FORESTRY & AGROFORESTRY

Forestry: Definition, Types, and Classifications

Definition of Forestry: Forestry encompasses the theoretical and practical aspects of creating, conserving, managing forests, and utilizing their resources. This field involves all activities related to the management and conservation of forests, including the harvesting, marketing, and use of forest products and services. It focuses on both the management of existing forests and the creation of new ones.

Classification Based on Functions (National Forest Policy, 1952):

1. **Protection Forests**: Managed primarily for their protective functions to stabilize terrain and soil.

2. **National Forests**: Designated for the conservation of national heritage and biodiversity.

3. **Village Forests**: Managed to meet the needs of local communities.

4. **Tree Lands**: Areas outside conventional forests dedicated to tree planting.

National Commission of Agriculture (1976) Classification:

1. **Protection Forests**: Focus on forest protection to prevent soil erosion, landslides, and other ecological imbalances.

2. **Production Forests**: Managed for the maximum production of timber, fuelwood, and other forest products. Subcategories include:

   - **Commercial Forestry**: Aimed at maximizing forest product output as a business venture.

   - **Industrial Forestry**: Targets the production of raw materials for industrial use.

   - **Mixed Quality Forests**: Forests with varied species and quality.

   - **Valuable Forests**: Forests containing high-value species.

   - **Inaccessible Forests**: Forests in remote areas not easily reachable for exploitation.

3. **Social Forests**: Aimed at fulfilling the requirements of rural and urban populations. This includes:

   - **Community Forestry**: Management on non-forest lands for local benefit.

   - **Farm Forestry**: Integration of forestry practices on village lands and farms.

   - **Extension Forestry**: Involves tree planting on community lands, along roads, canals, and railways.

- **Agro-Forestry**: Combines crop and forest plant/animal production on the same land, adhering to sustainable and culturally compatible practices.
- **Recreational Forestry**: Develops and maintains forests for recreational and scenic value.

Main Groups of Forestry:

1. **Basic Forestry**: Covers fundamental theories, practices of forest constitution, management, and product utilization. Key branches include:

   - **Silviculture**: The cultivation and management of forest trees.
   - **Forest Mensuration**: Measurement of forest produce and tree dimensions.
   - **Silvicultural Systems**: Methods for forest crop management, harvesting, and renewal.
   - **Forest Management**: Application of scientific, technical, and economic principles to forest management.
   - **Forest Utilization**: Branch focused on forest harvesting and product utilization.
   - **Forest Law**: Legal framework governing forest conservation, management, and wildlife protection.
   - **Forest Policy**: Social and economic objectives underpinning forest management and development.

2. **Applied Forestry**: Encompasses specialized subjects that enhance the core practices of forestry, with a significant emphasis on silviculture for comprehensive forest crop management.

   Geographical Overview of India:
   - Total area: 3,280,500 square kilometers (328.8 million hectares).
   - Forest coverage: 750,500 square kilometers (75.06 million hectares).
   - Agricultural land: Approximately 46.4% of the total area.

   National Forest Policy (1952):
   - Objective: To maintain one-third of India's total land under forest for ecological balance.
   - Special focus on hilly areas: Aim for 60% coverage with trees.
   - Recent decades: 2 million hectares of forest have been allocated for non-forest activities such as agro-industry, power, irrigation projects, and housing.

   Forest Conservation Act (1980):

- Purpose: To prevent the conversion of reserved forests to other categories and restrict the use of forest land for non-forest purposes.

Utilization of Forest Area:

- In use: 45.6 million hectares (60%).

- Potentially exploitable: 14.8 million hectares (20%).

- Unexploited areas: Primarily in Himalayan states, North Eastern regions, and Andaman and Nicobar Islands.

Energy Consumption Sources in India:

- Coal: 16.5%.

- Oil: 10%.

- Electricity: 15.7%.

- Wood: 37.6%.

- Cow dung: 8.7%.

- Vegetation waste: 11.5%.

Definitions and Terms in Forestry:

- **Forestry**: The science and practice of forest creation, conservation, management, and resource utilization.

- **Silviculture**: Focuses on the establishment, development, care, and reproduction of forest crops.

- **Pollarding**: Cutting branches to induce new shoot growth, practiced on certain tree species for protection from browsing animals.

- **Lopping**: Trimming branches or stems to encourage new shoots, used in various industries including the bidi industry.

- **Pruning**: Removing branches to improve timber quality.

- **Taungya System**: A method combining agriculture with forestry, originated in Burma for teak replanting.

- **Coppice**: Producing new shoots by cutting plants or seedlings near ground level.

- **Seed Orchards**: Plantations aimed at producing seeds from genetically superior trees.

- **Seed Production Areas or Seed Stands**: Designated for high-quality seed production from superior trees, involving the removal of inferior trees and establishment of seed orchards with controlled pollination. Types include clonal (grafted superior clones) and seedling (from superior tree seeds).

- **Pricking Out**: The process of relocating seedlings from their initial beds to other nursery beds or boxes after a year for further growth.

- **Wind Breaks**: Plantations designed to protect against strong winds, typically consisting of a few rows of trees or shrubs spaced between 0.5 to 2.5 meters apart.

- **Shelter Belts**: Large areas planted with trees, shrubs, and grasses in rows perpendicular to prevailing wind directions to deflect air currents, reduce wind velocity, and provide protection from hot winds.

- **Tending**: General care provided to forest crops at any stage of their life, including weeding, cleaning, thinning, and improvement cutting, but excluding regeneration activities.

- **Felling**: The act of cutting down trees, either individually or in small groups, throughout the forest.

- **Afforestation**: The creation of forests on land that has not been forested for a significant period through artificial means.

- **Reforestation**: The restoration of forest cover on land that previously had forest vegetation but was cleared, using artificial methods.

- **Age Crop**: The age of a forest stand determined by the average diameter of its trees.

- **Age Classification**: Sorting a forest based on the age of its trees or allocating sections of the forest into different age categories.

- **Alpine Zone**: High-altitude areas with severe winters, heavy snowfall, a mean annual temperature around 45°F, and a mean January temperature below 30°F, typically above 10,000 feet in the Himalayas.

- **Basal Area**: The cross-sectional area of a tree trunk at breast height, or the total area of all tree trunks per unit area of forest.

- **Bole**: The main trunk of a tree.

- **Breast Height**: The standard height for measuring tree dimensions, set at 4 feet 6 inches (1.37 meters) in India and 4 feet 3 inches (1.30 meters) in the UK and most Commonwealth countries.

- **Coupe**: A designated area for logging, part of a series and often numbered with Roman numerals.

- **Crown**: The top part of a tree where the branches grow out from the main trunk.

- **Dendrology**: The study of identifying and classifying tree species.

- **Reserved Forests**: Land designated under the Indian Forest Act or other laws for conservation and restricted use.

- **Protected Forests**: Areas with a degree of protection under the Indian Forest Act, with limited human activity allowed.

- **Unclassed Forest**: Government-owned forest land not designated as reserved, village, or protected forest.

- **Log**: A tree trunk or large branch that has been cut down and trimmed.

- **Logging**: The process of cutting down trees, removing branches, and transporting timber out of the forest.

- **Pole**: A young tree that has lost its lower branches and is in a stage of rapid height growth.

- **Raft**: A collection of logs, timbers, or bamboos tied together for transport by water.

- **Scrub**: Areas of poor growth, mainly small or stunted trees and shrubs.

- **Stand**: A group of trees or plants that are similar in type, age, and condition, forming a distinct unit within a forest.

- **Succession**: The natural process by which one type of plant community gradually replaces another, leading towards a stable climax community.

Forest cover, canopy density, RFA, TOF and tree cover-

Term	Definition	Characteristics
Forest Cover	Area covered by forest canopy on the ground, irrespective of legal status, with canopy density >10% and area >1 ha.	Includes all tree patches with a canopy density of more than 10% and an area of 1 ha or more.
Canopy Density	Proportion of an area in the field/ground covered by the crown of trees.	Used to measure the density of the forest canopy.
Recorded Forest Area (RFA)	All geographic areas recorded as forest in government records.	Includes Reserved Forests (RF) and Protected Forests (PF) under the Indian Forest Act, 1927, and other areas recorded as forests under State Acts or local laws.
TOF (Trees Outside Forest)	Trees found outside the recorded forest areas.	Refers to all trees growing outside RFA, irrespective of patch size, which could also be larger than 1 ha.
Tree Cover	Patches of trees occurring outside RFA with size less than 1 ha, including scattered trees.	Considered a subset of TOF. Includes all patches of trees outside RFA that are less than 1 ha in size.

Type of forest cover-

Type of Forest Cover	Definition	Relative Composition in India (%)	Characteristics
Very Dense Forest	Lands with tree canopy density of 70% and above.	3.04	Highest level of canopy density, usually rich in biodiversity and biomass.
Moderately Dense Forest	Lands with tree canopy density of 40% and more but less than 70%.	9.33	Moderate level of canopy density, often transitional zones between very dense and open forests.
Open Forest	Lands with tree canopy density of 10% and more but less than 40%.	9.34	Lower canopy density, often found at forest edges or in areas with less rainfall.
Scrub Forest	Lands with canopy density less than 10%.	1.42	Lowest level of canopy density, often found in arid regions or as a result of deforestation.
Non-forest	Lands not included in any of the above classes (includes water).	76.87	Includes all other land types like agricultural land, urban areas, and bodies of water.

Definitions of Silviculture:

1. **Tourney and Karstien**: Silviculture involves the establishment, development, care, and reproduction of timber stands.

2. **Indian Forest and Forest Products Terminology (1957)**: Silviculture combines art and science in the cultivation of forest crops.

3. **Society of American Foresters (1983)**: Described as both science and art, silviculture is dedicated to the cultivation of forest crops, emphasizing the establishment, composition, constitution, and growth based on silvios knowledge.

4. **Rao (1987)**: Focuses on the theoretical and practical aspects of raising forest crops, including methods of cultivation, growth, and aftercare until final harvest.

Importance of Silviculture:

- Essential for managing forests to enhance wildlife, timber, forage production, and recreational and watershed values.

Objectives of Silviculture:

1. **Control Crop Composition for Economic Value**:

   - Natural conditions produce diverse species; silviculture prioritizes economically valuable ones by removing inferior species and supporting desirable ones.

2. **Manage Stand Density for Maximum Volume**:

- Adjusts tree density to optimize wood production, using thinning methods to prevent overcrowding or underutilization of space.

3. **Afforestation of Depleted Areas**:

- Targets reforestation in areas affected by natural or human activities, applying silvicultural knowledge for effective seed collection, nursery techniques, and plantation methods.

4. **Quality Timber Production**:

- Addresses the challenge of producing quality timber in unmanaged forests by controlling factors like insects, fungi, fire, wind, and grazing through silvicultural practices.

5. **Regulate Rotation Period**:

- Silviculture helps adjust the density of forest stands to achieve desired sizes more quickly, potentially reducing the rotation period for crop harvesting.

6. **Enhanced Forest Management**:

- Managed forests allow for optimized growth and distribution, enabling efficient and economic utilization of produce. Forests can be organized by age classes and species composition for simplified management.

7. **Creation and Introduction of Man-Made Forests and Exotics:**

- **Man-Made Forests and Exotics**: Silviculture enables the creation of man-made forests, either by replanting with native species or introducing exotic ones. Techniques include identifying suitable exotics based on location, conducting trials, and perfecting nursery and plantation methods.

8. **Site Protection and Intangible Benefits**:

- The goal is to maximize site protection for sustained intangible benefits, such as climate moderation, precipitation increase, soil erosion reduction, flood control, soil and water conservation, and wildlife habitat provision. Preference is given to species that enhance site protection and offer continuous intangible returns.

Functions & Types of Forests in India:

- **Productive**: Supply timber, fuel, charcoal, beedi leaves, wax, resins, fruits, tanning materials, manure leaves, grass, bamboo, gums, lac, etc.

- **Protective**: Protect watersheds and river/stream catchments against erosion.

- **Aesthetic**: Enhance appearance and provide a scenic landscape.

- **Recreational**: Offer picnic spots, hiking, trekking, wildlife and bird watching opportunities.

- **Scientific**: Facilitate ecological studies.

- **Ameliorative**: Improve climate and reduce pollution.

- **Hygienic**: Enhance the environment, reduce noise, purify air, and produce oxygen.

- **Industrial Development**: Provide raw materials for industries like paper, rayon grade pulp, saw mills, plywood, and hardboard.

Classification of Forests Based on Various Criteria

Based on Age:

1. **Even-Aged Forests:**

   - Consist of trees of approximately the same age.

   - True even-aged forests are typically man-made.

   - Naturally regenerated forests may have some age variation, with up to 25% difference allowed.

2. **Uneven-Aged Forests:**

   - Trees vary widely in age.

Based on Regeneration:

1. **High Forest:**

   - Regeneration from seed.

2. **Coppice Forest:**

   - Regeneration through coppice or vegetative parts of the tree.

3. **Natural Forest:**

   - Regeneration occurs naturally.

4. **Man-Made Forest:**

   - Regeneration is achieved artificially.

Based on Composition:

1. Pure Forests:

   - Composed almost entirely of one species.

2. Mixed Forests:

   - Composed of two or more species intermingled.

Based on Management:

1. Protection Forests:

   - Managed for climate amelioration, soil erosion control, and other protective functions.

2. Production Forests:

   - Managed primarily for produce.

3. Social Forests:

   - Produce utilized by the neighbouring society.

Based on Ownership:

1. Government Forests:

   - Owned by government entities.

     - Reserved Forests: Complete protection under the Indian Forests Act, 1927.

     - Protected Forests: Limited degree of protection.

     - Village Forests: Assigned to village communities.

2. Private Forests:

   - Owned by individuals, juridical persons, or partnerships.

3. Corporations, Panchayats, Societies, and Other Agencies:

   - Owned by various entities outside of government or private ownership.

Based on Growing Stock:

1. Normal Forest:

   - Ideal in terms of growing stock, age class distribution, and increment.

2. Abnormal Forest:

   - Deviates from the norm in growing stock, age class distribution, and increment.

Structure of Forest:

- Forest Floor Layer: Blanketed with decaying matter, home to recycling organisms.

- Herb Layer: Dominated by herbaceous plants, adapted to low light conditions.

- Shrub Layer: Characterized by woody vegetation growing close to the ground.

- Understory Layer: Contains immature and small trees under the main canopy.

- Canopy Layer: Comprises the crowns of most of the forest's trees, forming a thick layer.

- Emergent Layer: Features trees whose crowns emerge above the rest of the canopy, receiving most sunlight.

Major Vegetation Types (Biomes) with Characteristics and Examples

Biome	Climate	Soil Characteristics	Dominant Vegetation	Dominant Animals	Example Locations	Key Characteristics
Tundra	Cold, dry; short summers (2–3 months), long winters; temperature: -40°C to 18°C; low precipitation (150–250 mm/year)	Permafrost, nutrient-poor, thin soils	Mosses, lichens, low shrubs, grasses (e.g., Arctic willow, sedges)	Caribou, Arctic fox, polar bear, migratory birds	Arctic regions (Alaska, Northern Canada, Siberia), Antarctic tundra	Low biodiversity, short growing season, treeless, adapted to extreme cold, permafrost prevents deep root growth
Taiga (Boreal Forest)	Cold, subarctic; long winters, short summers; temperature: -30°C to 20°C; moderate precipitation (300–850 mm/year)	Acidic, nutrient-poor, thin, often waterlogged	Coniferous trees (spruce, fir, pine, larch), some deciduous (birch)	Moose, wolf, lynx, snowshoe hare	Canada, Scandinavia, Russia (Siberia)	Evergreen needle-leaved forests, cold-resistant plants, largest terrestrial biome, supports lumber industry
Savannah	Warm, tropical; distinct wet/dry seasons; temperature: 20°C–30°C; precipitation: 500–1500 mm/year	Lateritic, moderately fertile, well-drained	Scattered trees (acacia, baobab), tall grasses	Lion, elephant, zebra, giraffe, cheetah	East Africa (Serengeti), Australia, South America	Grass-dominated with occasional trees, fire-adapted, supports grazing herbivores, seasonal droughts
Temperate Grassland	Temperate; cold winters, warm	Fertile, deep, rich in humus	Grasses (buffalo grass, blue	Bison, pronghorn, prairie	North America (Great Plains),	Treeless, fertile soils ideal for agriculture,

Biome	Climate	Soil	Vegetation	Animals	Location	Features
	summers; temperature: -20°C to 30°C; precipitation: 250–1000 mm/year	(e.g., chernozem)	grama), few trees	dog, coyote	Eurasia (Steppes), Argentina (Pampas)	fire and grazing maintain grasses
Temperate Deciduous Forest	Temperate; cold winters, warm summers; temperature: -30°C to 30°C; precipitation: 750–1500 mm/year	Fertile, rich in organic matter	Deciduous trees (oak, maple, beech), shrubs, ferns	Deer, bear, fox, owl, woodpecker	Eastern USA, Western Europe, East Asia	Seasonal leaf shedding, high biodiversity, four distinct seasons, hardwood trees
Tropical Rainforest	Hot, humid; year-round warmth; temperature: 20°C–35°C; precipitation: 2000–4000 mm/year	Nutrient-poor, thin, rapid nutrient cycling	Broadleaf evergreens (mahogany, ebony), vines, epiphytes	Jaguar, sloth, toucan, monkeys, parrots	Amazon Basin, Congo Basin, Southeast Asia	High biodiversity, dense canopy, rapid decomposition, supports 50% of Earth's species
Desert	Arid; extreme temperatures; temperature: -10°C to 50°C; precipitation: <250 mm/year	Sandy, rocky, low organic matter	Cacti, succulents (e.g., agave, aloe), sparse shrubs	Camel, fennec fox, rattlesnake, lizards	Sahara, Gobi, Sonoran Desert	Sparse vegetation, drought-resistant plants, extreme day-night temperature swings, low biodiversity
Mediterranean (Chaparral)	Mild, wet winters, hot dry summers; temperature	Rocky, moderately fertile	Shrubs (manzanita, chamise), small	Quail, lizard, mule deer, coyote	Mediterranean Basin, California, South Africa (Fynbos)	Sclerophyllous (hard-leaved) plants, fire-adapted,

: 10°C– 40°C; precipitatio n: 300–1000 mm/year	trees, drought- resistant	aromatic shrubs, seasonal rainfall

Types of Forests in India:

Forest Types in India Based on Average Annual Rainfall

India's forests can be broadly classified into five categories based on the average annual rainfall they receive. These categories encompass a diverse range of forest types, each with its unique climatic conditions, flora, and geographical distribution.

1. Tropical Evergreen Forests

- **Moist Evergreen Forests:**
  - **Location**: Southern India along the Western Ghats, Andaman and Nicobar Islands, and the northeastern region.
  - **Climate**: Warm and humid with annual precipitation over 200 cm and a mean annual temperature above 22°C.
  - **Common Trees**: Jackfruit, betel nut palm, jamun, mango, and hollock.

- **Semi-Evergreen Forests:**
  - **Location**: Less rainy parts of Western Ghats, Andaman and Nicobar Islands, and the Eastern Himalayas.
  - **Flora**: A mix of moist evergreen and moist deciduous trees including white cedar, hollock, and kail.

- **Dry Evergreen:**
  - **Location**: Along the coasts of Andhra Pradesh and Karnataka.
  - **Climate**: Prolonged hot and dry season with a cold winter.
  - **Common Trees**: Pomegranate, olive, and oleander.

2. Tropical Deciduous Forests (Monsoon Forests)

- **Moist Deciduous Forests:**
  - **Location**: Northeastern states along the foothills of the Himalayas, eastern slopes of the Western Ghats, and Odisha.
  - **Rainfall**: Regions with 100-200 cm of rainfall.
  - **Common Trees**: Teak, Sal, shisham, hurra, mahua, amla, semul, Kusum, and sandalwood.

- **Dry Deciduous Forests:**
  - **Location**: Throughout northern India, excluding the northeast.

- **Rainfall**: Areas receiving 70-100 cm of rainfall.
- **Common Trees**: Tendu, palas, amaltas, bel, khair, axlewood.

3. Thorn Forests

- **Characteristics**: Found in areas with less than 50 cm of annual rainfall.
- **Common Trees**: Babul, Acacia, Kokko, Khair, Khajuri, Ber, Neem, Khejri, Palas.

4. Montane Forests

- **Montane Wet Temperate Forests:**
  - **Location**: Eastern Nepal to Arunachal Pradesh (north) and parts of Nilgiris Hills, higher reaches of Kerala (south).
  - **Rainfall**: Minimum of 200 cm.
  - **Flora**: Northern forests are denser with species like rhododendrons, champa, eucalyptus; southern forests have replaced original trees with fast-growing varieties.

- **Montane Subtropical Forests:**
  - **Location**: Northwestern Himalayas excluding Ladakh and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh.
  - **Climate**: Rainfall of 100-200 cm with temperatures between 15°C to 22°C.
  - **Common Trees**: Chir (Pine), Oak, Jamun, and Rhododendron.

5. Alpine and Subalpine Forests

- **Flora**: Juniper, rhododendron, willow, black currant in the west; red fir, black juniper, birch, and larch in the east.

6. Mangroves

- **Spread**: Over 6,740 sq. km in India, making up 7% of the world's mangrove forests.
- **Location**: At the confluence of rivers and seas, notably the Sundarbans in the Ganges delta, the largest tidal forest globally.
- **Function**: Stabilize shorelines and protect coastal areas from erosion.

National Forest Policy, 1988 - Overview in Points

Preamble

1. **Origination**: Follow-up to the 1952 Forest Policy due to depletion of forests from various pressures.

2. **Need for Revision**: Urgent need for a new strategy focusing on conservation, including preservation, maintenance, sustainable utilization, restoration, and enhancement of the natural environment.

Salient Features

1. **Environmental Stability**: Preserve and restore ecological balance.

2. **Conservation of Natural Heritage**: Preserve natural forests and biodiversity.

3. **Soil and Water Conservation**: Check soil erosion and denudation in catchment areas.

4. **Desertification Control**: Prevent extension of sand-dunes in desert and coastal areas.

5. **Increase Forest Cover**: Through afforestation and social forestry on degraded lands.

6. **Meeting Rural and Tribal Needs**: Fulfill fuelwood, fodder, minor forest produce, and timber needs.

7. **Enhancing Forest Productivity**: To meet national needs.

8. **Efficient Utilization and Substitution of Forest Produce**: Maximize substitution of wood.

9. **People's Movement**: Involve communities, especially women, to minimize pressure on forests.

10. **Primary Aim**: Environmental stability and ecological balance over direct economic benefits.

Essentials of Forest Management

1. **Protection and Productivity Improvement**: Of existing forests and lands.

2. **Avoid Agricultural Land Conversion**: Due to the need for increased food production.

3. **Conservation of Biodiversity**: Strengthen and extend protected areas network.

4. **Provision of Fodder, Fuel, and Pasture**: Especially near forests to reduce depletion.

5. **Enhancement of Minor Forest Produce**: For tribal sustenance and employment.

Strategy

1. **National Forest Coverage Goal**: Minimum one-third of total land under forest/tree cover.

2. **Afforestation and Social Forestry Initiatives**: Time-bound programme for fuelwood and fodder development on degraded lands.

3. **Tree Planting Alongside Roads and Canals**: To improve micro-climate and check erosion.

4. **Community Land Use for Tree Crops**: With government technical assistance and revenue sharing.

5. **Legal and Incentive Measures for Tree Farming**: Modification of land laws and provision of leases or tree-pattas.

Management of State Forests

1. **Restriction on Projects in Sensitive Areas**: To protect ecological stability.

2. **Mandatory Management Plans for Forest Working**: Approved by the government and in line with National Forest Policy.

3. **Scientific Enhancement of Forest Cover and Productivity**: Without clear-felling of natural forests or introducing harmful exotics.

4. **Rights and Concessions**: To be related to the carrying capacity and optimized through increased investment.

5. **Tribal and Rural Communities**: Protection of their rights and involvement in forest development.

Special Considerations

1. **Forest Based Industries**: Must be self-sufficient in raw materials and prioritize local employment.

2. **Wildlife Conservation**: Special care in forest management plans and provision for wildlife corridors.

3. **Tribal People Engagement**: In protection, regeneration, and development of forests.

4. **Control of Shifting Cultivation and Encroachments**: With rehabilitation of damaged areas.

5. **Regulation of Forest Fires and Grazing**: With modern management practices.

Natural Regeneration of Forest:

1. **From Seed:**

   - **Seed Production:** Involves the maturation of ovules into seeds containing embryos, influenced by species, tree age, site conditions, weather, seasonality, pest/disease attacks, and predation.

   - **Seed Dissemination:** Essential for species survival, involving seed transport away from the parent plant via wind, water, animals, or explosive mechanisms to reduce competition and increase survival chances.

   - **Seed Germination:** Relies on factors like seed coat permeability, moisture, oxygen, embryo nature (dormancy), temperature, soil moisture, soil oxygen, and light. Additional influences include tree age, flowering phase, seed health, coppice origin, seed size, germination rate, dissemination type, soil nutrition, and pest/disease presence.

   - **Seedling Establishment:** The critical phase for integrating germinated seedlings into the forest ecosystem, influenced by climate (light, moisture,

rainfall, temperature, frost) and edaphic factors (soil nutrients, aeration, texture, structure).

2. **By Coppice and Root Suckers:**

   - **Coppice Regeneration:** Involves shoot growth from adventitious buds on stumps, categorized into seedling coppice, stool coppice, root collar shoots, and pollard shoots. Coppice shoots are shorter-lived than those from dormant buds.

   - **Natural Regeneration by Root Suckers:** Shoots emerging from roots, either naturally or through artificial stimulation.

Artificial Regeneration of Forests

Preliminary Considerations for Artificial Regeneration:

Alarming Deforestation Rate: Approximately 1.5 million hectares annually.

Basic Steps in Artificial Regeneration:

1. **Choice of Species:**

   - **Purpose Specification**: Define the objective of tree cultivation.

   - **Climatic Considerations**: Select species based on climate and microclimate.

   - **Soil Requirements**: Choose species suitable for specific soil types, e.g., wet soils (Salix, Populus), water-logged soils (Eucalyptus robusta, E. saligna), sandy loam (Albizia procera, Acacia nilotica, Dalbergia sissoo).

   - **Market Considerations**: Factor in market demand and facilities.

   - **Growth Rate**: Prefer fast-growing species for quicker results.

   - **Exotic Species**: Consider non-native species adaptable to local conditions.

   - **Establishment Base**: Evaluate the ease of species establishment.

   - **Management Objectives**: Align species choice with management goals.

   - **Site Conditions**: Assess physical and biological site factors.

   - **Successional Stages**: Understand vegetation development towards climax.

   - **Cost Considerations**: Account for the financial aspects of cultivation.

   - **Seed/Propagation Material Availability**: Ensure a reliable seed source.

2. **Choice of Method:**

   - **Sowing vs. Planting**: Determine the most suitable approach.

Sowing Advantages:

- Cost-effective and straightforward.

- Direct method without root disturbance.

- Quick execution with minimal complications.
- Possible direct field application without nursery requirement.

Planting Advantages:

- Higher success rate with controlled seed usage.
- Reduced weeding costs and less seedling damage.

Disadvantages of Planting:

- Nursery requirement.
- Potential root disturbance.
- Time-consuming and skill-dependent.
- Higher costs.

3. **Site Selection:**

- Consider ground cover, topography, soil type, erosion risks, area size, and accessibility.
- Prepare the site to ensure a suitable environment for species establishment.

4. **Manpower and Equipment Needs:**

- Skillful execution and appropriate equipment are crucial.

5. **External Constraints:**

- Legal responsibilities, smoke management, proximity to sensitive areas, and local community attitudes.

6. **Spatial Arrangement (Spacing):**

- Critical for optimal growth and development.

Artificial Regeneration by Vegetative Method:

Materials Beyond Seeds:

- Utilize bare root seedlings, containerized seedlings, cuttings, layering, rhizomes, suckers, offsets, bulbs, and corms.

Propagation by Cuttings:

- Types include stem cuttings (hardwood, softwood) and root cuttings, suitable for species with easy rooting like Shisam and Sandalwood.

Stumps Use:

- For species like Teak and Shisam, ensuring minimal stem and root portion for effective transport and planting.

Root Suckers:

- Employed for species like Pomegranate and Shisam, focusing on conservation of superior genotypes and commercial plantation suitability.

Vegetative Propagation Advantages:

- Conserves superior genotypes.

- Suitable for commercial plantations with specific traits (short-lived, non-timber focused).

Tending Operations in Silviculture

Tending operations in silviculture are essential for the establishment, growth, and development of forest crops up to the point of harvesting. These operations aim to create a conducive environment for the healthy growth of trees. The primary tending operations include:

1. **Weeding**:

    - **Objective**: To remove unwanted vegetation competing with the forest crop for nutrients, water, and light.

    - **Methods**:

        - **Mechanical**: Physical removal of weeds using tools and machinery.

        - **Biological**: Utilizing living organisms to control weed populations.

        - **Chemical**: Applying herbicides to suppress or kill weeds.

2. **Cleaning**:

    - **Definition**: The removal of undesirable trees of the same age as the crop trees, particularly in the sapling stage, to prevent competition and promote the growth of desired trees.

    - **Benefit**: Ensures optimal crop composition, especially in mixed-species stands.

    - **Methods**: Similar to weeding, involving mechanical, biological, and chemical techniques.

3. **Thinning**:

    - **Purpose**: To enhance the growth and form of remaining trees by removing some trees from an immature stand without permanently opening the canopy.

    - **Application**: Conducted from the sapling stage until the beginning of the regeneration period, primarily in pure or relatively even-aged stands.

    - **Principle**: Based on the natural development of the stand, adhering to the "survival of the fittest" concept.

4. **Improvement Felling**:

- **Objective**: To remove defective, diseased, or poorly formed trees to improve the overall quality and value of the forest stand.

5. **Pruning**:

   - **Purpose**: To remove lower branches from trees to improve timber quality by reducing knots and promoting straight, clear boles.

6. **Climber Cutting**:

   - **Definition**: The removal of climbing plants and vines that may strangle or compete with trees for light and nutrients

Important timber woods, their characteristics and defects-

Timber Wood Type	Characteristics	Common Uses	Defects
Teak	Durable, water-resistant, easy to work with	Furniture, boat building, flooring	Knots, shakes, wane
Oak	Strong, durable, good workability	Furniture, flooring, cabinetry	Checks, splits, warping
Pine	Soft, lightweight, easy to work with	Framing, furniture, paneling	Knots, pitch pockets, resin canals
Maple	Hard, fine-grained, smooth finish	Flooring, furniture, musical instruments	Bird pecks, mineral streaks, gum spots
Cedar	Lightweight, aromatic, natural insect repellent	Outdoor furniture, decking, fencing	Knots, splits, wane
Birch	Strong, fine-grained, pale colour	Furniture, cabinetry, veneer	Knots, pitch pockets, discolouration
Cherry	Fine-grained, reddish-brown, ages well	Fine furniture, cabinetry, veneer	Gum pockets, pitch pockets, splits
Mahogany	Durable, easy to work, reddish-brown	High-end furniture, boat building, cabinetry	Pinholes, splits, shakes
Spruce	Lightweight, straight-grained, soft	Construction, musical instruments	Knots, resin canals, shakes
Fir	Strong, straight-grained, light colour	Construction, plywood, furniture	Knots, pitch pockets, checks

Important Timber Defects-

Wood Defect	Detailed Description
Knots	Hard, cylindrical regions in wood where a branch once grew. Vary in size, may impact appearance and strength. Natural features formed during the tree's growth.
Shakes	Separations along the wood grain. Can occur radially or tangentially. May impact structural integrity. Caused by drying stresses or wood deterioration.
Wane	Bark or lack of wood along the edge or corner. Occurs when the wood doesn't entirely cover the cross-section, affecting dimensional stability and appearance.
Checks	Splits along the wood grain, usually at the ends. Result from drying or stresses. Some are normal, excessive checking may reduce strength.
Splits	Separations of wood fiber running parallel to the grain. Can result from drying stresses, mechanical damage, or natural characteristics of the wood species. May compromise structural integrity.
Warping	Distortion in the shape of the wood, including cupping, bowing, and twisting. Result of uneven drying, changes in humidity, or improper storage.
Bird Pecks	Small holes or indentations caused by birds feeding on insects or drilling for larvae. May not impact structural integrity but can affect visual appeal.
Mineral Streaks	Discolourations caused by minerals in the wood. Varies in colour and intensity. Does not necessarily impact strength but can affect appearance.
Gum Spots	Spots of hardened sap in the wood. Sticky or resinous. More common in certain softwood species. May affect finish and workability.
Pitch Pockets	Small openings filled with resin. Occurs when resin accumulates during wood growth. May not compromise strength but can affect appearance and workability.
Resin Canals	Tubes within the wood filled with resin. Natural part of certain wood species. Can affect appearance and workability.
Pinholes	Small holes caused by wood-boring insects. Evidence of insect activity. May not always impact structural integrity but can affect visual appeal.

Various implements used in forestry with their functions-

Tool	Function
Chainsaw	Cutting down trees, trimming branches
Crosscut Saw	Cutting down trees, especially in areas where chainsaws are not allowed

Tool	Function
Machete	Clearing brush and undergrowth
Pruning Shears	Trimming small branches and twigs
Pole Saw	Pruning high branches
Wedge and Maul	Splitting logs into smaller pieces
Cant Hook	Rolling and moving logs
Log Peavey	Similar to Cant Hook but with a spiked end for better grip
Clinometer	Measuring the height of trees, slope, topographic relief, and preliminary surveying
Increment Borer	Extracting cores from trees to determine age and health
Brush Grubber	Removing small trees and shrubs by the roots
Fire Rake	Clearing leaves and debris to prevent forest fires
Pulaski Axe	Multi-purpose tool for chopping wood and digging soil
Diameter Tape (D-tape)	Measuring tree's diameter, usually at breast or chest height
Callipers	Measuring tree and log diameters with high precision
Haga altimeter	A portable instrument used for measuring tree height from a distance without using any trigonometric formulae
Logger Tape	Measuring land dimensions of felled timber
Angle Gauge	Selecting or tallying trees in variable area plot sampling
Prism	Deflecting the tree trunk image when viewed, used in sampling
Surveyor Chain	Horizontal land measurement, length of 66 feet, divided into 100 "links"
Biltmore Stick (Cruiser Stick)	Measuring trees and logs based on the principle of similar triangles
Billhook	Used for cutting smaller woody material such as shrubs and branches

Types of Forest Mensuration Measurements-

Measurement Type	Description	Tools Used
Tree Height	Measures the height of individual trees	Clinometer, Hypsometer
DBH (Diameter at Breast Height)	Measures the diameter of the tree at breast height (1.3m from the ground)	Diameter tape, Calipers
Crown Diameter	Measures the width of the tree's crown	Measuring tape, Rangefinder
Basal Area	Measures the cross-sectional area of a tree at breast height	Basal area gauge, Prism
Tree Volume	Estimates the volume of wood in a tree	Volume tables, Form factor
Stand Density	Measures the number of trees per unit area	Quadrat method, Point sampling

Common Formulas in Forest Mensuration-

Formula Name	Formula	Description
Tree Height	$H = D \times \tan(\theta)$	H is height, D is distance to tree, θ is angle to top of tree
Basal Area	$BA = \pi \times \left(\frac{DBH}{2}\right)^2$	BA is basal area, DBH is diameter at breast height
Tree Volume	$V = BA \times H \times F$	V is volume, BA is basal area, H is height, F is form factor

Advanced Mensuration Techniques

Key Formulas

- **Basal Area (BA)**:
    - Formula: BA = π × (DBH/2)²
    - Example: For a tree with DBH = 30 cm, BA = 3.14 × (0.15 m)² = 0.07065 m².

- **Tree Volume**:
    - Formula: Volume = Basal Area × Height × Form Factor
    - Example: DBH = 30 cm, Height = 20 m, Form Factor = 0.4
        - BA = 0.07065 m², Volume = 0.07065 × 20 × 0.4 = 0.5648 m³.

- **Stand Density Index (SDI)**:
    - Formula: SDI = N × (DBH/25)$^{1.5}$, where N = number of trees per hectare.

o   Example: 500 trees/ha, average DBH = 20 cm, SDI = 500 × $(20/25)^{1.5}$ = 500 × $0.8^{1.5}$ ≈ 400.

Growth and Yield Models

- **Chapman-Richards Model**: Used to predict tree growth:

  o   Formula: $Y = A \times (1 - e^{(-k \times t)})^m$, where Y = yield, A = maximum yield, k = growth rate, t = time, m = shape parameter.

- **Yield Tables**: Provide expected volume production for specific species, age, and site conditions (e.g., teak plantations in Kerala).

Carbon Stock Estimation

- **Biomass Calculation**: Biomass = Volume × Wood Density × Biomass Expansion Factor (BEF).

  o   Example: Teak (wood density = 0.6 t/m³), Volume = 0.5648 m³, BEF = 1.3

    ▪   Biomass = 0.5648 × 0.6 × 1.3 = 0.4405 tonnes.

- **Carbon Content**: Carbon = Biomass × 0.47 (average carbon fraction).

  o   Example: Carbon = 0.4405 × 0.47 = 0.207 tonnes.

Tools and Techniques

- **LiDAR**: Used for precise canopy height and biomass estimation.

- **Allometric Equations**: Relate DBH and height to biomass for species-specific carbon estimation.

Standard rules for diameter or girth measurement in forest mensuration-

Method/Rules	Diameter/Girth Measured At	Tools Used	Purpose
DBH (Diameter at Breast Height)	1.3m or 4.5ft above ground	Diameter tape, Calipers	General inventory, growth studies
Merchantable Height	Up to first major branch	Diameter tape, Calipers	Timber valuation
Variable Radius Plot	1.3m or 4.5ft above ground	Angle gauge, Prism	Forest inventory, especially for variable area plot sampling
Coppice Stool Measurement	Ground level	Diameter tape	For coppiced trees, to assess regrowth potential
Sapling Measurement	0.3m or 1ft above ground	Calipers	For young trees, to assess potential for inclusion in timber inventory

Method/Rules	Diameter/Girth Measured At	Tools Used	Purpose
Irregular Form	Multiple points	Diameter tape, Calipers	For trees with irregular forms, to get an average diameter

Common Defects and Their Impact on Mensuration-

Defect Type	Impact on Measurement
Forks	Complicates height and volume calculations
Hollows	Reduces actual usable volume
Knots	May affect diameter measurements and timber quality
Decay	Reduces actual usable volume and quality

Important acts related to forestry in India-

Act Name	Year of Enactment	Key Provisions
Indian Forest Act	1927	Governs the management of forests and wildlife resources. Defines Reserved, Protected, and Village Forests.
Wildlife Protection Act	1972	Provides for the protection of wild animals, birds, and plants.
Forest (Conservation) Act	1980	Regulates the diversion of forest lands for non-forest purposes.
Environment (Protection) Act	1986	Provides for the protection and improvement of the environment.
Biological Diversity Act	2002	Provides for the conservation of biological diversity and sustainable use of its components.
Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act	2006	Recognizes the rights of forest-dwelling communities over land and other resources.
National Green Tribunal Act	2010	Establishes a National Green Tribunal for effective and expeditious disposal of environment-related cases.

Act Name	Year of Enactment	Key Provisions
Compensatory Afforestation Fund Act	2016	Establishes funds for compensatory afforestation and conservation.

Important forest related institutions in India-

Institution Name	Location
Forest Research Institute (FRI)	Dehradun, Uttarakhand
Indian Council of Forestry Research and Education (ICFRE)	Dehradun, Uttarakhand
Wildlife Institute of India (WII)	Dehradun, Uttarakhand
Indira Gandhi National Forest Academy (IGNFA)	Dehradun, Uttarakhand
Tropical Forest Research Institute (TFRI)	Jabalpur, Madhya Pradesh
Arid Forest Research Institute (AFRI)	Jodhpur, Rajasthan
Himalayan Forest Research Institute (HFRI)	Shimla, Himachal Pradesh
Institute of Forest Genetics and Tree Breeding (IFGTB)	Coimbatore, Tamil Nadu
Institute of Forest Productivity (IFP)	Ranchi, Jharkhand
Centre for Social Forestry and Eco-Rehabilitation (CSFER)	Allahabad, Uttar Pradesh
National Institute of Forest Management (NIFM)	Bhopal, Madhya Pradesh

Introduction to Agroforestry

Agroforestry Overview:

- Agroforestry, a key component of social forestry, integrates the cultivation of trees, crops, and sometimes livestock on the same land parcel. This sustainable land management system enhances land yield through simultaneous or sequential cultivation of agricultural and forest crops, including trees and animals. It incorporates management practices aligned with local cultural norms, facilitating the coexistence of agriculture and forestry to significantly boost overall land productivity.

Current Forest and Land Use Statistics in India:

- Total land area: 329 million hectares.

- Agricultural land: 143 million hectares (47%).

- Forested land: 75 million hectares (22.7%).

- Barren land: 21 million hectares.

- Non-agricultural land: 18 million hectares.

- Illegally occupied land: 24 million hectares.

- Population: 1 billion.

- Cattle population: 400 million.

Challenges and Objectives:

- With half of India's forests denuded to varying degrees due to human activity, and the country's rapidly growing population and livestock numbers demanding substantial resources, there's a critical need for afforestation and tree planting with widespread community involvement. Achieving a forest cover of 30-33% of the total geographical area is internationally recommended for environmental and ecosystem balance.

Agroforestry as a Solution:

- Recognizing the inadequacy of the existing 75 million hectares of forest cover to maintain environmental health, a national policy resolution in 1952 aimed to increase forest cover by 35 million hectares to achieve 33% forest coverage. Despite the wisdom of this decision, implementation has faltered.

- Agroforestry has emerged as a crucial land use system, recognized in the planning of India's seventh five-year plan, with recommendations for its inclusion in the agricultural curriculum of state universities.

Classification of Agro-forestry Systems

1. Structural Basis:

A. Nature of Components:

- **Agrisilvicultural Systems:**

    - Integration of agricultural crops with tree crops in the spaces between trees.

    - Agricultural crops can be grown under protective irrigated conditions for up to two years and under rainfed conditions for up to four years.

    - Beyond the specified period, it becomes uneconomical to grow grain crops, though fodder, shade-loving, and shallow-rooted crops remain viable.

    - Wider spacing is adopted to facilitate cultural operations and ensure sufficient sunlight for the intercrop, enhancing tree crop performance compared to monoculture.

- **Silvopastoral Systems:**

- Combines woody plant production with pasture, serving dual purposes such as fodder production for livestock or growth for timber, fuelwood, fruit, and soil improvement.

- Classified into:
    - **Protein Bank**: Multipurpose, protein-rich trees are planted for fodder production to support livestock during fodder-deficit winters.
    - **Live Fence of Fodder Trees and Hedges**: Utilizes various fodder trees and hedges as live fences for property protection.
    - **Trees and Shrubs on Pasture**: Incorporates tree and shrub species within pastures to enhance forage production.

- **Agrosilvopastoral Systems:**
    - Merges the production of woody perennials with annuals and pastures, categorized into:
        - **Home Gardens**: Dense mixtures of trees, bushes, vegetables, and herbaceous plants, often supporting animal life and fodder production.
        - **Woody Hedgerows**: Fast-growing, coppicing fodder shrubs and trees planted for browse, mulch, green manure, and soil conservation.

- **Other Systems:**
    - **Apiculture with Trees**: Involves planting nectar-producing trees to support honeybee activity.
    - **Aquaforestry**: Trees preferred by fish are planted around fish ponds for feed and bund stabilization.
    - **Mixed Wood Lots**: Location-specific Multi-Purpose Trees (MPTs) are grown for wood, fodder, soil conservation, etc.

B. Arrangement of Components:

- **Spatial Arrangement**: Can result in either dense mixed stands (like home gardens) or sparse stands (trees in pastures).

- **Temporal Arrangement**: Ranges from short cropping cycles to longer fallow periods with strategic planting of woody species.

2. Functional Basis:

- **Productive Functions**: Include food, fodder, fuelwood, cloth, shelter, and Non-Timber Forest Products (NTFPs).

- **Protective Functions**: Encompass windbreaks, shelterbelts, soil conservation, and soil improvement.

3. Socio-Economic Classification:

- **Commercial Agroforestry Systems**: Focused on large-scale production for commercial output.

- **Intermediate Agroforestry Systems**: Balance between commercial and subsistence production.

- **Subsistence Agroforestry Systems**: Primarily meet the basic needs of the owner's family.

4. Ecological Classification:

- **Humid/Subhumid Lowlands**: Home gardens, trees on rangelands, improved fallow, and woodlots.

- **Semiarid/Arid Lands**: Silvopastoral systems, windbreaks, and shelterbelts.

- **Tropical Highlands**: Plantation crops integration, woody perennials for soil conservation.

Benefits of Agroforestry System:

- **Environmental Benefits**: Reduced pressure on natural forests, nutrient recycling, ecological protection, reduced soil erosion, microclimate improvement, and soil structure enhancement.

- **Economic Benefits**: Increased output of food, fuelwood, fodder, and timber; reduced risk of crop failure; and higher farm income levels.

- **Social Benefits**: Improved living standards, nutrition, health, and community stabilization.

Common Types of Agro-Forestry:

- **Agri-silviculture**: Trees with food and fodder crops.

- **Silvi-pasture**: Tree species with improved pasture.

- **Agri-Horti System**: Interspaced agricultural crops and fruit trees.

- **Agri-silvipasture**: Combination of agri-silviculture and silvi-pasture.

- **Agri-Horti-Silviculture**: Fruit trees with crops and MPTs.

- **Homestead Agroforestry**: Trees planted around habitations for daily needs.

- **Horti-pastoral System**: Horticultural crops with pastures.

- **Agri-Horti-Pastoral System**: Marginal lands utilized for fruit crops, forest trees, and food grains.

- **Apiculture with Trees**: Honey-producing trees for beekeeping.

- **Aqua Forestry**: Trees around fish ponds for feed and stabilization.

- **Multipurpose Wood Lots**: Specific MPTs grown for various purposes.

Social Forestry vs. Agroforestry:

Social Forestry Explained: Social Forestry refers to the practice of managing and growing forests outside traditional forest areas, specifically tailored to fulfill the needs of the local community. It emphasizes the production of forest goods to meet the demands of local people, focusing on cultivating forests according to the preferences of the local population.

Agroforestry Defined: Agroforestry, on the other hand, combines agricultural and forestry technologies to create more integrated, diverse, productive, profitable, healthy, and sustainable land-use systems. It involves the strategic use of land for the simultaneous cultivation of trees and agricultural crops, aiming to achieve beneficial interactions.

Key Concepts in Tree Cultivation Outside Traditional Forest Areas

1. Farm Forestry: Farm Forestry promotes commercial tree cultivation by farmers on their own lands. As defined by the National Commission on Agriculture (1976), it integrates forestry practices within and around farm or village lands, harmonizing them with other agricultural operations.

2. Extension Forestry: Extension Forestry targets areas lacking in tree growth and vegetation outside traditional forest zones, with the goal of expanding tree-covered areas. It encompasses:

- **Mixed Forestry**: Involves raising fodder grass, scattered fodder trees, fruit trees, and fuelwood trees on wastelands, panchayat lands, and village commons.

- **Shelterbelts**: Strips of trees or shrubs maintained to provide protection from wind, sun, and snow drift.

- **Linear Strip Plantations**: Plantations of fast-growing species planted in linear strips of land.

3. Rehabilitation of Degraded Forests: Focuses on the ecological restoration and socio-economic upliftment of communities surrounding degraded forest areas, necessitating prompt and effective restoration practices.

4. Recreation Forestry: Also known as Aesthetic Forestry, this practice revolves around cultivating flowering trees and shrubs to create recreational spaces for urban and rural populations. It aims at developing or maintaining forests with high scenic value, enhancing the aesthetic and recreational appeal of the landscape.

Shifting cultivation:

Sifting cultivation, also known as slash-and-burn agriculture, is a traditional agricultural practice found in various parts of the world but predominantly practiced in the northeastern hill regions of India. This method involves clearing forested land, burning the felled vegetation, and using the ash-enriched soil for farming activities for a few years until the soil's fertility declines. Subsequently, the land is left fallow to naturally regenerate while the cultivator moves to a new plot, repeating the process.

- **Geographical Spread**: It's prevalent in Assam, Meghalaya, Manipur, Nagaland, Tripura, and to some extent in Arunachal Pradesh, Mizoram, Andhra Pradesh, Bihar, Madhya Pradesh, Odisha, and Karnataka.

- **Local Nomenclature**: Referred to as "Jhum" in the northeastern regions and "Podu" in Andhra Pradesh and Odisha.

- **Environmental Impact**: Criticized for its destructive impact on forests, leading to deforestation, soil erosion, and loss of biodiversity.

Improved Fallow System in Agroforestry:

To counteract the soil depletion inherent in shifting cultivation, the improved fallow system integrates specific plant species known for their soil-enriching properties into the fallow period.

- **Objective**: The primary goal is to enhance soil fertility through nitrogen-fixing plants or species that add organic matter to the soil, preparing it for future agricultural use.

- **Implementation**: Methods include direct seeding of fallow species after crop harvest and selective enrichment planting, where high-quality fallow species are introduced to degraded lands.

Taungya System:

The Taungya system represents a synergistic approach to agroforestry, where agricultural crops are grown alongside forest plantations, allowing for dual land use that benefits both the environment and local communities.

- Origin and Practice: Introduced in India by Dr. Brandis in 1890, with the first Taungya plantation established in North Bengal in 1896. It's practiced across various Indian states, including Kerala, West Bengal, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, Odisha, and the northeastern hill regions.

- System Variants: Includes Departmental Taungya, where agricultural and plantation crops are raised by the forest department; Leased Taungya, involving leasing forest land for agriculture; and Village Taungya, which is considered the most successful variant involving local communities in crop cultivation and tree planting.

Wind Breaks and Shelter Belts

Windbreaks and shelter belts are strategic plantings of trees and shrubs designed to reduce wind speed and mitigate its effects on crops, soil, and livestock.

- **Design and Composition**: Typically involves multiple rows of trees and shrubs of varying heights, strategically placed to block or reduce wind speed. The selection of species is crucial, with preference for fast-growing, dense-crowned trees that provide additional benefits such as fruit, fodder, and timber.

- **Benefits**: Include reduction of soil erosion, enhancement of microclimate conditions, improvement in water retention, support for biodiversity, and provision of economic resources to farmers.

- **Implementation**: Effective windbreaks require careful planning regarding the choice of species, spacing, and arrangement to ensure maximum protection and benefits. Cooperative efforts are encouraged to extend benefits across community lands.

Shelterbelt Composition:

1. **Grasses:** Varieties such as Cenchrus barbatus and Saccharum spontaneum are utilized for their soil binding properties and erosion control capabilities.

2. **Shrubs:** Species including Calotropis procera and Jatropha curcas are selected for their drought resistance and utility in providing mid-level coverage and contributing to biodiversity.

3. **Small Trees:** Acacia jacquemontii and Salvadora oleoides are chosen for their adaptability to semi-arid conditions and their role in enhancing the microhabitat.

4. **Trees:** Larger tree species like Acacia arabica and Azadirachta indica are integral for creating a substantial barrier against wind, offering significant ecological benefits and resources like timber and medicinal extracts.

Implementation Techniques:

- Seeds are initially sown in polythene bags to ensure healthy sapling development, facilitating easier transplantation.

- Site-specific nurseries are recommended for effective sapling acclimatization and management.

- Consistent watering during the initial one to two years post-planting is critical to establish the plants.

- Protective fencing is essential to safeguard young plants from grazing by livestock.

Wind Breaks:

- Wind breaks consist of 2-3 rows of trees or shrubs, spaced 0.5m to 2.5m apart, encircling gardens, farms, or fields to guard against strong winds.

Soil Conservation Hedges:

- Comprise multipurpose/fruit trees and common agricultural species.

- Mainly for soil conservation and yielding various tree products.

- Key species include Grevillea robusta, Acacia catechu, and Leucaena leucocephala.

Horti-Silviculture:

- Integrates horticultural trees with timber trees for simultaneous fruit and timber production.

- Timber trees on orchard bunds serve as windbreaks.

Horti-Silvopastoral:

- Combines improved leguminous grasses in orchards for livestock forage.
- Trees on orchard bunds act as windbreaks and provide multiple products.

Silvi-Pastoral System (Trees + Pasture/Animals):

- Focuses on producing woody plants alongside pasture for fodder or other uses.
- Categories include protein banks, live fodder fences, and trees/shrubs on pasture land.

  A. Protein Bank:

- **Purpose:** Protein banks utilize multipurpose, protein-rich trees around farmlands and rangelands to provide cut-and-carry fodder for livestock, especially during winter's fodder deficit.

- **Benefits:** Trees in protein banks are selected for their high protein content, aiding in meeting nutritional needs of livestock during lean periods.

- **Common Tree Species:** Key species include Grewia optiva, Bauhinia variegata, Morus alba, Artocarpus spp., Anogeissus latifolia, Cordia dichotoma, Dalbergia sissoo, Eutralobium saman, and Zizyphus jujube, selected for their ability to thrive in the targeted environment and their nutritional value.

- **B. Live Fence of Fodder Trees and Hedges:**

- **Function:** Live fences of fodder trees and hedges serve dual purposes of providing fodder and acting as a barrier to protect property from stray animals and other biotic influences.

- **Implementation:** These barriers are created by planting fodder trees and shrubs in a way that forms a living fence around the property, offering a sustainable and eco-friendly solution.

- **Species Used:** The assortment includes Sesbania grandiflora, Gliricidia sepium, Erythrina abyssinica, Euphorbia spp., and Acacia spp., chosen for their robustness, growth habit, and fodder value.

- **C. Trees and Shrubs on Pasture Land:**

- **Concept:** This approach integrates tree and shrub species within pasture lands, either irregularly scattered or systematically arranged, to enhance the pasture's biodiversity and productivity.

- **Objective:** The primary goal is to enrich the pasture ecosystem, providing additional fodder sources and improving the soil and microclimate for the benefit of both livestock and pasture grasses.

- **Arrangement and Management:** Careful planning is essential to ensure that the selected tree and shrub species complement the existing pasture system without

competing for resources, thereby maximizing the benefits of this integrated approach.

Agrisilvopastoral/Agrosilvopastoral System (Crops + Trees + Grasses/Animals):

- Includes home gardens and woody hedges for browsing, mulching, green manuring, and soil conservation.
- Home gardens mix trees, crops, and animals in spatial/temporal sequences, often found in high rainfall areas of South and Southeast Asia.

Fertilizer trees:

Fertilizer trees are a group of trees that have the unique ability to improve soil fertility through various mechanisms. They can be used in agroforestry systems to enhance crop productivity and sustainability. Some common examples of fertilizer trees include:

1. **Albizia lebbeck (Siris)**: This tree is known for its nitrogen-fixing ability, which helps in improving soil fertility. It also provides shade and can be used as fodder.

2. **Gliricidia sepium (Gliricidia)**: Gliricidia is a fast-growing tree that is often used as a living fence or as a source of green manure. It can fix nitrogen in the soil and improve soil structure.

3. **Leucaena leucocephala (Leucaena)**: Leucaena is a fast-growing tree that is commonly used for fodder, fuelwood, and green manure. It is known for its nitrogen-fixing ability and can improve soil fertility.

4. **Calliandra calothyrsus (Calliandra)**: Calliandra is a small tree or shrub that is used for its nitrogen-fixing ability and as a source of fodder. It is also known to improve soil structure and fertility.

5. **Acacia species (Acacias)**: Several species of Acacia trees are used in agroforestry for their nitrogen-fixing ability and soil improvement properties. They are also valued for their wood and as a source of fodder.

Other Specified Systems:

- **Apiculture with Trees:** Focuses on nectar and pollen-rich trees for honey production.
- **Aqua-forestry:** Common in coastal regions for integrating fish/prawn cultivation with tree growth on pond bunds.
- **Multipurpose Wood Lots:** Grow specific multipurpose trees for wood, fodder, soil protection, etc.

Shelterbelt Benefits:

- Regulate temperature, increase humidity, reduce evapo-transpiration, and enhance soil moisture.
- Decrease wind velocity and erosion, boosting agricultural and horticultural crop yields.

- Provide protection to infrastructure and promote environmental conservation.

Agroforestry Systems Based on Component Arrangement:

- Spatial arrangement can vary from dense mixed stands (e.g., home gardens) to sparse (e.g., trees in pastures).

- Temporal arrangement includes coincident, concomitant, overlapping, separate, and interpolated systems.

Functional Basis of Agroforestry Systems:

- Classified by productive (e.g., food, fodder, fuelwood) and protective (e.g., windbreaks, soil conservation) functions.

Ecological and Socio-Economic Classifications:

- Based on ecological conditions (tropical, sub-tropical, temperate, sub-alpine, alpine) and socio-economic factors (subsistence, commercial, intermediate systems).

Forest Legislation and Institutions in India

The Indian Forest Act, 1927

- Enacted to consolidate laws related to forest management, transit of forest produce, and duties on timber and other forest products.

The Wildlife Protection Act, 1972 and Amendments

- Provides protection for birds and animals, including their habitats, waterholes, and sustaining forests.

- Amendments in 1991, 2002, and 2006 introduced measures for conservation, including the National Tiger Conservation Authority and the Wildlife Crime Control Bureau.

The Forest (Conservation) Act, 1980

- Aims to provide a higher level of protection for forests and regulate the diversion of forest lands for non-forestry purposes.

- Requires prior approval from the Central Government for de-reservation and diversion activities.

Role of Forests in Biodiversity Conservation

- Forests support 50% of India's terrestrial biodiversity, hosting species like the Bengal tiger (*Panthera tigris*), Indian rhinoceros (*Rhinoceros unicornis*), and Great Indian Bustard (*Ardeotis nigriceps*).

- Tropical rainforests (e.g., Western Ghats, Northeast India) and mangroves (Sundarbans) are biodiversity hotspots.

Protected Areas in India

- **National Parks**: 106 (e.g., Jim Corbett, Kaziranga, Sundarbans).

- **Wildlife Sanctuaries**: 573 (e.g., Periyar, Ranthambore).

- **Biosphere Reserves**: 18 (e.g., Nilgiri, Sundarbans, Nanda Devi).

- **Tiger Reserves**: 54, covering 78,135 km² under Project Tiger (National Tiger Conservation Authority, 2006).

- **Management**: Governed by the Wildlife Protection Act 1972, with corridors for wildlife movement.

Conservation Programs

- **Project Tiger (1973)**: Aims to protect tigers and their habitats; increased tiger population from 1,411 (2006) to 3,167 (2022).

- **Project Elephant (1992)**: Protects elephant corridors and habitats.

- **Vulture Conservation**: Breeding programs for critically endangered vultures (e.g., Gyps bengalensis) due to diclofenac poisoning.

- **Eco-Restoration**: Assisted Natural Regeneration (ANR) and rewilding to restore degraded habitats.

Forestry Institutes in India

- Indira Gandhi National Forest Academy, Dehradun

- Directorate of Forest Education, Dehradun

- Forest Survey of India, Dehradun

- Indian Council of Forestry Research and Education, Dehradun

- Indian Institute of Forest Management, Bhopal

- Indian Plywood Industries Research and Training Institute, Bangalore

- Wildlife Institute of India, Dehradun

- Central Zoo Authority, New Delhi

India State of Forest Report (ISFR), 2023 - Key Points

- Biennial survey assessing forest and tree resources.

- First published in 1987, with the 2023 report marking the 18th publication.

- Prepared by the Forest Survey of India (FSI).

Major Findings of India State of Forest Report (ISFR) 2023

Category	Key Findings	Details/Notes

Total Forest and Tree Cover	8,27,356.95 km² (25.17% of India's geographical area)	Increased by 1,445.81 km² since 2021; includes 7,15,342.61 km² forest cover (21.76%) and 1,12,014.34 km² tree cover (3.41%). Below the National Forest Policy (1988) goal of 33.3% for plains and 66.6% for hilly regions.
Forest Cover Increase	156.41 km² increase since 2021	Top states: Mizoram (+242 km²), Gujarat (+180 km²), Odisha (+152 km²). Forest cover includes all lands ≥1 ha with ≥10% canopy density, including orchards and plantations.
Tree Cover Increase	1,289.40 km² increase since 2021	Driven by agroforestry; 21 states/UTs show increased tree cover. Tree cover includes patches <1 ha outside recorded forest areas.
Top States (Forest & Tree Cover)	Madhya Pradesh (85,724 km²), Arunachal Pradesh (67,083 km²), Maharashtra (65,383 km²)	Top forest cover (area): Madhya Pradesh (77,073 km²), Arunachal Pradesh (65,882 km²), Chhattisgarh (55,812 km²). Top % forest cover: Lakshadweep (91.33%), Mizoram (85.34%), Andaman & Nicobar (81.62%).
High Forest Cover States	19 states/UTs >33% forest cover; 8 states/UTs >75%	Mizoram, Lakshadweep, A&N Islands, Arunachal Pradesh, Nagaland, Meghalaya, Tripura, Manipur have >75% forest cover.
Carbon Stock	7,285.5 million tonnes (30.43 billion tonnes CO2 equivalent)	Increased by 81.5 million tonnes since 2021; India has achieved 2.29 billion tonnes of additional carbon sink, nearing the Paris Agreement NDC target of 2.5–3 billion tonnes by 2030. Top states: Arunachal Pradesh (1,021 Mt), Madhya Pradesh (608 Mt), Chhattisgarh (505 Mt).
Mangrove Cover	4,991.68 km² (0.15% of geographical area)	Decreased by 7.43 km² since 2021; Gujarat (-36.39 km²) and A&N Islands (-4.65 km²) saw declines, while Andhra Pradesh (+13.01 km²) and Maharashtra (+12.39 km²) saw increases.
Bamboo Cover	1,54,670 km²	Increased by 5,227 km² since 2021; top states: Madhya Pradesh, Arunachal Pradesh, Maharashtra, Odisha. Included in tree cover for the first time.
Forest Fires	Top states: Uttarakhand, Odisha, Chhattisgarh (2023-24 season)	Recognized as a national disaster in the 2019 National Disaster Management Plan.

Western Ghats Eco-Sensitive Areas (WGESA)	60,285.61 km², with 44,043.99 km² (73%) under forest cover	Lost 58.22 km² of forest cover since 2013; indicates degradation in biodiversity-rich areas.
Northeast Region	1,74,394.70 km² (67% of geographical area)	Decreased by 327.30 km² since 2021; states like Arunachal Pradesh, Manipur, Meghalaya, Mizoram, and Nagaland show declines.
Dense Forest Loss	3,913 km² loss since 2021; 24,651 km² (6.3%) since 2003	Moderately dense forest decreased by 1,043.23 km²; open forest by 2,480.11 km². Indicates degradation of natural forests.
Agroforestry	1,27,590 km² of tree cover; 1,292 million m³ growing stock	Top states: Maharashtra, Karnataka, Odisha, Rajasthan. Contributes to tree cover but not equivalent to natural forests.
Growing Stock	6,430 million m³ (4,479 million m³ inside forests)	Increased by 262 million m³; top states: Arunachal Pradesh (457.83 million m³), Uttarakhand (400.02 million m³), Chhattisgarh (398.54 million m³). Timber from trees outside forests: 91.51 million m³ annually.
Forest Cover Degradation	93,000 km² identified for density upgradation	Potential to sequester 636 Mt of carbon through restoration; highlights internal degradation despite overall cover increase.