and teeth. Scurvy is one of the very common gum and teeth issues faced by children, which leads to swelling and causes ulcers on the inner lips and tongue. Mosambi juice helps in taking care of these issues and also relieves gum issues. The fruit helps in keeping our teeth white and shiny. Regular consumption of sweet oranges can help in reducing bad breath.

Recovers immune system

Due to the increasing use of private vehicles, there is a lot of pollution in and around us in which we are forced to travel. Our immune system is ruined because of the exhausts and chemical gases thrown out by vehicles. This weakens your immune system and ultimately increases the risk of diseases and illnesses. Some medicines can help us to get rid of such issues, but they come with side effects that are not right in the long run. In such situations, a natural remedy works best and that is Mosambi juice. Its regular consumption can help in recovering and strengthening the immune system, thanks to the abundance of vitamin C available in various fruits as a natural source having no side effects.

Aids weight control

The problem that is increasing in the world right now is obesity and weight gain. With the increasing consumption of processed foods, this problem is way far from going away. We can have a glass of Mosambi juice for weight loss that is just enough to take care of the issue. One sweet orange serving consists of approximately 40 calories and all of it is just goodies. No fats, only minerals and vitamins, which help in solving other issues too in addition to aiding weight loss.

Take care of the "gout" issue

Mosambi juice is beneficial when you want to lower the levels of uric acid, preventing gout. The antioxidants present in Mosambihelp in flushing out toxins, uric acid, and other free radicals in our bodies. So those suffering from gout or who face the issue regularly should consume sweet orange juice two times every day. Sweet orange benefits are immense and we have more if we think that we have covered most of them.

Aids diabetes

Diabetes is one of the lifestyle diseases that people are facing in the majority in India as well as abroad. There used to be an age constraint a few years ago, but nowadays it is becoming irrespective of our age. We can say it is one of the diseases that have no cure yet but might lead to other issues as well because of diabetes. We can make a solution of Mosambi juice onan empty stomach mixed with Aonla juice and honey in the morning to see the best results.

Treat ulcers

One of the most important benefits of drinking sweet orange juice is that it helps in treating ulcers. The reason is, sweet orange juice is acidic and it reacts with the alkalinity of our body, which treats peptic ulcers and lowers gastric acidity.

Boosts blood circulation

Mosambi benefits the blood circulation process in our body. Drinking sweet orange juice regularly can help in boosting blood circulation and maintain proper parameters and organs of the body. It accelerates blood circulation and keeps our body and mind hale and hearty all the time.

Helps aid the nervous system

One of the most important parts of the body is our nervous system. Everything starts here and hence it has to be healthy. Sweet orange juice has cooling properties that help our brain to function just fine as expected. It keeps our nerves calm and also controls anxiety levels, so they stay within limits.

Relief from motion sickness

Tanginess helps us well in relieving motion sickness. A glass of Mosambi juice helps in solving the issue of heartburn and acidity. It reduces abdominal complaints and minimizes or soothes the gastrointestinal tract.

Mosambi fruit has many benefits, and we cannot just say these are the only ones. There are many more than we expect to have. The ones mentioned here are the most critical. Many Mosambi health benefits will take us towards a fit and perfect immunity. Also, Mosambi's health benefits are many and it is one of the natural ways to help us to tackle health issues in the long run.

Agro-climate required

Sweet oranges can be grown even up to an elevation of 900 m above mean sea level. Extremetemperatures are necessary for achieving higher yields. Temperature 25^{0} c is ideal and extreme cold and high temperatures are determinate. For commercial cultivation of Mosambi, a dry climatic condition with about 60 to 75 cm of rainfall from June to September is required. It is also suitable to be cultivated during the summer and winter seasons.Mosambi plants are able to sustain well-drained red soils or loamy soils.

Soil type

Deep well drained loamy soils are the best for the cultivation of sweet oranges. Heavy soils, if well drained, yield good crops but cultivation becomes difficult. Mosambi plants are able to sustain well-drained red soils or loamy soils. The soil pH preferred is 6.5 to 7.5 for its optimal growth and higher yields. The EC of soil water should be less than 1.0. The plant is highly sensitive to water-logged soils. If you are planning to cultivate Mosambi on large scale, it is recommended to carry out a soil test. As Mosambi plants are sensitive to water-logging, cause root rot diseases in plants. So a well-suitable drainage system should be adopted.

Plant propagation

Mosambi propagates through the budding technique. The root-stock raised in nurseries is later transplanted to the main field and during the month of September-October and March-April budding processes are carried out in the pencil-thickness stem of the root-stock.

Land preparation, planting and spacing

The field should be prepared well by ploughing and land should be properly levelledand brought to a fine tilth of the soil. Previous weeds and rock particles should be removed as a part of land preparation. The suitable pit size should be with a dimension of 3 ft(width) x 3 ft(length) x 3 ft(depth). The pit-to-pit or plant-to-plant distance should be 5 meters. A row-to-row distance of 5 meters should be maintained. It is recommended to expose the tree saplings to the sun for a couple of weeks before starting the plantation. It is better to plant Mosambi at good distances as these trees go very big and occupy a large space. For a good fertility status soil it may plant at 6m x 6m spacing.

We should purchase a high-quality, disease-free Mosambi plant from certified nurseries to transplant in the field. These seedlings/saplings should be at least 2 years old. Place the saplings at the centre of the pit and cover them with topsoil. Don't forget to irrigate them immediately.

Varieties

Mosambi (Maharashtra), Sathgudi, Batavian or Bathayi (Andhra Pradesh) and Malta and Jaffa (Punjab) are the sweet orange cultivars traditionally grown in Indian states.

Planting materials

Budded plants are the best planting materials. Healthy and vigorously growing buds budded on Rangpur Lime rootstock from a certified nursery has to be selected.

Irrigation

Watering should be done immediately after planting the saplings, which helps in proper root establishments. The frequency of irrigation depends on climatic conditions, the variety of the plant and the soil type. We should ensure good soil moisture at the plant base.

In winter, irrigation should be carried out every 3 to 4 days and in summer, every alternate day. Try to avoid excess irrigation as these plants cannot tolerate water logging. The drip irrigation system is recommended for the best yields and plant growth. A subsidy would be available for drip irrigation systems from the local horticulture department.

Pruning operations

Pruning is the process of removing unwanted leaves/branches/stems. Pruning is done for straight growth and to form a strong framework for the plant. For proper growth of the trunk, remove the shoots in 50 cm to 60 cm near ground level. The Centre of the Mosambi plant should remain open. Make sure to remove water suckers at the early stages of plant growth.

In order to allow the growth of a strong trunk, initially shoots up to 40 - 50 cm from the ground level should be removed. The centre of the plant should remain open. Branches should be well distributed to all sides. Cross twigs and water suckers are to be removed early. The bearing trees require little or no pruning. All diseased, injured and drooping branches and dead wood are to be removed periodically.

Manures and fertilizers to be used

Nitrogen has to be applied in two doses during March and October. However Farm Yard Manure (FYM), phosphorous and potash are to be applied in October.

Fertilizers are applied in a circular band at a radial distance of 120 cm from the tree trunk region. Deep placement or application of fertilizers at two to three areas in a basin should be avoided. In fact, the maximum activity in the sweet orange plantation was found within a depth of 25 cm and in acid lime, they are more surface-oriented, with 80-95% located in the top 10cm.

Manures should be applied in the basin 75 cm away from the trunk and incorporated into the soil. A solution containing sulphates of zinc (0.5%), iron (0.25%), magnesium (0.5%), manganese (0.05%), boron (0.1%) and molybdenum (0.003%) should be sprayed once in 90 days at the time of new flush production. In addition to these, apply 50 grams in each sulphate of zinc, manganese and iron/tree/year.

Table 2: Nutrient management in sweet orange

S. No.	Manures and fertilizers	Ist year (kg/plant)	Annual increase (kg/plant)	From 6th year(kg/plant)
1	FYM	20	5	30
2	N	0.100	0.100	0.500
3	Phosphorus	0.050	0.050	0.250
4	Potassium	0.025	0.025	0.250

Spray solution containing sulphate of zinc (0.5%), manganese (0.05%), iron (0.25%), magnesium (0.5%), boron (0.1%) and molybdenum (0.003%) once in 3 months at the time of new flush production. In addition to that apply 25 g in each sulphate of zinc, manganese and iron per tree per year.

Intercultural operations

Regular intercultural operations are required in the Mosambi orchard for better growth yield as well as management of several weeds, diseases and pests. Preparation basin and levelling of land surrounding the main stem of the plant as per the requirement of the season i.e. check basin system for irrigation during winter and summer whereas, well-levelled land for better drainage during the rainy season. Ploughing in the plots is required to control weeds and other herbs/shrubs during the rainy season are essential. A suitable intercropping system may also be adopted to increase cropping intensity and income per unit area of land for the income enhancement of the orchard growers.

Weed control

Manual weeding at the plant base and shallow cultivation between rows every 4 months should be carried out with care. There are many herbicides available to effectively control the weeds in Mosambi cultivation. We could make use of glyphosate at the rate of 1.6 litres/150 litres of water. Take care to use glyphosate only on weeds, not on Mosambi plants. It is better to opt for a selective herbicide like Paraquat to control weeds and other unwanted herbs in the established orchard.

Mulching

We can mulch the plants for controlling soil temperatures which saves the water from evaporation. We can use plastic mulch materials available in the market.

Intercrops

Inter-spaces are made in a Mosambi orchard for growing nitrogen-fixing crops until the plants start flowering during the initial 3 years of plantation. Legumes and vegetable crops can be raised as an intercrop during the pre-bearing age to get additional income. Green gram, black gram or any other legume crops, groundnut, vegetables like beans etc. are cultivated to be used as nitrogen fixation crops.

Pests and diseases

Pests: leaf miners, citrus psylla, scale insects and aphids, and mealybugs are common pests found in Mosambi cultivation.

Diseases: citrus / Mosambi canker, gummosis, powdery mildew, black spot, zinc deficiency, and iron deficiency are common diseases found in Mosambi cultivation.

Leaf miner: Spraying with azadirachtin (1%) @ 10 ml/ l immediately after the appearance of new foliage and 2nd spray after a week period with chemicals thiamethoxam 0.3g + dichlorvos 0.5ml or thiamethoxam 1ml or NSKE 5% + dichlorvos 0.5 ml or imidacloprid (confidor 100 sl) 0.5 ml or profenophos 2 ml per litre of water was recommended. But care should be taken that the same chemicals should not be sprayed repeatedly. Removal of water shoots which serve as off seasonal source of survival.

Citrus root nematode

- During replanting of the nurseries neem cake or castor cake or pongamia cake should be applied @ 60-80 kg per ha area.
- Do not grow solanaceous crops or okraor banana crops in citrus orchards.
- Apply carbofuran granules @ 130-160g or regent @ 40-80g per plant basin. After 3 months, based on plant age apply 15-25 kg neem or castor or pongamia cake per plant for every 6 months.
- Seedlings should be selected from nematode-free nurseries

Control of fruit drop

Early and pre-harvest fruit drop is common in citrus fruits. To control this physiological disorder, it is better to give three sprays of 2,4-D at 10 ppm (1g/100ℓ), one at the time of flowering, the second one month after fruit set and the third one month before harvest which is beneficial and increases the yield considerably minimizing the fruit drop.

Bahar treatment

There are three flushes *Ambe bahar* (Dec-Jan),*Mrig bahar* (June-July), and *Hastha bahar* (Sept-Oct) in sweet orange. The *Hastha bahar* crop comes to harvest in summer and gets a remunerative price. A stress period of 20-25 days is sufficient for the induction of flowering under Andhra Pradesh conditions. The main season of *bahar* is August-September which comes to fruiting in March which is having very good market price. The second season practised for *bahar* is Nov-Dec whenfruits come to harvest in the months of July-August.

Harvesting

Mosambi plant starts flowering after 3 years of plantation. These flowerings should be removed for better and string fruiting for next year. We could expect yield from the 4th year of plantation. Manual harvesting of these fruits can be facilitated using a sharp sickle. Two harvest seasons are available in a year, April to May and August to September. Usually, Mosambi fruit turns green to light yellowish colour on attaining maturity. Pluck the fruits before they are fully ripe.

Yield

The yield of the crop commences from the 5th year with 40 - 50 fruits per tree &stabilizes around the 8th year. Average production is about 500 - 600 fruits per tree after stabilization. Yield depends on soil type, variety, irrigation, plant age, season and other crop management practices. Commercial yield is expected only after the 4th year of plantation. Initially, we can get 60 kg/plant or 5.0 tons/acre. After the 5th year, the yield increases to 100 kg/plant or 9 tons/acre. The yield reaches its peak after 10 years. The economical lifespan of Mosambi is about 20 years. The yield decreases gradually when the plant reaches its last few years of lifespan.

Post harvesting

Harvested Mosambifruits should be cleaned, graded (on size and colour), packed and transported to the local fruit markets. These fruits can be sold in both wholesale and retail markets. They are also sold to different fruitselling agents.Sweet oranges can be stored at 7 - 8°C with 85 - 90% RH for 4 - 8 weeks. Sweet oranges may be treated with ethylene gas for de-greening and the development of colour. A temperature of 6-7°C, 5-10 ppm of ethylene and 90-95% RH in a de-greening chamber can set a change in colour in about 48 hours.

From waste to wealth

Vermicompost: Turning Organic Residues into a SoilSaving Resource

Rashmi
Centre for Socio-Economic Development
G.B. Pant National Institute of Himalayan Environment (NIHE),
Kosi-Katarmal, Almora–263643, Uttarakhand, India
Email: rashrai.bhu@gmail.com

Fig. 1: Earthworms in active vermicompost

Every farm produces organic material. Cow dung, crop residues, fallen leaves, vegetable scraps and other biodegradable wastes appear throughout the year. What looks like a disposal problem can become a valuable farm resource. Vermicomposting offers a biological way to convert these materials into a dark, nutrient-rich organic amendment with the help of earthworms.

Vermicompost is produced when earthworms and associated microorganisms break down suitable organic materials. The process turns a stream of residues into a useful agricultural input while keeping nutrients within the farm system. Instead of burning or discarding organic material, farmers can return it to the soil in a more useful form.

Vermicomposting offers a practical way to connect organic waste recycling with soil health and more efficient nutrient management. When the process is organized at farm or community level, it can also become a small but useful source of rural income.

The appeal is practical. Many of the raw materials required for vermicomposting are available locally, the production unit can be adapted to farm conditions, and the finished product can be used on the farm or marketed. In this way, vermicomposting connects soil management, waste recycling and livelihood generation.

Vermicompost in one sentence

Organic residues are prepared and biologically processed by suitable earthworms to produce a stable, nutrient-rich material that can be returned to agricultural soils.

Why Vermicompost Matters

Healthy soil is a living system. Organic matter supports soil structure, biological activity and nutrient cycling, and its maintenance is central to long-term farm productivity. Vermicompost provides an additional organic input that can be incorporated into integrated nutrient-management programmes.

Its value should not be reduced to the claim that it can replace every chemical fertilizer. Crop nutrient requirements vary, soils differ, and farmers need balanced nutrientmanagement strategies. Vermicompost is most useful when it is treated as one component of a broader soil and nutrient management system.

A wide range of biodegradable materials can serve as feedstock, including animal dung, crop residues, kitchen and vegetable wastes and selected organic residues from other activities. Whatever the material, cleanliness and suitability are essential for producing a good quality compost.

Vermicomposting creates a circular pathway: livestock and crops generate residues; residues are processed into vermicompost; nutrients and organic matter return to the soil; and the next crop is produced from a system that has recycled part of its own resources.

Four reasons to vermicompost

- Recycle organic residues
- Return nutrients and organic matter to soil
- Reduce disposal problems
- Create a potential farm or community enterprise

Meet the Earthworm

The Living Engine of Vermicomposting

Fig. 2: A close-up of the biological workers of vermicomposting

Earthworms are the biological workers at the centre of the process. By feeding on decomposing organic matter and interacting with microorganisms, they fragment and transform the material into fine, biologically active castings.

Several earthworm species are suitable for vermicomposting, including Eisenia fetida, Eudrilus eugeniae and Perionyx excavatus. These composting worms differ from many common garden earthworms in their feeding behaviour, reproduction and ability to thrive in organic-rich environments.

Earthworm biology explains why management matters. The worms need suitable feed, moisture, temperature, aeration and protection. Earthworm activity is generally favoured by moderate temperatures of about 20–30°C, while excessive heat can cause stress and reduce survival.

A vermibed is therefore a living production system. Direct sunlight, excessive heat, waterlogging, unsuitable feed, chemical contamination and predators can all reduce worm survival and reproduction. Good vermicomposting starts by creating the right environment for the worms.

The key lesson

The aim is not simply to let organic waste rot. The aim is to maintain a healthy population of suitable composting earthworms while the organic material is transformed into mature vermicompost.

What Goes Into a Vermibed?

Clean feedstock is the first quality-control step

Fig. 3: Preparing organic feedstock.

Good vermicompost begins with good raw material. Useful feed materials include animal dung, crop residues, household and kitchen wastes, vegetable and fruit residues, selected municipal organic wastes and some agro-industrial residues.

Cow dung is particularly useful, but fresh dung should not be placed directly into a vermibed. Fresh material can heat up during microbial decomposition, and excessive heat can harm earthworms. Pre-decomposition or partial digestion is therefore an important preparation step.

Crop residues can be chopped and mixed with suitable organic materials. Kitchen and vegetable residues can also be incorporated after careful segregation. Plastics, glass, metals and other non-biodegradable materials should be removed before the feed enters the production unit.

The quality of the finished compost can never be better than the quality of the feedstock. Producers should therefore make segregation a routine activity, keep contaminated material out, and avoid materials that may introduce unwanted chemicals or other hazards.

A simple feedstock check

Is the material biodegradable? Is it clean? Has fresh material been allowed to cool or partially decompose? If not, keep it out of the vermibed until it is suitable.

Building the Right Home for Earthworms

Shade, moisture, temperature and drainage

Vermicomposting does not require a sophisticated structure, but the production unit must provide a stable environment. Vermicomposting can be carried out in beds, pits or tanks, provided the system offers a stable and protected environment for the worms.

Shade protects the bed from direct solar heating. Drainage prevents excess water from accumulating and helps maintain aeration. Moisture must be maintained regularly, but the material should not remain waterlogged.

Temperature is another key factor. A temperature of about 20–30°C is generally favourable for earthworm activity. During very hot or cold periods, additional protection may be needed, depending on local conditions.

The production area should also be protected from predators and unnecessary disturbance. Regular observation is more useful than frequent turning or handling. Farmers should look for excessive dryness, waterlogging, foul conditions, heat stress or unusual worm behaviour and correct the underlying cause.

Four essentials

- Moisture
- Moderate temperature
- Shade/protection
- Good drainage and aeration

From Waste to Finished Compost

A managed biological production cycle

Fig. 4: Vermicompost production bed

The production cycle begins with collection and segregation of suitable organic materials. Fresh material is then prepared and allowed to undergo partial decomposition before earthworms are introduced. This preparation phase reduces the risk of excessive heat.

The prepared material is placed in a suitable bed, pit or tank and healthy earthworms are introduced. The unit is then maintained under favourable moisture and temperature conditions. Earthworms and microorganisms gradually transform the feed material into vermicompost.

During the active phase, management should focus on maintaining moisture, avoiding excessive heat, protecting the worms and ensuring that the feed remains suitable. The bed should not be disturbed unnecessarily.

Harvesting requires care because the earthworm population is itself a valuable part of the production system. Mature compost is separated while healthy worms are retained for the next cycle. The finished material can then be screened, packaged or applied to the farm.

A well-managed unit can operate as a continuing cycle rather than a one-time activity. Feed preparation, worm multiplication, composting, harvesting and marketing can be planned in stages so that production becomes more regular.

The production cycle

Collect → segregate → pre-decompose → prepare bed → introduce worms → maintain conditions → mature → separate worms → harvest → use or sell

Quality, Maturity and Farm Use

Good vermicompost is more than a darkcoloured material

Quality matters especially when vermicompost is sold. A marketable product should be clean, mature and consistent and should meet the applicable quality requirements under the Fertilizer Control Order (FCO).

Important quality checks include moisture, colour, odour, particle size, electrical conductivity and nutrient characteristics. Together, these indicators help distinguish mature vermicompost from material that is still decomposing or has been contaminated.

Maturity is essential. Material that is still undergoing active decomposition may not perform in the same way as stable vermicompost. Producers should allow adequate processing and use appropriate maturity indicators before harvesting and marketing.

On the farm, application should be based on crop requirement, soil condition and the overall nutrient-management plan. Vermicompost can be combined with other organic inputs and appropriate fertilizer sources rather than being treated as a universal substitute for all nutrient inputs.

For commercial production, screening, packaging and labelling are part of quality management. A consistent product, clear information and clean packaging improve buyer confidence and help build a sustainable enterprise.

Quality checklist

- Clean feedstock
- Proper maturity
- Consistent texture
- Appropriate moisture
- Acceptable quality parameters
- Responsible packaging and labelling

From Farm Practice to Rural Enterprise

Vermicomposting as a circular livelihood opportunity

Fig. 5: Vermicomposting as a rural livelihood activity

Vermicomposting can remain a small farm practice, but it can also develop into a rural enterprise. A well-managed unit can generate value in more than one way: farmers can sell finished vermicompost, multiply and sell earthworms, or use the compost on their own land to reduce expenditure on external inputs.

The opportunity is strongest where organic raw materials are readily available. Livestock owners have dung, crop farmers have residues, and households and institutions generate biodegradable waste. Organized collection and processing can turn these resources into a useful agricultural input.

A local enterprise may involve feedstock collection, segregation, pre-decomposition, bed management, earthworm multiplication, harvesting, screening, packaging and marketing. Farmer groups, self-help groups, nurseries and other local organizations can participate according to their capacity.

Profitability is not automatic. Construction or bed preparation, labour, earthworm stock, water, feed handling, harvesting, screening, packaging and transport all involve costs. Producers should maintain simple records of inputs, production, labour and sales before deciding to expand.

The larger opportunity lies in linking soil health with resource recycling. Vermicompost can reduce the waste burden, return organic matter to farmland and create an additional income stream. It is a relatively small technology with the potential to contribute to a more circular and resource-efficient rural economy.

The message is simple: waste becomes valuable when it is managed well. Clean inputs, healthy worms, suitable environmental conditions, proper maturity, quality control and reliable markets are the foundation of a successful vermicompost system.

Five golden rules

- Use clean feedstock
- Pre-decompose fresh materials
- Protect the worms
- Harvest mature compost
- Record costs, production and sales

Anti-predator crouching behaviour and breeding observations of the Endangered Indian Skimmer *Rynchops albicollis* on the Chambal River, Rajasthan, India

Anchal Sharma[1] and V. Chethan Kumar[2]
[1]Department of Wildlife Management, CHF, Jhalawar
[2]DCF, Dholpur, Rajasthan Forest Department

Abstract

The Indian Skimmer *Rynchops albicollis* is an endangered riverine bird that breeds on exposed sandy areas of large rivers in the Indian subcontinent. Despite its conservation importance, detailed field observations on its breeding ecology remain short. During systematic monitoring of breeding colonies along the Chambal River in Dholpur District, Rajasthan, between May and June 2026, nesting colonies were documented along with clutch characteristics, cryptic anti-predator behaviour of chicks and colony attendance by breeding adults. The observations include two-egg ground nests, newly hatched chicks, downy chicks exhibiting crouching behaviour within shallow depressions and of large congregations of breeding adults on exposed sandbars. These observations provide additional insights into the reproductive ecology and survival strategies of the species and emphasize the conservation significance of undisturbed riverine sandbars within the National Chambal landscape.

Keywords: *Rynchops albicollis*, breeding biology, anti-predator behaviour, chick camouflage, Chambal River, Rajasthan, nesting ecology.

Introduction

The Indian Skimmer *Rynchops albicollis* is one of South Asia's most threatened riverine birds and is currently categorized as Endangered by the IUCN Red List. Its breeding distribution has been limited considerably due to habitat degradation, river regulation, sand mining, livestock grazing, and human disturbance. The Chambal River supports one of the largest remaining breeding populations of the species, making the protection of its nesting habitat critical for the species long-term survival.

Although breeding colonies have been reported from the National Chambal Sanctuary, detailed field documentation of nesting behaviour, chick development, and anti-predator adaptations remains limited. Here, observations made during the 2026 breeding season from Dholpur District, Rajasthan are reported.

Observations

Field surveys were conducted during May to June 2026 on exposed sandbars of the Chambal River in Dholpur District, Rajasthan. Surveys were carried out using binoculars (10×42), spotting scopes, and telephoto photography from observation distances that minimized disturbance to breeding birds.

Several breeding colonies were encountered on open sandy islands. Nests consisted of simple shallow scrapes excavated directly into loose sand without nesting material. The observed clutch size was 2-3 eggs, with eggs heavily pigmented in brown and black, closely matching the surrounding substrate and providing effective camouflage (Figure 1).

A newly hatched chick covered with pale buff down bearing dark mottled markings was observed resting inside a shallow depression in the sand (Figure 2). The chick remained completely motionless despite nearby observer activity, relying entirely on cryptic plumage for concealment. Similar behaviour was observed in older chicks occupying individual shallow depressions on sparsely vegetated sandbars (Figure 3). Rather than fleeing from perceived threats, chicks flattened their bodies against the substrate, lowered their heads, partially closed their eyes, and remained immobile, rendering them almost indistinguishable from the surrounding sand.

Large numbers of adult skimmers were observed resting and nesting communally on exposed sandbars (Figure 4), confirming the colonial breeding behaviour typical of the species. Adults remained vigilant throughout the observation period and frequently responded collectively to potential disturbances.

This behaviour appears to represent an effective anti-predator strategy against visually hunting predators such as raptors, gulls, crows, jackals, and feral dogs. The shallow depressions further reduce the chick's profile while improving camouflage against the heterogeneous sandy substrate.

Discussion

The breeding ecology documented during this study agrees with previous descriptions of Indian Skimmer nesting on exposed sandy river islands. The observed two-egg clutch corresponds with the typical clutch size reported for the species.

The cryptic behaviour displayed by chicks represents one of the most important behavioural adaptations for survival during the early post-hatching period. Unlike many colonial birds that actively defend chicks, Indian Skimmer chicks primarily depend upon camouflage and immobility to escape detection. The mottled down closely resembles the surrounding sand, while crouching inside shallow depressions further enhances concealment.

The communal nesting observed on the Chambal River likely provides additional protection through collective vigilance and predator detection. Nevertheless, colonial nesting also makes breeding sites vulnerable to catastrophic disturbance caused by sand mining, recreational activities, livestock movement, uncontrolled tourism, flooding, or predation.

The breeding season of May–June coincides with increasing human activity on exposed river islands, highlighting the need for temporary protection of active nesting colonies. Restricting human access during the breeding period and maintaining undisturbed sandbars should be considered priority conservation measures.

Conservation Implications

The present observations support the importance of the Chambal River as a major breeding refuge for the Endangered Indian Skimmer. Protection of nesting sandbars during the breeding season is essential to improve breeding success. Regular monitoring of colony size, nesting success, chick survival, and habitat condition should be integrated into long-term conservation programmes within the National Chambal Sanctuary.

Figure 1. Ground nest of Indian Skimmer *Rynchops albicollis* containing a typical clutch having cryptically coloured eggs on an exposed sandbar of the Chambal River, Dholpur, Rajasthan.

Figure 2. Newly hatched Indian Skimmer chick resting inside a shallow sandy depression, illustrating cryptic down plumage and camouflage.

Figure 3. Older Indian Skimmer chicks exhibiting characteristic anti-predator crouching behaviour by remaining motionless inside shallow depressions on the breeding sandbar.

Figure 4. Breeding colony of Indian Skimmers resting on an exposed sandy island along the Chambal River during the 2026 breeding season

Traditional Water Storage Structures of Kumaon, Uttarakhand: Indigenous Wisdom for Sustainable Water Security in the Himalaya

Rashmi[1] and Utkarsh Kumar[2]
[1]G.B. Pant National Institute of Himalayan Environment, Almora-263643, Uttarakhand, India
[2]ICAR- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora- 263601, Almora, Uttarakhand, India
E-mail: rashrai.bhu@gmail.com

Introduction

The Himalayan region is often regarded as the "Water Tower" of India due to its abundant water resources. However, the rugged terrain, scattered settlements and seasonal variability of rainfall have historically posed significant challenges to water availability in mountain communities (Dhyani et al., 2013; Valdiya and Bartarya, 1989). To overcome these challenges, the inhabitants of Kumaon in Uttarakhand developed several ingenious water harvesting and storage systems that efficiently captured, stored, and distributed water for domestic and agricultural purposes.

These traditional structures, including Naulas, Dharas, Chals, Khals and Guls, represent centuries of accumulated indigenous knowledge and community-based resource management. Besides ensuring water security, these systems contributed significantly to groundwater recharge, biodiversity conservation and ecosystem sustainability. In the present era of climate change and increasing water scarcity, these traditional systems offer valuable lessons for sustainable water resource management (Agarwal and Narain, 1997; Government of Uttarakhand, 2020).

Naula: The Water Temples of Kumaon

Among the traditional water structures of Kumaon, the Naula is perhaps the most unique and architecturally significant. A Naula is a stone-lined underground reservoir constructed around a perennial spring. Typically rectangular in shape, it is covered with a stone roof that protects the water from direct sunlight, contamination, and evaporation.

The construction of Naulas demonstrates remarkable engineering skills. Water naturally seeps through surrounding rocks and accumulates within the chamber, providing a continuous source of clean drinking water throughout the year. Several Naulas in Kumaon date back to the Katyuri and Chand dynasties and are known for their intricate stone carvings and architectural elegance(Dhyani et al., 2013; Agarwal and Narain, 1997).Beyond their functional value, Naulas are deeply embedded in local culture and traditions. Many are associated with temples and religious beliefs, and villagers often perform rituals and ceremonies around these water sources. Because of their sacred nature and architectural beauty, Naulas are often referred to as the “water temples” of Kumaon.

Figure 1. Traditional Naula in Kumaon used for yearround drinking water supply.

Dharas: Lifelines of Mountain Communities

Dharas are natural springs where groundwater emerges through rock fissures. Local communities traditionally enhanced these springs by constructing stone outlets and collection platforms, making them more accessible for domestic use.

For centuries, Dharas served as the primary source of drinking water for many villages. Their location often determined settlement patterns, and many temples and religious sites were established near perennial springs. The cultural significance of Dharas is reflected in numerous local traditions and festivals associated with water worship.

However, changes in land use, deforestation, and declining groundwater recharge have led to the drying of many traditional springs in recent decades (Valdiya and Bartarya, 1989; Government of Uttarakhand, 2020). This has increased the importance of spring rejuvenation and watershed conservation efforts across the Himalayan region (Government of Uttarakhand, 2020).

Figure 2. A traditional Dhara providing freshwater to rural households in Kumaon

Chals and Khals: Traditional Rainwater Harvesting Systems

Chals and Khals are traditional rainwater harvesting ponds excavated on hilltops, forest slopes, and grazing lands. While Chals are generally smaller in size, Khals are larger structures capable of storing substantial quantities of rainwater.

These systems play a crucial role in conserving water by capturing runoff during the monsoon season and allowing it to percolate slowly into the ground. As a result, they help recharge groundwater aquifers, sustain springs, and maintain stream flows during dry periods (Government of Uttarakhand, 2020).

In addition to improving water availability, Chals and Khals reduce soil erosion, enhance soil moisture, and provide drinking water for wildlife. Their role in watershed management and ecosystem conservation has gained renewed attention in recent years as communities seek climate-resilient solutions to water scarcity.

Figure 3. Chal/Khal system used for rainwater harvesting and groundwater recharge.

Guls: Traditional Irrigation Channels

Agriculture in the mountainous terrain of Kumaon depends heavily on efficient irrigation systems. Guls are traditional gravity-fed channels that divert water from streams, rivers, and springs to terraced agricultural fields.

Constructed using locally available materials such as stones, mud and wooden planks, these channels distribute water across villages without requiring external energy inputs. Their maintenance and operation have traditionally been managed collectively by local communities, ensuring equitable water sharing among farmers.

The Gul system represents an excellent example of community-based natural resource management and has played a vital role in sustaining agriculture and food security in the Himalayan region for generations ((Dhyani et al., 2013).

Figure 4. Traditional Gul channel irrigating terraced agricultural fields in Kumaon

Ecological and Socio-Cultural Importance

Traditional water structures are not merely engineering innovations; they are integral components of the Himalayan socioecological system. These structures facilitate groundwater recharge, regulate hydrological processes, conserve biodiversity, and improve ecosystem resilience.

The close relationship between forests and water sources is particularly evident in Kumaon. Healthy forest ecosystems enhance infiltration and groundwater recharge, thereby sustaining springs, Naulas, and Dharas(Dhyani et al., 2013). Consequently, local communities have traditionally protected forests surrounding water sources through various cultural practices and customary regulations.Furthermore, these structures serve as important cultural landmarks that strengthen community identity and preserve traditional ecological knowledge.

Figure 5. Community-led restoration of traditional water sources in Uttarakhand.

Challenges and Conservation Needs

Despite their immense importance, many traditional water structures have deteriorated due to changing lifestyles, rural outmigration, urbanization, and dependence on modern piped water supply systems. Climate change has further aggravated the situation through altered rainfall patterns and reduced groundwater recharge.

Many Naulas and Dharas have dried up, while Chals, Khals, and Guls have gradually fallen into neglect. The revival and conservation of these systems require a combination of scientific interventions and community participation. Protecting catchment areas, restoring traditional structures, promoting spring-shed management, and documenting indigenous knowledge are essential for ensuring their long-term sustainability (Government of Uttarakhand, 2020).

Conclusion

The traditional water storage structures of Kumaon represent a remarkable legacy of indigenous knowledge, environmental stewardship, and community participation. Naulas, Dharas, Chals, Khals and Guls have sustained mountain communities for centuries while maintaining ecological balance and cultural identity.

In the context of growing water scarcity and climate uncertainty, these time-tested systems offer valuable insights for sustainable water management. Their conservation and revival can contribute significantly to water security, biodiversity conservation, and climate resilience in the Himalayan region. Preserving this rich water heritage is therefore not only a matter of cultural significance but also a practical necessity for achieving sustainable development in mountain ecosystems.

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Nature-based solutions (NbS) for climate change mitigation

Sudhir Prajapati[1], Dr. Pawan Kumar Poonia[1], Dr. Bhalendra Singh Rajput[2], Rakesh Parasriya[1] and Monika[1]
[1]Department of Forestry, College of Agriculture
CCSHAU, Hisar, Haryana.125004
[2]Department of Silviculture and Agroforestry, College of Forestry
BUAT, Banda, Uttar Pradesh .210001

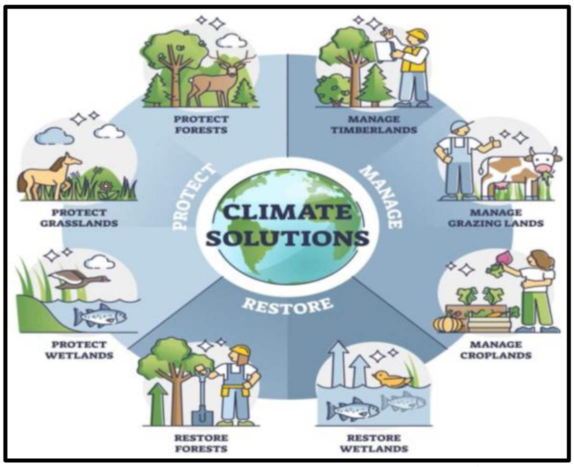
Abstract
Climate change has emerged as one of the most pressing global challenges, causing rising temperatures, extreme weather events, biodiversity loss, and ecosystem degradation. Conventional mitigation strategies, such as reducing fossil fuel emissions and adopting renewable energy, are essential but often insufficient on their own. In this context, Nature-Based Solutions (NbS**)** have gained global recognition as effective, sustainable, and cost-efficient approaches for climate change mitigation. NbS involve the protection, restoration, and sustainable management of natural and modified ecosystems to address societal challenges while simultaneously providing human well-being and biodiversity benefits. These solutions help sequester atmospheric carbon, reduce greenhouse gas emissions, enhance ecosystem resilience, and improve environmental sustainability. This article highlights the concept, major types, benefits, challenges, and future potential of Nature-Based Solutions in mitigating climate change.

Introduction

Climate change is driven by the excessive buildup of greenhouse gases such as carbon dioxide, methane, and nitrous oxide, largely due to human activities like deforestation, industrialization, land-use change, and fossil fuel combustion. Its impacts—rising sea levels, extreme heat, droughts, floods, and reduced agricultural productivity—demand integrated and sustainable solutions. Nature-Based Solutions (NbS) have emerged as a promising approach, as they harness natural processes to capture and store carbon while restoring ecosystem health. Defined by the International Union for Conservation of Nature as actions to protect, sustainably manage, and restore ecosystems that address societal challenges while benefiting biodiversity and human well-being, NbS stand apart from purely technological interventions by simultaneously advancing climate regulation, ecological restoration, and livelihood security.

Concept of Nature-Based Solutions

Nature-Based Solutions (NbS) harness the power of healthy ecosystems—forests, wetlands, grasslands, mangroves, and agroforestry—to regulate climate, conserve



biodiversity, and sustain human life. By capturing and storing carbon in vegetation and soils, restoring degraded landscapes, and enhancing water regulation through infiltration and evapotranspiration, NbS reduce greenhouse gas emissions while mitigating floods, droughts, and heat stress. They also strengthen ecosystem resilience by protecting habitats and supporting diverse species interactions, enabling natural systems to better withstand climate disturbances. Beyond ecological benefits, NbS provide socio-economic co-benefits such as green jobs, food security, disaster risk reduction, and livelihood support, making them a cost-effective and integrated approach for both climate mitigation and adaptation, ultimately advancing long-term sustainability and resilience.

Major Types of Nature-Based Solutions for Climate Change Mitigation

Forest Conservation and Afforestation

Forests are among the most effective natural carbon sinks, as they absorb large amounts of atmospheric carbon dioxide (CO_2) through photosynthesis and store it in biomass, roots, and soil. Forest conservation helps prevent carbon emissions caused by deforestation and land degradation, while afforestation and reforestation increase carbon storage by establishing new forest cover on degraded or barren lands. Healthy forests also regulate temperature, maintain rainfall patterns, and support biodiversity. In the context of climate change mitigation, conserving and expanding forests directly reduces greenhouse gas concentration in the atmosphere, thereby slowing global warming and enhancing ecosystem resilience.

Agroforestry Systems

Agroforestry combines trees, crops, and livestock within the same land-use system to improve both productivity and sustainability. Trees in agricultural landscapes capture carbon and store it in aboveground biomass and soil organic matter. Additionally, agroforestry improves nutrient cycling, soil fertility, moisture retention, and microclimate regulation, leading to more resilient farming systems. This is especially important in dryland and climate-vulnerable regions, where crop productivity is often affected by drought and heat stress. From a climate mitigation perspective, agroforestry reduces atmospheric CO_2 while promoting sustainable agriculture and reducing pressure on natural forests.

Wetland Restoration

Wetlands, including marshes, peatlands, and swamps, are highly efficient ecosystems for storing carbon in waterlogged soils, often referred to as "carbon-rich ecosystems." When wetlands are degraded or drained, large amounts of stored carbon are released into the atmosphere as greenhouse gases. Wetland restoration helps prevent this carbon loss and enhances long-term carbon sequestration. Wetlands also regulate floodwater, improve groundwater recharge, and filter pollutants, thereby improving water quality. In relation to climate change mitigation, restoring wetlands reduces greenhouse gas emissions while strengthening ecosystem stability and hydrological balance.

Mangrove Conservation

Mangrove forests are among the most carbon-dense ecosystems in the world and are highly efficient in storing blue carbon within biomass and coastal sediments. They serve as natural barriers that protect coastal communities from storms, cyclones, and sea-level rise while reducing shoreline erosion. Mangroves also support fisheries and marine biodiversity. Their ability to capture and store carbon at very high rates makes them extremely valuable for climate change mitigation. Conserving mangrove ecosystems helps reduce atmospheric carbon while simultaneously improving climate adaptation in coastal regions.

Grassland and Rangeland Management

Grasslands and rangelands play a major role in carbon storage, particularly through their extensive root systems and soil organic carbon pools. Although often overlooked compared to forests, these ecosystems store significant amounts of carbon below ground. Unsustainable grazing and land degradation reduce their carbon sequestration potential. Through sustainable grazing management, controlled livestock movement, and restoration of degraded lands, grasslands can recover their productivity and improve carbon storage. In terms of climate mitigation, healthy grasslands reduce land degradation, enhance carbon sequestration, and support sustainable livestock production.

Urban Green Infrastructure

Urban green infrastructure includes urban forests, parks, green roofs, roadside plantations, and green corridors designed to integrate natural elements into cities. These green spaces absorb carbon dioxide, reduce air pollution, and help mitigate the urban heat island effect, where cities become significantly warmer than surrounding rural areas. Vegetation also improves stormwater management by increasing water infiltration and reducing runoff. In the context of climate change mitigation, urban green infrastructure lowers carbon emissions, improves energy efficiency by reducing cooling demand, and enhances urban resilience against heat waves and extreme weather events.

Benefits of Nature-Based Solutions

Nature-Based Solutions provide multiple co-benefits beyond climate mitigation.

Environmental Benefits

Nature-Based Solutions provide significant environmental benefits by enhancing ecosystem functions and improving climate resilience. They contribute to increased carbon sequestration by capturing and storing atmospheric carbon in vegetation and soils, thereby helping to mitigate climate change. These solutions also play an important role in reducing soil erosion by stabilizing soil through plant roots and minimizing land degradation caused by wind and water. Additionally, NbS support biodiversity conservation by protecting habitats and promoting the survival of various plant, animal, and microbial species. Furthermore, they help in improving water quality and hydrological regulation by enhancing water infiltration, reducing runoff, and maintaining the natural water cycle, which supports sustainable ecosystem functioning.

Economic Benefits

Nature-Based Solutions (NbS) provide significant economic benefits by offering a cost-effective alternative to conventional engineered solutions. Their implementation and maintenance costs are often lower than infrastructure-based approaches, making them economically efficient for long-term climate mitigation and adaptation. NbS also generate employment opportunities through activities such as afforestation, ecosystem restoration, and sustainable land management. Additionally, they contribute to enhanced agricultural productivity by improving soil fertility, water retention, and ecosystem stability, which supports better crop yields. These improvements ultimately create better livelihood opportunities for rural communities, especially for populations that depend directly on natural resources for income and survival.

Social Benefits

Nature-Based Solutions also offer important social benefits by strengthening human well-being and community resilience. They improve food and water security by maintaining ecosystem services essential for sustainable agriculture and water availability. NbS also contribute to better public health through cleaner air, improved water quality, and reduced environmental degradation. Furthermore, they play a vital role in disaster risk reduction by minimizing the impacts of floods, droughts, storms, and land degradation. By enhancing adaptive capacity and reducing vulnerability to climate-related risks, NbS help build stronger and more resilient communities capable of facing future environmental challenges.

Benefits of Nature-Based Solutions (NbS)

Challenges in Implementing NbS

Despite their potential, large-scale implementation of NbS faces several challenges. Limited financial resources, inadequate policy support, land-use conflicts, and lack of awareness often restrict adoption. In some regions, weak governance and poor monitoring systems reduce the effectiveness of restoration programs. Furthermore, climate extremes such as prolonged droughts and wildfires can affect the long-term success of ecosystem restoration projects.

Future Prospects

The future of Nature-Based Solutions (NbS) is highly promising, particularly in the context of growing global efforts toward climate change mitigation and adaptation. As the impacts of climate change become more severe, including rising temperatures, extreme weather events, biodiversity loss, and land degradation, the need for sustainable and long-term solutions is increasing rapidly. Greater investment in ecosystem restoration, carbon markets, and sustainable land management practices can significantly accelerate the adoption and large-scale implementation of NbS. International frameworks such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs) strongly emphasize ecosystem-based approaches as essential tools for achieving climate resilience and sustainable development. However, realizing the full potential of NbS requires strengthening policy and institutional frameworks to support implementation at local, national, and global levels. Increased financial support for restoration projects is crucial to scale up conservation efforts and ensure long-term sustainability. Active community participation must also be promoted, as local knowledge and stakeholder engagement play a vital role in successful ecosystem management. Furthermore, integrating NbS into national climate strategies and development policies can enhance their contribution to emission reduction targets and adaptation planning. The development of robust scientific monitoring and evaluation systems is equally important to assess carbon sequestration, ecosystem health, and overall effectiveness. With strong policy support, technological advancements, and collaborative action, Nature-Based Solutions can become a central pillar of future climate action and environmental sustainability.

Conclusion

Nature-Based Solutions represent an effective and sustainable pathway for mitigating climate change while delivering ecological, social, and economic benefits. By protecting, restoring, and sustainably managing ecosystems, NbS help capture atmospheric carbon, improve biodiversity, and strengthen resilience against climate-related risks. Although challenges remain in implementation, greater policy support, investment, and public awareness can unlock the full potential of NbS. Therefore, Nature-Based Solutions should be considered a central component of future climate mitigation and sustainable development strategies.

Growth simulation models: Predicting forest development for sustainable forest management

Yerrawada Naveen[1], Milkuri Chiranjeeva Reddy[1], Mhaiskar Priya Rajendra[2], Katikala Anish[1], Bheemreddyvalla VenkateshwarReddy[1], Rohith Ravula[1], Sachin Kumar[1], Varun Podishetti[1] and Mallu Laxmi Sai[1]
[1] Department of Silviculture and Agroforestry
Forest College and Research Institute (FCRI), Mulugu, Telangana, India, 502279
[2] Department of Forest Ecology & Climate Science
Forest College and Research Institute (FCRI), Mulugu, Telangana, India, 502279
E-mail: naveenyerrawada@gmail.com

Introduction

Forests are a dynamic system whose growth and development is affected by climate, soil, species composition, competition, nutrient availability, disturbances and silvicultural practices. Most forest trees need several decades to reach maturity and direct observations of trees are not enough to make management decisions. Forest managers need to decide on planting density, thinning programs, rotations for any harvests, and restoration plans before the stand is mature. Therefore, forest growth prediction has proven to be crucial for sustainable forest management (Sustainable Forest management) (Boukhris *et al.*, 2025).

Growth simulation models have emerged in quantitative silviculture as essential instruments to simulate forest development as a function of time using mathematical equations, ecological laws, physiological processes and statistical tools. These models calculate tree diameter at breast height (DBH), total height, basal area, stand volume, biomass, carbon sequestration, mortality and regeneration among various environmental and management scenarios (Collalti *et al.*, 2024). Empirical models have been updated in recent years to become integrated systems that incorporate process-based modeling, Geographic Information Systems (GIS), remote sensing, artificial intelligence (AI), and machine-learning algorithms. The innovations have greatly enhanced predictions of accuracy, and their importance in climate change assessment and sustainable forest management (Boukhris *et al.*, 2025; Reitberger *et al.*, 2025).

Growth Simulation Models

Growth simulation models are mathematical and computer-based systems that describe interactions between the physiology, competition, environmental factors and silvicultural practices of forest trees to predict future forest growth. These models differ from traditional yield tables by simulating the changes that occur in stand structure, timber volume, biomass accumulation, carbon storage, mortality, and regeneration over time. They are useful tools for modern forestry to support decision-making because they can analyze and compare various management scenarios before the forest is put into production (Collalti *et al.*, 2024).

Empirical observations are now increasingly paired with physiological understanding and data-driven techniques, like machine learning and AI. Hybrid models have been developed, that include mechanistic processes and statistical learning, which leads to an increased prediction accuracy without losing the biological realism under variable climatic conditions (Pichler & Käber, 2025; Boukhris *et al.*, 2025).

Whole-Stand Models

Whole-stand models are one of the most ancient and widely used forest growth models. They look at an average stand instead of each tree or stand as a separate management unit and estimate future productivity based on average stand characteristics such as dominant height, mean diameter, basal area, stand density, and total volume of the stand. They are relatively simple models that involve few variables and can be used for even aged plantations, especially for commercial plantations of teak, eucalyptus, and pine and poplar species. They are widely applied to estimate timber yields, to compute rotation age, for thinning schedules, and for management options. They are not less appropriate in structurally complex mixed-species and uneven-aged forests, since they do not consider individual tree variability (Gilson *et al.*, 2025), though they may be less appropriate in such forests.

Size-Class Distribution Models

Growth, mortality and recruitment rates can be estimated separately in each class of trees by using size-class distribution models. The trees get bigger, shift to a larger diameter class and regeneration constantly adds to smaller diameter classes. These models are able to simulate well the changes in structure in uneven-aged and mixed-species forests and offer a more realistic stand dynamic prediction than whole-stand models. As a result, they are extensively employed in sustainable management practices seeking to preserve structural diversity and long-term productivity (Zhang *et al.*, 2023).

Single-Tree Models

Single-tree models simulate growth and survival of each tree in a forest stand. There are a number of tree variables that describe each tree, including species, diameter, height, crown size, age, health and competitiveness. Growth equations are used to predict annual growth with consideration for neighbouring trees. These models take into account individual variability and therefore are especially useful for precision forestry, biodiversity conservation, and adaptive silvicultural management and mixed species forests. The accuracy of regional calibration methods and statistical modeling has improved in recent years, leading to their greater predicting ability in various ecosystems (Zhang *et al.*, 2023).

Distance-Independent Models

Distance-independent models estimate competitiveness without reference to specific location of trees. Rather, competition is represented in terms of stand-level variables (stand density, basal area, average tree size and relative diameter). The models are limited in the amount of field data required and thus are useful in operational forestry, plantation management, and regional forest inventories. They do not explicitly model spatial interactions between neighbouring trees, but are reliable predictions where detailed spatial information is lacking (Gilson *et al.*, 2025).

Distance-Dependent Models

Distance dependent models explicitly consider spatial structure of trees in a forest. The distance between neighboring trees and crown overlap, tree size, growing space are used to estimate competition. Within the confines of a nearby forest, the trees don't have to fight for the same resources so these models are more representative of the forest dynamics. Geographic Information Systems (GIS), LiDAR, terrestrial laser scanning, drone technology and GPS based inventories have increased the applicability of these models significantly by enabling precise spatial information to be used for simulation of stand development and silvicultural treatments (Reitberger *et al.*, 2025).

Process-Based Models

Process-based models are the most advanced type of forest growth simulation models that explicitly simulate the biological and physiological processes that underlie tree growth. These involve photosynthesis, respiration, transpiration, nutrient uptake, carbon allocation, water transport and root development. These processes are directly affected by environmental factors like temperature, precipitation, solar radiation, concentration of CO_2 in the air and soil moisture. Process-based models are therefore especially useful for assessing forest responses to climate change, drought and other management options.

A number of recent studies have focused on hybrid methods that will tap into the advantages of understanding the mechanics more thoroughly and simultaneously incorporate machine-learning algorithms to enhance predictive capability under future climate projections. They are increasingly relevant for climate change adaptation planning, carbon accounting and ecosystem restoration thanks to their high prediction accuracy and biological realism (Boukhris *et al.*, 2025; Pichler & Käber, 2025; Wang *et al.*, 2025).

Model evaluation, calibration, verification and validation

Forest growth simulation model performance is dependent on the accuracy and reliability of the model's predictions. Thus, all models need to be thoroughly evaluated by calibration, verification, and validation.

Forest growth is influenced by climate, soil fertility, forest species composition, and management history, and thus requires calibration of forest model parameters to adequately capture local site conditions. Verification ensures that mathematical equations, algorithms and computer programs are correctly implemented and free from computational errors. The last step, called validation, involves comparing model predictions against independent field observations not used in the model development process. Prediction accuracy is often evaluated using various statistical measures, including the coefficient of determination (R^2), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and model bias. Recent research has highlighted the critical need for robust calibration and validation of climate-sensitive models, as uncertainties related to future environmental conditions can significantly affect the reliability of predictions (Gilson *et al.*, 2025; Boukhris *et al.*, 2025).

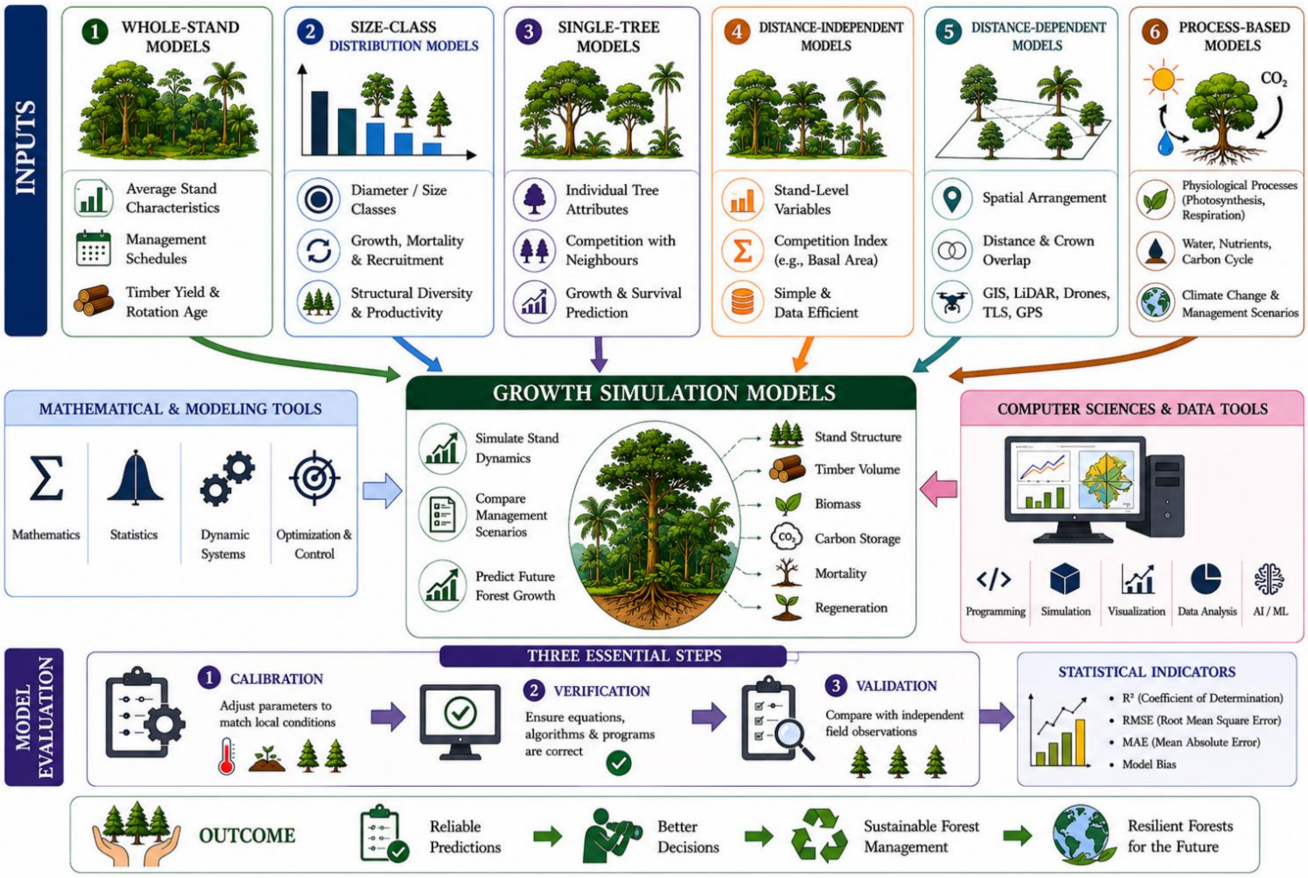


Figure 1. Conceptual framework of forest growth simulation models, their types, evaluation procedures, and applications in sustainable forest management.

The use of forest growth simulators

Forest growth simulators are essential tools for supporting forest decisions in sustainable forestry. They are commonly applied to timber production estimate, carbon sequestration, biodiversity conservation, climate change adaptation, ecosystem restoration, plantation management and precision forestry.

These models are used in commercial forestry to provide an estimation of timber volume, help schedule harvests, assess thinning regimes, and boost the economic return. They are also vital to carbon accounting efforts for biomass growth estimation and for greenhouse gas inventories, carbon credit schemes, and carbon mitigation projects (Fischer *et al.*, 2023). Climate-sensitive growth models can be used to predict how forests will respond to projected changes in temperature and precipitation, drought, and higher concentrations of atmospheric CO_2, and can also be helpful when choosing species and silvicultural practices that are likely to withstand the impacts of climate change (Gilson *et al.*, 2025).

Growth simulators are further enhanced by the combination of process-based models, GIS, remote sensing, machine learning and high-resolution environmental datasets. Today, these technologies are used for precision forestry, assessment of ecosystem services, restoration planning, management of wildlife habitats, and evidence-based forest policy (Collalti*et al.*, 2024; Reitberger *et al.*, 2025).

Conclusion

Forest management shifted from an experience-driven to a science-driven predictive approach through the use of growth simulation models. These models combine ecological theory, physiological processes, statistical modeling, and state-of-the-art computing methods to deliver accurate predictions of future forests under a variety of environmental and management scenarios. In recent years their predictive power and use in sustainable forestry has been significantly enhanced by the development of climate-sensitive models, hybrid simulation methods, process-based models, machine learning and remote sensing and GIS.

Growth simulation models will play a key role in forest adaptive silviculture, sustainable timber production, forest restoration, and in the development of forest policies under the continued challenges forests are experiencing due to climate change, biodiversity loss, carbon management, and the increased demand for forest resources. As modeling methods continue to evolve and improve, forest managers and researchers will better be able to meet the goals of economic productivity and ecological sustainability, helping to sustain and enhance forest ecosystems globally.

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Climate change and trees: Adapt, migrate or perish?

Manoj Aruri, Ravi Kiran Potluri and Shalini Mudalkar
Department of Forest Biology and Tree Improvement
Forest College and Research Institute, Mulugu, Siddipet, Telangana-502279
Email: manojaruri198@gmail.com

Introduction

Forests are complex terrestrial ecosystems that play a fundamental role in regulating the Earth's climate through carbon sequestration, hydrological regulation, nutrient cycling, and the maintenance of biodiversity. They represent dynamic biological systems whose structure and functioning are governed by interactions among genetic, physiological, ecological, and environmental processes operating across multiple spatial and temporal scales. Contemporary climate change is imposing unprecedented selective pressures on forest ecosystems by altering temperature regimes, precipitation patterns, atmospheric CO_2 concentrations, and disturbance frequencies, thereby influencing tree growth, productivity, regeneration, species composition, and ecosystem stability. These changes have intensified scientific interest in understanding the mechanisms that underpin forest resilience and adaptive capacity. Advances in tree physiology, conservation genetics, genomics, biotechnology, and climate-smart forest management are providing new insights into the responses of forest ecosystems to environmental change and informing strategies for sustaining forest productivity, biodiversity, and ecosystem services under future climatic conditions.

Trees and climate change: Nature's first line of defence

Climate change has emerged as one of the greatest environmental challenges of the twenty-first century. The Earth's average surface temperature has already increased by approximately 1.3°C above the 1850-1900 average, primarily due to greenhouse gas emissions from fossil fuel combustion, deforestation, industrialization, and land-use change (IPCC, 2023). Before the Industrial Revolution, atmospheric carbon dioxide (CO_2) concentrations remained relatively stable at about 280 ppm for thousands of years. However, continuous anthropogenic emissions have raised atmospheric CO_2 concentrations to over 428 ppm, representing an increase of nearly 149 ppm (approximately 53%), which has intensified the greenhouse effect and accelerated global warming (NOAA, 2025; WMO, 2024).

Forests are among the Earth's most effective natural climate regulators. Through photosynthesis, trees remove atmospheric CO_2 and convert it into organic biomass, storing carbon in their stems, branches, leaves, roots, and forest soils (Pan et al., 2011). Globally, forests absorb nearly 30% of annual anthropogenic CO_2 emissions, making them one of the largest terrestrial carbon sinks and significantly slowing the rate of climate change (Friedlingstein et al., 2023). Beyond carbon sequestration, forests regulate local and regional climates through transpiration, which cools the surrounding environment, enhances cloud formation, and contributes to rainfall recycling (Bonan, 2008). Tree root systems stabilize soils, reduce erosion, improve nutrient cycling, and maintain watershed health, while forest ecosystems support nearly 80% of the world's terrestrial biodiversity, sustaining countless ecological interactions and ecosystem services (FAO & UNEP, 2020). Ironically, the very forests that mitigate climate change are becoming increasingly vulnerable to its consequences. Rising temperatures, prolonged droughts, altered rainfall patterns, pest outbreaks, and more frequent wildfires are reducing forest productivity, increasing tree mortality, and threatening ecosystem stability across the globe (Allen et al., 2010). Understanding this dual role of trees-as both regulators and victims of climate change-is fundamental to developing resilient forests capable of supporting biodiversity and human well-being in an increasingly uncertain future.

Adapt, migrate or perish? How trees respond to climate change

Trees are among the longest-living organisms, with many species surviving for centuries. Unlike animals, they cannot move when environmental conditions become unfavourable, making their survival dependent on physiological adjustments, structural modifications, genetic adaptation, and gradual migration. However, the current rate of global warming (~0.2°C per decade) is occurring much faster than most forest trees have historically experienced, challenging their adaptive capacity (IPCC, 2023).

The first response to climate stress occurs at the physiological level. Drought stimulates the production of abscisic acid (ABA), which induces stomatal closure to reduce water loss through transpiration (Cutler et al., 2010). Although this conserves water, it also restricts carbon dioxide uptake, reducing photosynthesis and potentially causing carbon starvation under prolonged stress (McDowell et al., 2008). Heat and drought also increase reactive oxygen species (ROS), prompting trees to activate antioxidant enzymes and accumulate osmoprotectants such as proline and soluble sugars to maintain cellular integrity (Hasanuzzaman et al., 2020).

Trees also undergo morphological adaptations by developing deeper root systems, smaller and thicker wax-coated leaves, and modified crown architecture, all of which improve water-use efficiency (WUE) under drought conditions (Nicotra et al., 2010). Climate warming further alters phenology, advancing leaf flushing, flowering, and fruit maturation by approximately 2-5 days per decade, although these shifts may disrupt pollination and regeneration (Peñuelas & Filella, 2001).

Over longer timescales, genetic adaptation enables populations to evolve through natural selection. Individuals possessing drought- and heat-tolerant genes are more likely to survive and reproduce. Recent genomic studies have identified key stress-responsive genes, including NCED, PYR/PYL, SnRK2, ABF, DREB, and NAC, which regulate ABA signalling and stress tolerance (Aitken et al., 2008;).

When local adaptation becomes insufficient, many tree species shift their distribution toward higher latitudes and elevations. However, natural migration is slow-typically 100-500 m per generation-while climate zones are moving several kilometres each decade, limiting the ability of many forests to keep pace with climate change (Chen et al., 2011). As warming continues, the adaptive capacity of numerous long-lived tree species may be exceeded, increasing the likelihood of forest's decline and biodiversity loss.

When adaptation is not enough

Anthropogenic climate change is exceeding the adaptive capacity of many forest tree species. Increasing drought, heatwaves, altered fire regimes, and expanding pest and pathogen outbreaks are causing hydraulic failure, reduced regeneration, and widespread forest mortality (McDowell et al., 2020; IPCC, 2023). Climate-sensitive species such as whitebark pine, European beech, and Norway spruce, together with forests in the Himalayas and Western Ghats, are experiencing range contractions and ecosystem degradation as climate change outpaces natural evolutionary and migration processes.

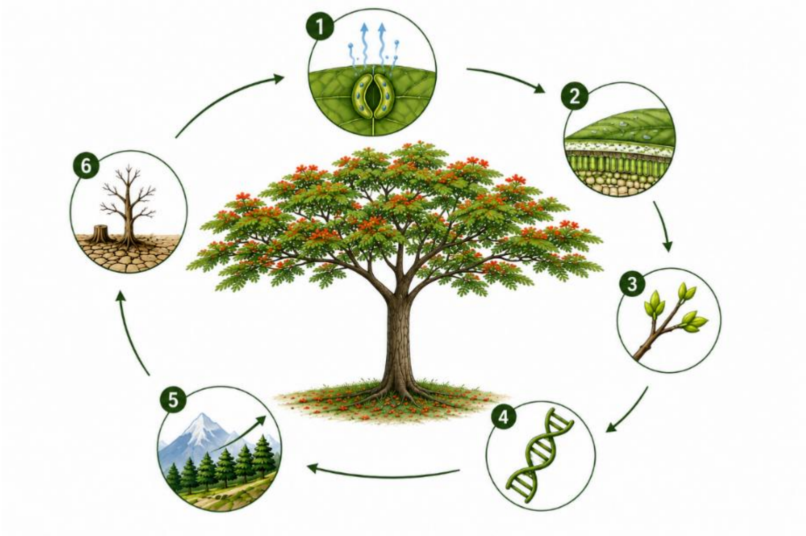

Fig 1. Major adaptive strategies employed by tree

1) Regulates water loss through stomatal closure, osmotic adjustment and antioxidant defense during environmental stress. 2) Develops deeper roots and thicker leaves to improve water uptake and reduce transpiration. 3) Adjusts flowering, leaf flushing and fruiting time to match changing climatic conditions. 4) Natural selection favours stress-tolerant genes, enhancing resilience across successive generations. 5) Species gradually move toward cooler latitudes or higher elevations as temperatures increase. 6) Severe stress causes tree mortality.

Building climate-resilient forests

Improving forest resilience requires integrating climate-smart forestry with advanced conservation and breeding strategies. Assisted migration, assisted gene flow, genomic selection, and conservation of adaptive genetic diversity can improve the capacity of tree populations to withstand future climates. Emerging technologies, including Pangenomics, CRISPR/Cas genome editing, single-cell and spatial transcriptomics, environmental DNA (eDNA), AI-driven decision support systems, hyperspectral imaging, LiDAR, UAV-based phenotyping and precision forestry, are transforming forest conservation by enabling rapid identification, monitoring, and deployment of climate-resilient tree genotypes at landscape scales (Chakraborty et al., 2024).

Are we helping evolution-or hindering it?

Human intervention is increasingly shaping forest evolution. Although genetically improved planting stock can enhance productivity, widespread monoculture plantations often reduce genetic diversity and adaptive potential, increasing vulnerability to climatic extremes, pests, and diseases (McDowell et al., 2020). Conserving wild genetic resources, maintaining diverse breeding populations, and integrating biodiversity into sustainable forest management are therefore essential for developing climate-resilient forests capable of adapting to future environmental change (Chakraborty et al., 2024).

The future of forests lies in our hands

For millions of years, trees have survived natural climatic fluctuations through physiological resilience, genetic adaptation and gradual migration. However, the unprecedented pace of human-induced climate change is testing these natural coping mechanisms beyond their limits. Rising temperatures, prolonged droughts, habitat fragmentation, invasive pests and frequent wildfires are increasing the vulnerability of forests worldwide, making natural adaptation increasingly difficult. While advances in climate-smart tree breeding, genomics, biotechnology and conservation genetics provide powerful tools to develop resilient tree populations, these innovations must complement - not replace - the conservation of natural forests and their rich genetic diversity. Protecting wild tree populations ensures the preservation of valuable adaptive traits that will be essential for future restoration and breeding efforts.

The future of forests will depend on the interaction between natural adaptation, climate change, and evidence-based management strategies. Conserving genetic diversity, restoring degraded ecosystems, and implementing climate-smart forestry can enhance forest resilience. Continued research and sustainable management will play an important role in maintaining biodiversity, ecosystem functions, and long-term forest stability under changing climatic conditions.

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Changing phenology of himalayan trees under climate change

SahreenAltaf and Aafaq A. Parray
Division of Silviculture and Agroforestry
Faculty of Forestry, (SKUAST-K), J&K-191201
Email: sehreenk61@gmail.com

Abstract
Phenology, the study of recurring biological events in plants and their relationship with seasonal and climatic changes, is a clear indicator of climate variability and ecological change (IPCC, 2007). In the Himalaya, evidence suggests shifts in bud burst, leafing, flowering, fruiting, and senescence, mainly linked to rising temperatures. Recent studies from the Western Himalayas and Kashmir show earlier spring phenophases and changes in the length of the growing season. This article brings together current evidence on climate-driven phenological changes in Himalayan trees, focusing on Kashmir. It examines the climatic factors involved and highlights ecologically and economically important species. Their changing phenology offers valuable insights into the vulnerability and adaptive capacity of Himalayan forests.

Keywords: Phenology, Western Himalayas, climatic factors, vulnerability and adaptive capactity

Introduction

Long before instruments and satellites, Himalayan communities used the seasonal changes in vegetation to sense about environmental rhythms and guide their farming and livestock activities. Important ecological cues were given by leaf emergence, flowering, fruiting and leaf fall. Collectively known as phenology, these biological events are sensitive indicators of climate change, because plant development is closely related to temperature, precipitation and other environmental factors. Rising temperatures have been linked to earlier spring events, such as budburst, leaf emergence and flowering, and changes in the length of the growing season (Piao*et al.*, 2019).

The Himalayas are vulnerable to ecological changes caused by climate because of its steep gradients of elevation, temperature and vegetation. Rising temperatures and changing patterns of precipitation are increasingly affecting the ecosystems of the Himalayas and their biological processes (Hamid *et al.*, 2020). Some studies have reported significant variation in tree phenology along elevation and climatic gradients including *Rhododendron arboreum* (Singh *et al.*, 2023). These changes can affect forest productivity, regeneration, species interactions and the availability of seasonal resources. It is therefore important to understand these changes for forestry, conservation of biodiversity and mountain livelihoods, especially in the Western Himalayas and Kashmir.

What Phenology Reveals About a Warming Mountain

Phenology is a sensitive integrator of climatic conditions because these events are sensitive to temperature, photoperiod and in some species winter chilling. A systematic review of 145 studies, including 116 tree species from major biomes, revealed that budburst, leaf emergence, flowering and fruiting are among the most climate-sensitive biological indicators, with generally consistent trends across regions (Gusain*et al.*, 2026). Contrary to the conventional emphasis on monsoon rainfall, field studies in the Western Himalayas indicate that minimum temperature, not rainfall, is the key climatic cue governing tree phenology (Singh *et al.*, 2023). This underscores the role of temperature warming in winter and early spring in shaping Himalayan forest phenology.

Advancing Spring and Lengthening (or Shortening) Growing Seasons

The main phenological response reported throughout the Himalayas is an advancement of spring phenophases, with budburst, leaf flushing and flowering generally taking place earlier. By analysing two decades of satellite-derived **Moderate Resolution Imaging Spectroradiometer**(MODIS) surface reflectance data, significant acceleration in spring start-of-season in the Sikkim Himalaya, which exceeded shifts in maturity, senescence and dormancy onset, indicating an earlier growing-season start without a corresponding delay in termination was observed(Ingty*et al.*, 2023). However, an earlier phenological onset does not necessarily imply a longer growing season. Ground observations from the Kumaun Himalaya showed that warming advanced phenological events in several dominant tree species, but did not significantly increase the overall growing-season duration (Negi*et al.*, 2021). Caution is needed with satellite-derived greening trends, thus they may reflect phenological shifts rather than actual increases in forest productivity or biomass.

Elevational Gradients and the Retreat, and Advance, of the Treeline

The phenological change in the Himalayas is strongly related to elevational shifts in the species distribution. A systematic review of alpine treeline vegetation documented upward treeline shifts from <1 to >500 m across sites, with *Abiesspectabilis* and *Betulautilis* being the most climate sensitive. However, regeneration responses were species-dependent and some species exhibited poor natural regeneration despite persistence of adults, raising concerns of long-term treeline resilience with continued warming (Kumar &Khanduri, 2024). Repeat surveys in 2014 and 2018 at the Kashmir Himalayas showed increased species richness and cover of shrubs at lower-elevation summits, and thermophilization (replacement of cold-adapted species by warmth-loving taxa). These changes were strongest on north-facing, lower elevation slopes, indicating rapid community responses to warming (Hamid *et al.*, 2020).

Popular and Important Tree Species UnderPhenological Watch

The phenological responses of many Himalayan tree species to climate and elevation have been studied. The following species are important indicators of changing growth, flowering, leafing and fruiting patterns across the Himalaya.

Cedrusdeodara (Deodar/Himalayan Cedar): Growth was negatively affected by spring (March-May) temperature and positively affected by precipitation. Future projections showed reductions in growth at low and mid-latitude sites but moderate increases at high-latitude sites (Bhattacharyya *et al.*, 2023).

Pinusroxburghii (Chir Pine): Chir pine may threaten deodar under changing climatic conditions due to increased drought and fire tolerance. However, no direct upward expansion or climate driven replacement of deodar was demonstrated (Bhattacharyya *et al.*, 2023).

Abiesspectabilis (Himalayan Fir): One of the most climate-sensitive treeline species in the Himalaya, with strong upward shifts under climate change. Changes in growing seasons and phenophases have also been reported in Himalayan treeline vegetation (Kumar &Khanduri, 2024).

Betulautilis (Himalayan birch): It is one of the most climate sensitive treeline species of the Himalayas, along with *Abiesspectabilis*, with significant upward shifts due to climate change (Kumar &Khanduri, 2024).

Rhododendron arboreum (Buransh): Initiation of leaf and flowering showed a positive correlation with climatic variables, whereas fruiting showed an inverse correlation. The fruit maturity period lasted for about four months (Singh *et al.*, 2023).

Myricae sculenta (Kaphal/Box Myrtle): The phenological stages were strongly influenced by the minimum temperature. Leaf initiation and flowering were positively correlated with climate, while fruiting was negatively correlated; fruit maturation took about two months (Singh *et al.*, 2023).

Aesculus indica (Indian Horse Chestnut): Phenological events were earlier at 1,900 m and were gradually delayed with elevation. Earlier events were linked to earlier attainment of the optimum temperature range of 9.0–19.5°C (Singh & Mittal, 2018).

Cedrus deodara (Location: Faculty of Forestry, *Pinus Roxburgii* (Location: Shankaracharya Benhama Ganderbal, J&K

Conclusion

Climate-driven changes in Himalayan tree phenology are disrupting ecological synchrony, regeneration and species interactions, with potential consequences for forests and mountain livelihoods. Increased climate sensitivity is indicated by earlier phenological events and upward range shifts, while regeneration lags at treelines are a conservation concern. Therefore, integrated field monitoring with satellite and dendrochronological approaches is essential for planning climate-resilient forestry and horticulture in Kashmir.

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दहीमन (*Cordia macleodii*): दुर्लभ औषधीय वृक्ष

मनोज पूसाम, कौशल त्रिपाठी, फातिमा शिरीन एवं नसीर मोहम्मद
आनुवंशिकी एवं वृक्ष सुधार प्रभाग
भारतीय वानिकी अनुसंधान एवं शिक्षा परिषद-उष्णकटिबंधीय वन अनुसंधान संस्थान,जबलपुर
E-mail:manoj.poosam@gov.in

प्रस्तावना

भारत में सदियों से वृक्षों को केवल जीवन दाता नहीं, बल्कि जीवन-रक्षक भी माना गया है। आयुर्वेद, सिद्धा, यूनानी और लोक चिकित्सा की जड़ें जंगलों में छुपी हजारों वनस्पतियों से जुड़ी रही हैं। ***Cordia macleodii***,जिसे स्थानीय रूप से दहीमन,दहीवरस (दाई वास) भोटी, शिकारी का पेड़, दहीपलास, सीता पत्र कहा जाता है। यह वृक्ष ग्रामीणों और आदिवासियों के जीवन का हिस्सा रहा है, लेकिन आधुनिक वैज्ञानिक शोधों में इसे अपेक्षाकृत कम स्थान मिला है।

वानस्पतिक विवरण और पारिस्थितिकी

Cordi macleodii बोराजिनेसी (Boraginaceae) कुल का सदस्य है। यह एक मध्यम आकार का पर्णपाती वृक्ष है जिसकी ऊँचाई 08–12 मीटर तक हो सकती है। इसकी छाल मोटी, दरदरी और भूरी होती है। पत्तियाँ चौड़ी, खुरदरी और रोमयुक्त होती हैं। वसंत ऋतु में पीले-सफेद रंग के आकर्षक फूल और गर्मियों में पीले फल इसे विशेष बनाते हैं।यह वृक्ष भारत के पश्चिमी और मध्य भागों के शुष्क पर्णपाती वनों में पाया जाता है, विशेष रूप से विन्ध सतपुड़ा,अमरकंटक और सरगुजा संभाग से लगे वन क्षेत्र और कबीरधाम जिले के जंगलों में प्रमुखता से पाये जाते हैं, किन्तु महाराष्ट्र, मध्यप्रदेश, छत्तीसगढ़, गुजरात और कर्नाटक के वन क्षेत्रों में बहुत कम मात्रा में पाया जाता है। यह मिट्टी के क्षरण को रोकने, सूखा सहने की क्षमता रखता है।

दहीमन के पौधे की जनजातीय एवं स्थानिक प्रयोग

दहीमन के पौधे का उपयोग छत्तीसगढ़ एवं मध्यप्रदेश के विभिन्न स्थानियों के द्वारा बहुत से उद्देश्यों से किया जाता है। जो निम्नवत है। 1. किड़नी में सूजन और पाचन संबंधी रोग का उपचार (छाल का जूस) 3.सर्पदंश और ज़हर खुरानी का उपचार (छाल जूस) 4.ब्लड प्रेशर (लकड़ी की माला) 5. मोटापा की उपचार (छाल का जूस अथवा नीबू रस के साथ छिलके का चूर्ण) 6. शराब छुड़ाने के लिए उपयोगी (जूस, पत्ते या छाल) 7. घांव का उपचार (पत्ते का लेप) 8.पीलिया का उपचार (छाल या पत्ते का जूस या छाल का पावडर) स्थानिक व पारंपरिक उपयोग के लोगों से साक्षात्कार के दौरान जानकारी

चित्र -1 (दहीमन वृक्ष)

पारंपरिक औषधीय उपयोग

स्थानीय वैद्य और आदिवासी समुदाय दहीमन पलाश को बहुउपयोगी जड़ी-बूटी वृक्ष मानते हैं। इसके विभिन्न भागों का उपयोग छत्तीसगढ़ एवं मध्यप्रदेश के जनजातीयों (भील,बैगा, सहरिया इत्यादि) द्वारा पारंपरिक चिकित्सा में होता है:

भाग	**पारंपरिक उपयोग**
छाल:	दस्त, बुखार, पेट दर्द में काढ़ा
पत्तियाँ:	फोड़े-फुंसी, खुजली, त्वचा रोगों में लेप

फाइटोकेमिकल्स और औषधीय गुण

विगत एक दशक में कुछ भारतीय विश्वविद्यालयों और आयुर्वेदिक शोध संस्थानों ने *Cordia* *macleodii* पर प्रारंभिक अध्ययन किए हैं:टैनिन्स (Tannins) सूजन कम करने, घाव भरने में सहायक, फ्लावोनॉयड्स (Flavonoids) - एंटीऑक्सीडेंट, उम्र बढ़ने की प्रक्रिया धीमी करने में सहायक, सैपोनिन्स (Saponins) रोगप्रतिरोधक क्षमता को सक्रिय करने वाले,अल्कलॉइड्ससूजन,बैक्टीरियाऔरविषाणुओं से लड़ने में सक्षमइन यौगिकों के कारण इसेएंटीबैक्टीरियल,एंटीफंगल,एंटीऑक्सीडेंट,और एंटीइन्फ्लेमेटरी गुणों वाला वृक्ष माना गया है।

दहीमन के संबंध में पारंपरिक मान्यता

1. दहिमन पेड़ के छांव में बैठने से शांति मिलती है।

2. दहिमन पेड़ के छांव में या इसके लकड़ी के टुकड़े/अल्कोहल के अत्यधिक नशे को कम करता है।

दहीमन के पेड़ को पहचानें कैसे?

आप दहिमन के पत्तों पर आप कुछ भी लिखेंगे तो आपका लिखा हुआ शब्द या चित्र पत्ते में भीतर की ओर रेखा खिंचने के बजाय थोड़ी ही देर में ऊपर की ओर उभर कर आता है।

वैज्ञानिक अनुसंधान और परीक्षण

हालाँकि दहीमन पर किए गए शोध सीमित हैं, लेकिन कुछ महत्वपूर्ण अध्ययन सामने आए हैं:Kshirsagar et al. (2018) – पत्तियों के अर्क में *Staphylococcus aureus* और *E. coli* पर प्रभावी एंटीबैक्टीरियल क्षमता पाई गई। Kulkarni & Joshi (2021) – ग्रामीण चिकित्सा पद्धतियों में *Cordia macleodii* के उपयोगों का वर्णन, BSI (Botanical Survey of India) – वितरण और पारिस्थितिकी संबंधी विस्तृत सर्वेक्षण, ICMR द्वारा समर्थित एक अध्ययन (2020) – छाल में फ्लावोनॉयड्स की उच्च मात्रा पाई गई, जो औषधीय दवाओं में उपयोगी है।

वैज्ञानिक और पारंपरिक ज्ञान

पारंपरिक ज्ञान सैकड़ों वर्षों से पीढ़ी दर पीढ़ी समुदायों द्वारा जांचा-परखा गया है, जबकि आधुनिक विज्ञान साक्ष्यों और परीक्षणों पर आधारित होताहै।*Cordia macleodii* एक ऐसा वृक्ष है जिसमें इन दोनों धाराओं की वास्तविकता पर गहन अनुसंधान की जरूरत है। इस स्थानिक ज्ञान को मजबूत करने के लिए आवश्यक है, कि पारंपरिक प्रयोगों का वैज्ञानिक विश्लेषण किया जाए। दहिमन के औषधीय गुणों को देखते हुए लोक चिकित्सकों को अनुसंधान प्रक्रिया में शामिल करना, एक बड़ा और आधुनिक कदम साबित होगा।

पौधों रोपण की तैयारी

स्थान का चयन (Site Selection): धूप-पानी की उपलब्धता देखें – अधिकांश पौधों को अच्छी धूप चाहिए। मिट्टी की गुणवत्ता(भुरभुरी, जलनिकासी युक्त) होनी चाहिए। वातावरण और तापमानपौधों के अनुसार अनुकूल हो।मिट्टी की जांच और सुधार (Soil Testing & Preparation) pH जांचें(अधिकांश पौधों के लिए 6–7 उपयुक्त होता है)। उपजाऊ मिट्टीके लिए गोबर खाद, कम्पोस्ट या वर्मी कम्पोस्ट मिलाएँ। यदि मिट्टी भारी (काली मिट्टी) होतो बालू मिलाकर हल्की करें। गड्ढा या बेड तैयार करना पौधे के आकार के अनुसार गड्ढा खोदें (छोटे पौधों के लिए 1x1 फीट, बड़े के लिए 2x2 फीट)।

चित्र -2 (दहीमन के पौधे)

चित्र -3 (गड्ढा खुदाई)

चित्र-4 (घास और झाड़ियों की साफ सफाई)

चित्र-5 (गड्ढे में गोबर खाद डलाई)

चित्र-6 (पौधारोपण)

भा.वा.अ.शि.प. उष्ण कटिबंधीयवन अनुसंधान संस्थान,जबलपुर का दहीमन के संरक्षण का प्रयास: मध्य भारत के क्षेत्रों में दहीमन की उपयोगिक एवं पारम्परिक ज्ञान को देखते हुए, ICARE -TPRI में दहीमन के वृक्षों पर 2023 से कार्य करना प्रारम्भ किया। यह बहुउपयोगी पौधा अपने प्राकृतिक आवास में बहुत सिमट चुका है। 2023 में एक परियोजना के तहत छत्तीसगढ के जंगलों का सघन सर्वेक्षण कर वैज्ञानिकों ने दस्तावेज बनाया। संकटपन्न स्थिति में होने के कारण दहीमन के संरक्षण कार्यो पर अत्यधिक बल दिया गया, विगत दो वर्षों के अनुसंधान कार्यो एवं चुनौतियों को देखते हुए इसके Sapling का प्रचुर मात्रा में उत्पादन किया गया, साथ ही साथ बीजों की अनुपलब्धता को देखते हुए संस्थान में 90 पौधों के साथ VMG भी स्थापित किया गया है। दहीमन के संरक्षण का यह प्रयास और रणनीति आने वाले समय में विशेष परिवर्तन लाने में मदद करेगा।

चित्र-7 (निर्देशक के द्वारा पौधारोपण)

चित्र-8 (अनुदेशक के द्वारा पौधारोपण)

चित्र-9 (सामूहिक पौधारोपण)

चित्र-10 (सामूहिक पौधारोपण)

चित्र-11(पौधारोपण के 1 साल बाद का पौधा)

चित्र-12 (पौधारोपण के 1 साल बाद का पौधा)

संरक्षण की आवश्यकता

वर्तमान में *Cordia macleodii* **IUCN** के दिशा निर्देश के अनुसार मध्य भारत में संकटग्रस्त की सूची में शामिल है। और इसके आवास क्षेत्रों में लगातार कमी हो रही है ।

कारण

वनों की कटाई, सड़क निर्माण और खनन, कृषि विस्तार

परिणाम

स्थानीय जैव विविधता पर असर, पारंपरिक चिकित्सा ज्ञान का लोप, इसलिए आवश्यक है कि इसे क्षेत्रीय स्तर पर संरक्षित किया जाए।दहीमन के सफल संरक्षण के लिए सहयोग और क्षमता निर्माण आवश्यक है। अतः स्थानीय समुदायों को शामिल करने और शैक्षिक कार्यक्रमों को बढ़ावा देने से संरक्षण के लिए एक मजबूत नींव प्राप्त की जा सकती है। राष्ट्रीय एवं अंतर्राष्ट्रीय सहयोग से ज्ञान और संसाधनों को साझा करने में मदद मिलेगी, जिससे वैश्विक स्तर पर संरक्षण के प्रयासों में तेजी सकती है। सन 2023 में छत्तीसगढ़ राज्य जैवविविधता बोर्ड द्वारा दहीमन के संरक्षण हेतु पहला कदम उठाते हुए इस परियोजना को वित्त पोषित किया। यह परियोजना उष्ण कटिबंधीय वन अनुसन्धान संस्थान में सफलतापूर्वक किया जारहा है।

नीति और विधायी समर्थन

(1) कानूनी ढांचे का विकास:- लुप्तप्राय पौधों की प्रजातियों की सुरक्षा के लिए मजबूत कानून और नियम बनाना।

(2) नीति का कार्यान्वयन: - यह सुनिश्चित करना कि संरक्षण नीतियां प्रभावी ढंग से लागू की जाएं और उनका नियमित रूप से मूल्यांकन किया जाए।

(3) प्रवर्तन और निगरानी:- अवैध व्यापार और पर्यावास विनाश को रोकने के लिए कठोर प्रवर्तन और निगरानी तंत्र स्थापित करना।

दहीमन के प्रजाति-विशिष्ट संरक्षण के लिए मजबूत नीति और विधायी समर्थन अनिवार्य है। इसमें प्रभावी कानूनी ढांचे का विकास, नीतियों का कुशल कार्यान्वयन और उल्लंघन को रोकने के लिए सख्त प्रवर्तन और निगरानी अत्यंत आवश्यक है। यह कानूनी विधायी समर्थन दहीमन के संरक्षण प्रयासों को आवश्यक अधिकार और संसाधन प्रदान कर सकेगा।

भविष्य की दिशा

Cordia macleodii पर केंद्रित अनुसंधान की अत्यधिक आवश्यकता है। आगे की संभावनाएँ:

(1) **क्लिनिकल ट्रायल्स** — मनुष्यों पर प्रभावों की पुष्टि

(2) **औषधीय उत्पाद विकास** — हर्बल दवाएँ, त्वचा-चिकित्सा उत्पाद

(3) **बायो टेक्नोलॉजिकल प्रयोग** — जैव सक्रिय यौगिकों की पहचान

(4) **सामुदायिक जागरूकता** — स्थानीय स्तर पर प्रचार-प्रसार

निष्कर्ष और आगे के कदम

Cordia macleodii न केवल एक वनस्पति प्रजाति है, बल्कि वह ज्ञान, चिकित्सा, और प्रकृति का एक सजीव प्रतीक है। इसकी उपेक्षा नहीं बल्कि संग्रह और संरक्षण आवश्यक है। अगर वैज्ञानिक समुदाय, नीति निर्धारक और ग्रामीण

समाज मिलकर प्रयास करें, तो यह वृक्ष न केवल पर्यावरण बल्कि स्वास्थ्य क्षेत्र में भी क्रांति ला सकता है।दहीमन जैसे अत्यंत दुर्लभ संकटग्रस्त वृक्षों के प्रजाति-विशिष्ट संरक्षण रणनीतियों को सफल होने के लिए एक बहुआयामी दृष्टिकोण की आवश्यकता है। इसमें अनुसंधान, इन-सीटू और एक्स-सीटू संरक्षण, आनुवंशिक विविधता का प्रबंधन, और मजबूत नीतिगत समर्थन शामिल है। आगे बढ़ते हुए, निरंतर अनुसंधान राष्ट्रीय और वैश्विक सहयोग पौधों के पॉपुलेशन की समृद्ध जैव विविधता को बनाए रखने के लिए महत्वपूर्ण होंगे, जिससे आने वाली पीढ़ियों के लिए महत्वपूर्ण वृक्ष प्रजाति का संरक्षण हो सकेगा।

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https://www.facebook.com/share/14NemNgfVyQ/?mibextid=wwXIfr

Publishedby:

Impact Factor

SJIF: 2024-6.017

ICFRE-Tropical Forest Research Institute
(Indian Council of Forestry Research & Education)
(Anautonomous council under Ministry of Environmnet, Forests and Climate Change)
P.O.RFRC, Mandla Road
Jabalpur–482021, M.P. India
Phone: 91-761-2840484
Fax: 91-761-2840484
E-mail: vansangyan_tfri@icfre.gov.in, vansangyan@gmail.com
Visitusat: http://tfri.icfre.org or http://tfri.icfre.gov.in