HORNBILL CLASSES

Forestry Optional

IFoS | 2025 | Paper 1	
Date	
Syllabus	

SECTION – A

1 (a) : How does light affect the forest vegetation? Explain with suitable examples. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants an explanation of how the intensity, quality and duration of light influence the physiology, regeneration, growth, form and composition of forest vegetation, supported by suitable Indian species examples.

❶ ***Introduction*** **:** *Begin with light as the primary energy source (PAR, 400–700 nm) and its three attributes: intensity, quality and duration.*

❷ ***Main Body*** **:** ❖ *Physiological effects (photosynthesis, photoperiod)* ❖ *Light demanders vs shade bearers with examples* ❖ *Stratification, regeneration, natural pruning and light increment*

❸ ***Conclusion*** **:** *End with light regulation as a silvicultural tool (thinning, canopy opening).*

Solar radiation, especially its visible band (400–700 nm, **PAR**), is the primary energy source for ***photosynthesis***. Its ***quality, intensity*** and ***duration*** (***photoperiod***) influence tree physiology directly and the whole forest ecosystem indirectly—governing *growth, regeneration, stem form* and *species composition.* Being regulable through ***canopy manipulation***, it is a powerful ***silvicultural tool***.

EFFECTS OF LIGHT ON FOREST VEGETATION

A. *Attributes of Light*

1. ***Intensity*:** High light produces thick *sun leaves*; low light produces thin, broad *shade leaves*. Prolonged darkness causes *etiolation*.
2. ***Quality*:** A low *red : far-red ratio* under the canopy keeps light-requiring seeds (*e.g. Eucalyptus, Betula*) dormant until a gap forms.
3. ***Duration (Photoperiod)*:** Controls bud-break, flowering and dormancy, *e.g.* short days induce winter dormancy in temperate trees.

B. *Light Tolerance of Species*

Category	*Examples*
Strong light demanders	*Tectona grandis, Pinus roxburghii,*
Intermediate	*Shorea robusta, Cedrus deodara (shade-bearing when young)*
Shade bearers	*Abies pindrow, Picea smithiana, Taxus baccata*

C. *Effects on Forest Vegetation*

1. ***Stratification:*** Light demanders form the upper canopy and shade bearers the lower strata.
2. ***Regeneration:*** *Canopy gaps* release suppressed regeneration (gap-phase dynamics). Dense shade causes failure of light-demanding species such as Sal and Teak.
3. ***Stem form:*** Side shade promotes *natural pruning* and clean, knot-free boles. Open-grown trees become branchy, and crowns bend towards light (*phototropism*).
4. ***Growth:*** Thinning increases crown illumination, which causes *light increment* in diameter, *e.g.* teak plantations.
5. ***Undergrowth:*** Canopy opening favors weeds such as *Lantana camara*.

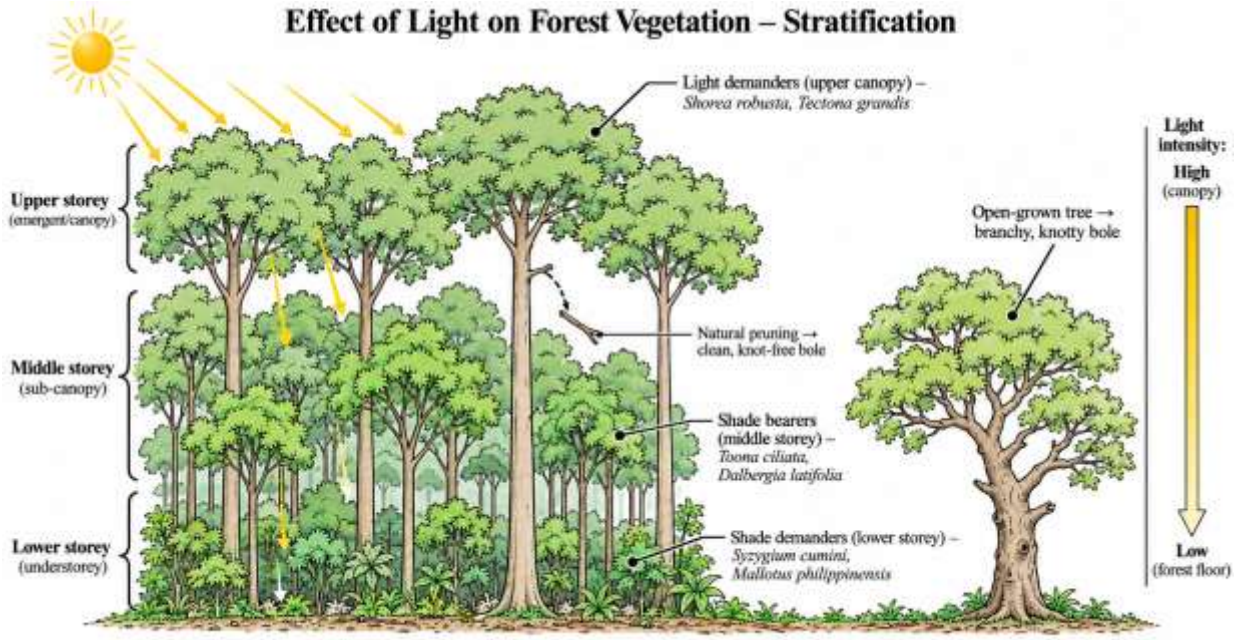


Fig.: Light-driven stratification and natural pruning in a forest stand

Thus, regulating light through ***thinning*** and ***canopy opening*** enables foresters to optimize ***regeneration, species composition, stand structure*** and ***timber quality.***

1 (b) : Describe the felling pattern adopted under Uniform System. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants the sequence of regeneration fellings under the Uniform (shelterwood) System, with the purpose of each felling.

❶ **Introduction** : *Define the Uniform System as concentrated regeneration under the uniform shelter of seed-bearers.*

❷ **Main Body** : ❖ *Preparatory felling* ❖ *Seeding felling (number of seed-bearers)* ❖ *Secondary fellings* ❖ *Final felling, with an Indian example (Chir)*

❸ **Conclusion** : *Conclude that canopy removal is synchronised with the progress of regeneration, giving an even-aged crop.*

The *Uniform System* is a *shelterwood system* of ***concentrated regeneration*** in which the canopy of a mature crop is opened ***uniformly*** over the ***whole compartment*** through successive *regeneration fellings, seed-bearers* providing both *seed and shelter*. Regeneration is completed within the ***regeneration interval*** (5–30 years), giving an ***even-aged crop***.

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FELLING SEQUENCE

Felling	Purpose	Key features
1. *Preparatory felling* *(optional)*	Prepares the stand and the soil for seeding	Light opening of dense, unthinned crops to develop the crowns of future seed-bearers and hasten the decomposition of raw humus. Skipped in regularly thinned stands.
2. *Seeding felling*	Induces regeneration	Done in a *good seed year*. The canopy is opened uniformly and only vigorous, well-formed *seed-bearers* are retained (≈ 25–50/ha in Chir). Slash is disposed of and the soil is worked to expose mineral soil.
3. *Secondary fellings*	Gives light to the regeneration	Seed-bearers are removed *gradually, in one or more stages*, as the seedlings establish. Timing depends on the *light requirement* of the species.
4. *Final felling*	Frees the new crop	The last shelter trees are removed once the regeneration is ***established and no longer needs protection***.

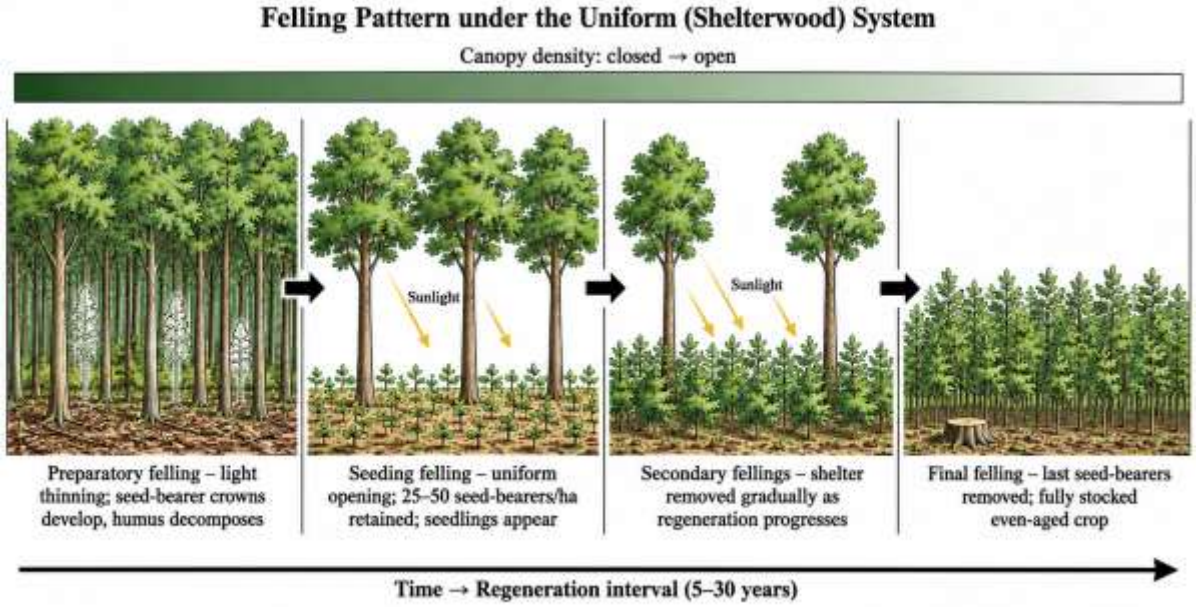


Fig.: Sequence of regenenation fellings in the Uniform System

INDIAN PRACTICE

- Applied mainly in ***Chir pine*** forests of Uttarakhand and Himachal Pradesh, and in some ***Sal*** and ***Deodar*** areas.
- In Chir, more seed-bearers are retained on ***hot, dry southern/SW aspects*** than on ***cool northern/NE aspects***, because the hot aspects need more shelter for the seedlings.

Merit **:** The crop is uniform and wind-firm, and working is simple. ***Limitation*****:** The system depends on a ***good seed year***, and opening the canopy exposes the soil to weeds and erosion.

Thus, the Uniform System converts a mature stand into a ***regular, even-aged regenerated crop*** by *synchronising canopy removal with the progress of natural regeneration*.

1 (c) : Write the scientific names and uses of eight mangrove species. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants the correct scientific names of eight mangrove species, each with its specific economic or ecological uses.

❶ **Introduction** : *Briefly define mangroves and their halophytic adaptations.*
❷ **Main Body** : ❖ *A table: Scientific name (local name) | Uses* ❖ *Coverage of tannin, timber, honey, food and fodder uses*
❸ **Conclusion** : *Close with the livelihood value and Indian mangrove cover.*

Mangroves are ***salt-tolerant*** (***halophytic***), evergreen trees and shrubs of tropical and subtropical ***intertidal*** coasts, estuaries and deltas. Adapted to ***saline, anaerobic*** and tidally flooded mudflats through ***pneumatophores, stilt roots, salt glands*** and ***vivipary***, they provide important ***timber, tannin, food, medicine, fodder*** and ***livelihood products.***

IMPORTANT MANGROVE SPECIES AND USES

Species	Important uses
Rhizophora mucronata	Bark yields *tannin*; wood used for *poles*, *fuelwood* and *charcoal*.
Bruguiera cylindrica	Fresh bark provides *tannin* and *dyes*.
Ceriops decandra	Bark yields ***tannin***; flowers contribute to *Sundarban honey* production.
Avicennia officinalis	Leaves used traditionally for stomach and urinary disorders; foliage also used as ***fodder***.
Sonneratia apetala	Fruits used for ***pickles*** and preparation of *Keora water*; flowers support honey production.
Nypa fruticans	Inflorescence sap used for ***molasses***; leaves used for *thatching*.
Aegiceras corniculatum	Important nectar source for *Sundarban honey*.
Heritiera fomes	Provides hard, *durable timber* used for *poles*, *boats* and *construction*.

Thus, mangrove species have substantial *economic* and *livelihood value* in addition to their wider ***ecological role*** in ***coastal ecosystems***.

1 (d) : Discuss the silvicultural characters of Acacia nilotica and Cedrus deodara. **[8 M]**

Approach

Understanding the Question !!
Here, the examiner wants the silvicultural characters (light, frost, drought, coppicing, root system, regeneration, injuries) of Babul and Deodar, compared clearly.

❶ **Introduction** : *Introduce both species with their habitat and zone (dry plains vs western Himalayan temperate).*
❷ **Main Body** : ❖ *Silvicultural characters of Acacia nilotica* ❖ *Silvicultural characters of Cedrus deodara* ❖ *A comparison table and the management implication*
❸ **Conclusion** : *Link the characters to the silvicultural system suited to each species.*

Acacia nilotica (***Family***: ***Fabaceae***; ***Common name***: ***Babul***) occurs widely in ***dry India***, prefers ***alluvial/black soils***, is ***frost-resistant, but comparatively fire-sensitive***.
Cedrus deodara (***Family***: ***Pinaceae***; *Common name*: ***Deodar***) occurs in the *Western Himalayas*, prefers *well-drained loamy soils*, and is *frost-hardy* but *fire-sensitive.*

Character	Acacia nilotica (Babul)	Cedrus deodara (Deodar)
Light	*Strong light demander*	*Shade-bearer in youth*; needs more light later (moderate light demander)
Frost	***Frost-tender***; seedlings are killed by frost	***Frost-hardy***
Drought	*Highly drought-resistant*	*Seedlings are* ***drought-sensitive***

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Snow / Water	Tolerates periodic ***inundation*** (riverain babul)	***Snow-break*** of poles in dense, untinned crops
Root system	***Deep taproot***; suits dry and ravine sites	Moderately deep taproot with strong laterals; fairly ***wind-firm***
Coppicing	*Poor Coppicing*	*Does not coppice*
Fire	Moderately fire-hardy	***Fire-tender*** when young
Browsing	***Heavily browsed*** by goats and camels	Seedlings suffer from *grazing and trampling*
Injuries	Root rot (*Ganoderma*), stem borers	*Root rot (Heterobasidion/Fomes annosus)*

REGENERATION

- ***Babul*:** Seed passing through the gut of *goats and cattle* germinates better because the hard seed coat is softened. It is raised easily by *direct sowing* of pre-treated seed.
- ***Deodar*:** It seeds heavily in *good seed years*, but the seed *loses viability quickly*. Germination needs ***exposed mineral soil with moderate shade***.

MANAGEMENT IMPLICATION

- ***Babul*: *Clear-felling*** with artificial regeneration or ***coppice*** in dry plains and *tank-bed forests*.
- ***Deodar*:** The *Uniform / Irregular Shelterwood* system, with ***early and regular thinning*** to cut snow damage.

Thus, Babul suits *open, dry, light-demanding management*, while Deodar needs a *protective shelterwood regime with careful density control.*

1 (e) : Give the phenological characters of Tectona grandis and Albizia lebbeck. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants only the phenology (leaf fall, leaf flush, flowering, fruiting/seed ripening) of Teak and Siris, with months and regional variation.

❶ **Introduction** : *Give a one-line identification of both species (family, nature).*

❷ **Main Body** : ❖ *Phenology of Tectona grandis* ❖ *Phenology of Albizia lebbeck* ❖ *A phenogram table (Jan–Dec)*

❸ **Conclusion** : *Mention the use of phenology in seed collection and nursery planning.*

Phenology is the study of the ***timing of recurring life-cycle events*** in plants and its relation to climate. ***Tectona grandis*** (Teak; **Verbenaceae**, formerly Verbenaceae) and ***Albizia lebbeck*** (Kala Siris; **Mimosaceae**) are both ***deciduous***, and their phenology shifts with *rainfall and latitude*.

1. ***Tectona grandis* (Teak)**
   - ***Leaf fall*: Nov–Jan** in dry localities, extending to *March* in moist areas.
   - ***Leaf flush*:** *April–June*, with the pre-monsoon showers.
   - ***Flowering*:** *June–September*, in large terminal panicles soon after the new leaves appear.
   - ***Fruiting*:** Drupes ***ripen Nov–Jan*** and *fall gradually through the dry season*.
2. ***Albizia lebbeck* (Siris)**
   - ***Leaf fall*: Oct–Nov** in North India; **Dec–Feb** elsewhere.
   - ***Leaf flush*: March–April**.
   - ***Flowering*: April–May**, with fragrant, greenish-white powder-puff flowers.

- ***Fruiting*: Pods *ripen Dec–Feb*** in North India and earlier in the south. Dry pods *persist and rattle on the tree* for months (hence "woman's tongue tree").

SILVICULTURAL SIGNIFICANCE

- ***Seed collection*:** Teak fruits are collected *Jan–April* from the ground. Siris pods are collected ***Dec–Feb***, before they dehisce.
- ***Nursery and planting schedules*** are timed to the phenology. Leafless periods also *raise fire risk and change light conditions* in the stand.

Thus, both species follow *distinct, climate-controlled seasonal cycles*, and knowing them is essential for *seed collection, nursery operations and stand management*.

2 (a) : Describe the external factors of environment which affect the germination of seeds in the natural forests. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***external (environmental) factors*** *that control seed germination* ***in natural forests****, grouped as* ***climatic, edaphic and biotic****, each explained with* ***forest species examples****. Internal factors need only a one-line mention.*

❶ ***Introduction :*** *Define germination and separate internal from external factors.*

❷ ***Main Body :*** ❖ *Climatic factors* ❖ *Edaphic and seedbed factors* ❖ *Biotic factors and fire* ❖ *Physiographic factors*

❸ ***Conclusion :***

Seed germination is the resumption of growth by the embryo, leading to the emergence of a ***normal seedling***. In natural forests it links ***seed fall to seedling establishment***. It depends on ***internal factors*** (viability, dormancy, seed-coat permeability) and on ***external environmental factors***. A viable, non-dormant seed stays ***quiescent*** until these external conditions are favorable.

A. CLIMATIC FACTORS

1. ***Moisture*:** Water is needed for *imbibition*, enzyme activation and the mobilization of food reserves. *Shorea robusta* seed is *recalcitrant* (viable for about a week), so it falls at the *onset of the monsoon* and germinates at once. Alternate *wetting and drying* helps break the hard endocarp of ***Teak***. Both ***drought and prolonged waterlogging*** cause failure.
2. ***Temperature*:** Each species has *cardinal temperatures*, mostly *20–35 °C* for tropical species. Low temperature delays germination, while very high *surface-soil temperatures* kill germinant. In temperate forests, *winter chilling* (natural ***cold stratification***) breaks dormancy, *e.g. Abies, Picea.*
3. ***Light*:** *Light demanders* such as *Teak, Sal and Chir* need canopy openings. *Shade bearers* such as ***Silver fir*** germinate under cover. Canopy density also changes soil *temperature and moisture*.
4. ***Frost and snow*:** *Frost-lifting* uproots germinant in temperate forests and frost hollows. ***Snow cover*** gives moisture and stratification, but it also delays germination.

B. EDAPHIC AND SEEDBED FACTORS

1. ***Aeration*:** Germination needs *oxygen*. Waterlogged or ***compacted*** soils accumulate CO_2, which inhibits germination.
2. ***Litter and raw humus*:** A thick *needle mat* in *fir and spruce* forests stops the radicle from reaching ***mineral soil***, causing ***regeneration failure***.
3. ***Soil texture and reaction*:** *Loose, porous, neutral to slightly acidic* soils help germination. *Saline–alkaline, compact or stiff clay* soils hinder it.

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C. BIOTIC FACTORS AND FIRE

1. ***Seed predators:*** *Rodents, birds and insects* destroy seed. Passage through animal guts helps germination of ***hard-seeded*** species, *e.g.* ***Babul, Khair***.
2. ***Pathogens and weeds:*** *Damping-off fungi (Pythium, Fusarium)* kill germinants. ***Weeds*** (*e.g. Lantana*) and ***allelopathy*** suppress establishment.
3. ***Fire: Light, controlled burning*** removes litter, exposes mineral soil and cracks hard seed coats (*e.g.* ***Chir pine***). ***Intense fire*** destroys seed and germinants.

D. PHYSIOGRAPHIC FACTORS

1. ***Aspect and slope:*** In dry tracts, *cooler north/NE aspects* keep more moisture and favour germination. ***Steep slopes*** lose seed and soil to ***runoff***.

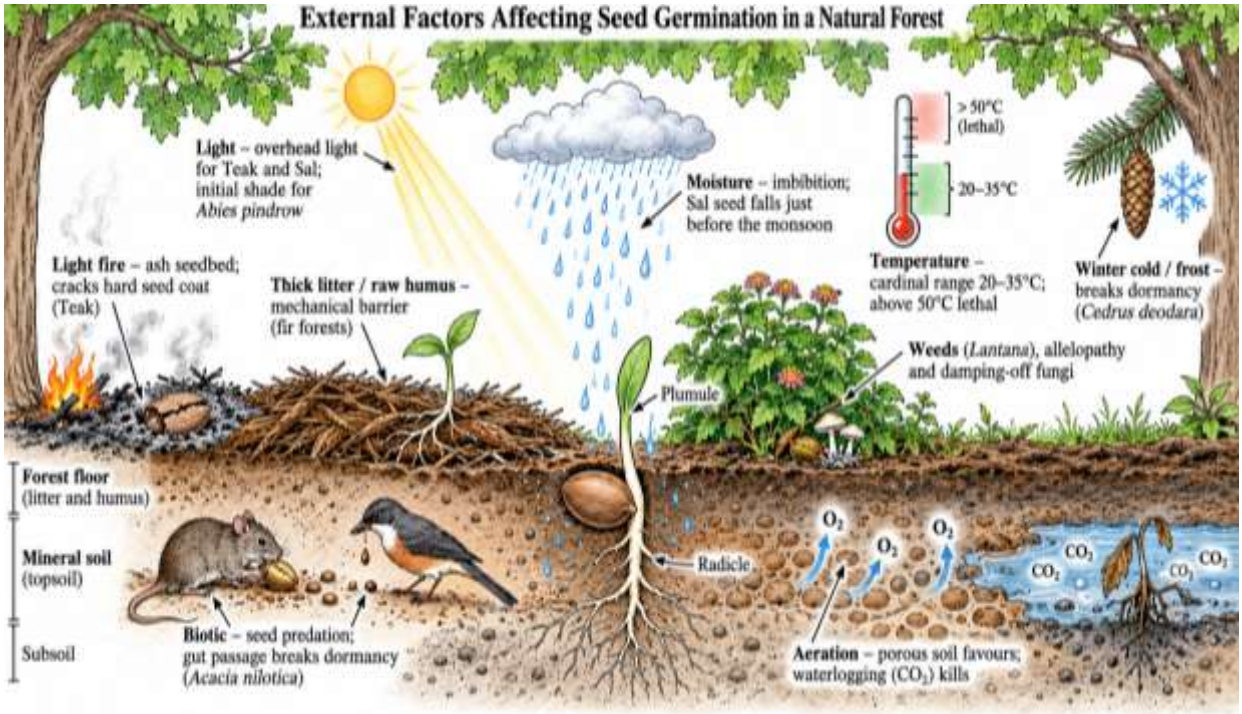


Fig.: Climatic, edaphic and biotic factors controlling seed germination on the forest floor

Thus, successful germination in natural forests depends on a ***favorable microsite*** that combines ***moisture, temperature, aeration, light and a mineral-soil seedbed***. Silvicultural operations such as ***canopy regulation, soil working, litter removal, controlled burning, weed control and protection from grazing*** are used to create these conditions.

2 (b) : Describe the methods of regeneration followed under Clear-felling System with suitable examples. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***methods of restocking a clear-felled coupe****:* ***artificial*** *(main method) and* ***natural*** *(sources of seed). Each needs* ***Indian examples****, plus the* ***conditions*** *that decide which method is used.*

❶ ***Introduction :*** *Define the Clear-felling System and its annual coupes.*

❷ ***Main Body :*** ❖ *Artificial regeneration and its methods* ❖ *Natural regeneration and its sources* ❖ *Modifications that aid regeneration* ❖ *Factors governing the choice*

❸ ***Conclusion :*** *The method depends on species, site and protection needs.*

The *Clear-felling System* is a ***high-forest system*** in which the mature crop of the *annual coupe* is ***removed in one operation***. The cleared area is then regenerated, giving an ***even-aged crop***. Because the site is fully exposed, regeneration is obtained *mainly by artificial means*, with ***natural regeneration*** used where seed supply is assured.

1. ARTIFICIAL REGENERATION (PRINCIPAL METHOD)

It is *quick and certain*. It allows *choice of species*, the use of *improved planting stock*, and *conversion to fast-growing species*.

Method	Features	Example
Planting nursery stock	Naked-root, ball-of-earth or ***container (root-trainer)*** seedlings	*Eucalyptus* clonal plantations; ***Casuarina*** on coastal sands
Stump planting	Root-shoot cuttings, cheap and hardy	***Teak*** (Nilambur, Kerala); *Sal, Shisham*
Direct sowing	Pre-treated seed sown in lines or patches	*Babul, Khair, Neem* in dry tracts
Taungya	Tree rows with *agricultural crops* for 2–3 years, which lowers weeding and establishment cost	***Teak and Sal*** plantations in UP, West Bengal, Kerala
Cuttings / ETPs	Entire transplants or branch cuttings	***Poplar*** (ETPs), ***Willow***

2. NATURAL REGENERATION

Natural regeneration is adopted where *seed supply and site conditions are favourable*. Its sources are:

- ***Seed from adjoining uncut stands*:** Light, *wind-dispersed seed* reaches narrow coupes, *e.g. Chir and Blue pine, Alder, Poplar*.
- ***Seed stored on the site*:** Seed already in the *forest floor*, *e.g. Teak*, whose fruits stay viable in the soil for years.
- ***Advance growth*:** Established seedlings and saplings are *retained and protected* during felling, *e.g.* some ***Sal*** and ***Teak*** forests of *Madhya Pradesh, Chhattisgarh and Jharkhand*.

Natural regeneration is usually *supplemented by artificial planting* in blank patches.

3. MODIFICATIONS THAT AID REGENERATION

- ***Seed-tree method*:** A few good seed trees per hectare are retained until regeneration appears.
- ***Reserves / standards*:** A few trees are left for *shelter, frost protection and insurance*.
- ***Strip clear-felling (clear-strip / alternate strips)*:** Narrow strips get *side seed and shelter* from the adjacent uncut forest, which reduces exposure and erosion.

4. FACTORS GOVERNING THE CHOICE

Favour artificial regeneration	***Favour natural regeneration***
Change of species or industrial plantations	Adequate ***seed years*** and dispersal
Failure of natural regeneration	Abundant *advance growth*
Weed, frost and grazing problems	***Narrow coupes***, close to seed source

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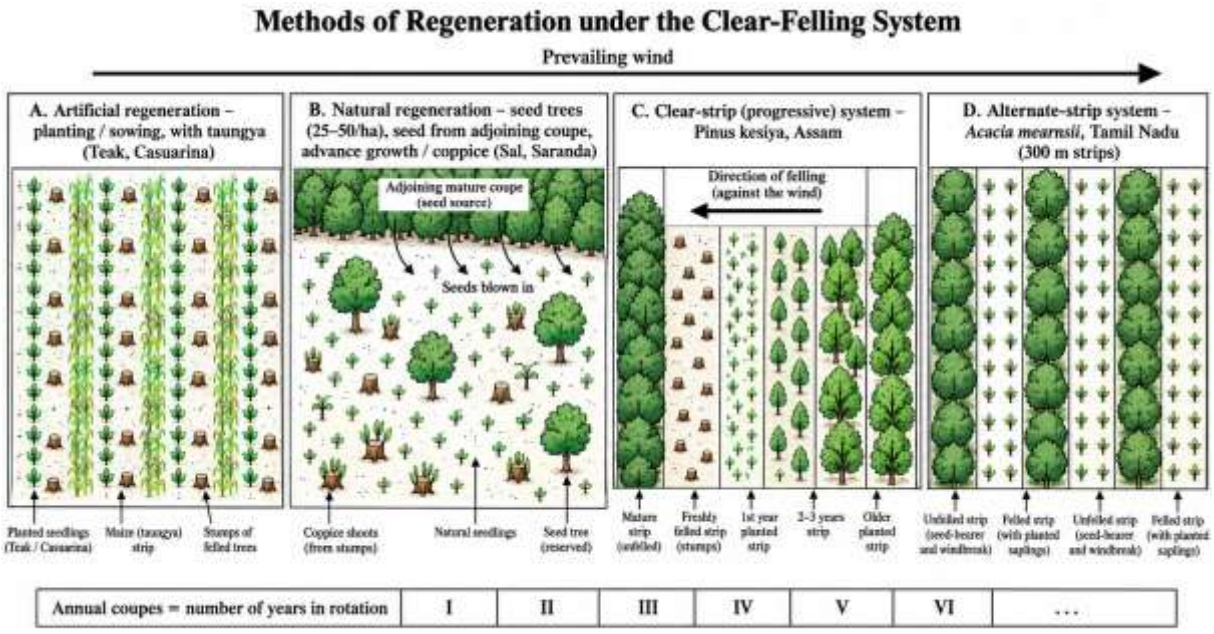


Fig.: Artificial, natural and strip-based regeneration of clear-felled coupes

Thus, the Clear-felling System relies *mainly on artificial regeneration* for rapid, controlled restocking. *Natural regeneration and strip or seed-tree modifications* are used where seed supply is dependable. Proper ***soil working, weeding and protection*** after felling are essential, because the *exposed site is prone to weeds, frost and erosion.*

2 (c) : (i) Write the advantages of Simple Coppice System and Coppice with Standards System. (ii) Differentiate between Coppice of Two Rotations System and Shelterwood Coppice System. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants ***(i)*** *the* ***advantages*** *of two coppice systems and* ***(ii)*** *a* ***point-wise distinction*** *between two* ***modified coppice systems****. The marks split roughly* **5 + 5**, *so the time should be balanced between the two parts.*

❶ ***Introduction*** **:** *Define coppice and stool shoots in 1–2 lines.*

❷ ***Main Body*** **:** ❖ *Advantages of Simple Coppice* ❖ *Advantages of Coppice with Standards* ❖ *Differentiation table*

❸ ***Conclusion*** **:** *The objective of each system in one line.*

Coppice systems regenerate the crop mainly from *stool shoots*, which arise from *dormant or adventitious* ***buds*** on the stumps after felling. Because coppicing power *declines with age*, these systems are worked on *short rotations* for *fuelwood, poles and small timber*.

Simple Coppice System	***Coppice with Standards System***
Simple working**:** the coupe is clear-felled, so no skilled marking is needed	***Dual output*****:** coppice gives fuel and poles, and ***standards*** give large timber
Certain and cheap regeneration from established stools	***Soil protection*****:** standards keep partial cover after the coppice felling
Rapid early growth, so weeding and tending costs are low	***Frost protection*** for the young coppice
High MAI on short rotations	Standards get *light increment* and *seed supply*

Quick financial returns Suits *fuelwood, pulpwood and pole demand*, *e.g.* ***Eucalyptus, Khair***	***Staggered income***: early from coppice, later from timber Better *aesthetics and biodiversity*, *e.g.* ***Sal coppice-with-standards*** (UP)

(i) COPPICE OF TWO ROTATIONS VS SHELTERWOOD COPPICE

Basis	***Coppice of Two Rotations***	***Shelterwood Coppice***
Basic principle	Modification of Simple Coppice to obtain some larger timber	Modification retaining temporary shelter over new coppice
Initial felling	Complete clear-felling at first rotation	Some shelter trees retained after felling
Retained trees	Selected coppice-origin poles	About 125–150 shelter trees/ha
Time of retention	Selected at end of first rotation and retained through the second rotation	Retained only during part of the coppice rotation
Final removal	Felled with coppice at end of second rotation	Gradually removed after coppice is well established
Main objective	Production of larger-sized timber in addition to ordinary poles	Mainly frost protection
Origin of retained trees	Coppice origin	Existing shelter/standard trees
Suitability	Where frost is not the principal constraint	Especially suited to frost-prone localities

Coppice of Two Rotations vs Shelterwood Coppice System

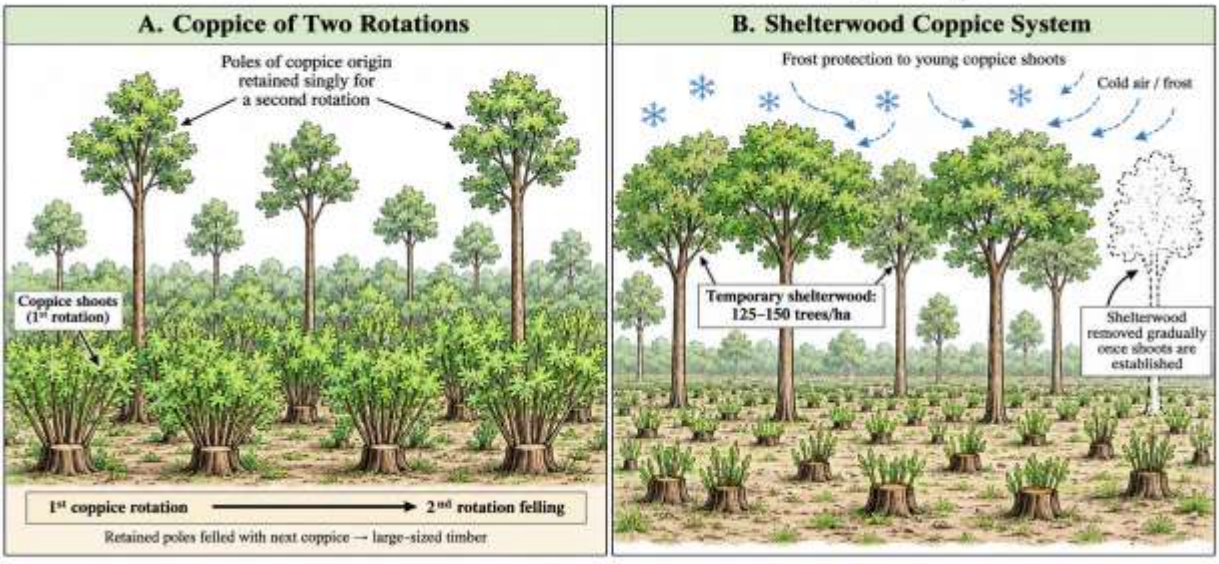


Fig.: Retention pattern in coppice of two rotations and shelterwood coppice systems

Thus, *Simple Coppice* gives *cheap and quick small produce*, while ***Coppice with Standards combines small and large timber***. The ***Two-Rotation*** modification aims at *bigger produce*, and the ***Shelterwood Coppice*** aims at *frost protection*.

3 (a) : Describe briefly: (i) Site quality (ii) Hardening (iii) Tending (iv) Thinning (v) Grading. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants ***brief but precise notes on five terms****, each with a* ***definition, key features or methods, and forestry significance****. Each term carries* ***≈ 3 marks****, so all five need* ***equal treatment****.*

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❶ **Introduction :** *Place the five terms in the sequence of forest establishment and management.*
❷ **Main Body :** ❖ *Site quality* ❖ *Hardening* ❖ *Tending* ❖ *Thinning* ❖ *Grading*
❸ **Conclusion :** *Together they build a productive, high-quality stand.*

These five concepts represent important stages in forest establishment and management: *site quality* assesses the productive potential of a locality; *hardening* and ***grading*** prepare suitable ***nursery stock*** for planting; while ***tending*** and ***thinning*** regulate the developing forest crop to improve *survival, growth, form* and ***final yield***.

(i) SITE QUALITY

Site quality is the *relative productive capacity of a site for a particular species*. It results from *climatic, edaphic and topographic factors*, so it is *species-specific*.

- ***Direct methods*: *Site index*** (the height of dominant trees at a base age) and *top height* (the mean height of the 100 largest trees per ha).
- ***Indirect methods*:** *Indicator plants*, soil and topography.
- ***In India*:** Yield tables recognise *Site Quality Classes I–V*, with *I as the best*.

***Significance*:** It guides *species choice, rotation, yield prediction and thinning regimes*.

(ii) HARDENING

Hardening is the ***gradual acclimatisation of nursery seedlings to field conditions*** before planting out. It is done by *reducing watering, shade and protection* step by step during the last few weeks in the nursery.

***Effects*:** *Lignified stems, tougher foliage, a better root–shoot ratio, tolerance to drought, heat and frost, and less transplant shock*, which together mean *higher field survival*.

(iii) TENDING

Tending covers *all operations from seedling stage to maturity that improve the crop's health, growth and form.*

- ***Includes*:** *Weeding, cleaning, climber cutting, thinning, pruning, improvement felling* and girdling of unwanted trees.
- ***Excludes*:** *Regeneration fellings* and *ground operations* such as soil working, drainage and controlled burning.

(iv) THINNING

Thinning is a *felling in an immature stand* to *improve the growth and form of the remaining trees, without permanently breaking the canopy*.

- ***Methods*:** *Mechanical*, *Ordinary (low)*, *Crown (high)*, ***Free***, *Advance and Numerical* thinning.
- ***Grades*:** From *light (A grade) to very heavy (D grade).*

***Principle*:** Thinning does not raise total volume production much. It *concentrates increment on fewer, better stems*, and it gives *intermediate yield, reduces fire and pest risk* and *improves wind-firmness*.

(v) GRADING

Grading is the *sorting of nursery stock into quality classes* before planting. The criteria are *height, root-collar diameter, root development, stem form, health and vigour*, together with a *sturdiness quotient* (height : collar diameter).

- ***Rejected*:** *Diseased, malformed, root-bound or lanky* seedlings.
- ***Example* – *Teak stumps*:** collar diameter ≈ **1.2–2.5 cm**, root ≈ **15–22.5 cm**, shoot ≈ **2–5 cm**.

Significance*:** *Uniform establishment*, ***higher survival and *better early growth*.

Thus, *assessing site quality, planting graded and hardened stock, and timely tending and thinning* together form the basis of *productive, high-quality forest stands*.

3 (b) : Describe the habitats and characteristics of mangroves. Discuss their ecological values. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants three things: the habitat conditions of mangroves, their morphological and physiological characteristics, and their ecological values.

❶ ***Introduction*** **:** *Define mangroves as intertidal halophytic forests under severe stress.*

❷ ***Main Body*** **:** ❖ *Habitat: tidal, saline, anaerobic, muddy* ❖ *Characteristics: roots, vivipary, salt regulation, zonation* ❖ *Ecological values: bio-shield, blue carbon, nursery*

❸ ***Conclusion*** **:** *Conclude on coastal ecological security and schemes such as MISHTI.*

Mangroves are *salt-tolerant* evergreen forest ecosystems of tropical and subtropical ***intertidal zones***. They occur where land and sea interact under periodic *tidal inundation* and survive under severe stresses such as *high salinity*, *anaerobic soils*, *unstable mud* and *physiological drought* through specialized ***morphological***, ***anatomical*** *and physiological adaptations*.

1. HABITAT

- ***Regular tidal inundation*** of the *intertidal zone*.
- ***Saline to brackish water***, with salinity varying with tides and freshwater inflow.
- ***Waterlogged, anaerobic (oxygen-deficient)*** *soils*.
- ***Soft, unstable, fine-textured mud*** rich in organic matter.
- A ***warm humid climate*** (above ≈ 20 °C) on ***sheltered, low-energy coasts***: estuaries, lagoons, deltas and creeks.

Types in India:

- ***Deltaic: Sundarbans, Mahanadi (Bhitarkanika),*** *Godavari–Krishna*, which get large freshwater and sediment input.
- ***Backwater–estuarine:*** West coast (*e.g. Kerala, Goa*).
- ***Insular:*** *Andaman & Nicobar*.

2. CHARACTERISTICS AND ADAPTATIONS

- Root adaptations: *Pneumatophores* are ***negatively geotropic*** aerial roots with ***aerenchyma***, *e.g.* ***Avicennia***; ***stilt/prop roots*** provide anchorage, *e.g. Rhizophora; knee roots* assist aeration, *e.g.* ***Bruguiera***; ***buttresses*** provide structural stability.
- ***Vivipary***: Seeds germinate while still attached to the parent plant; the developed ***propagule*** falls into soft mud and establishes rapidly, bypassing the vulnerable seed stage.
- Salt regulation: *Salt exclusion/ultrafiltration* at roots in *Rhizophora, Bruguiera* and *Ceriops*; *salt glands* in *Avicennia*; and *vacuolar accumulation* with *leaf shedding* of excess salts.
- ***Xeromorphic leaves***: Thick waxy cuticle, *sunken stomata, succulent tissues* and *water-storage tissue* reduce water loss under *physiological drought*.
- ***Zonation***: Mangrove species show characteristic ***seaward-to-landward*** zonation according to ***salinity***, ***tidal flooding*** and *sediment conditions*; understorey vegetation is usually poorly developed.

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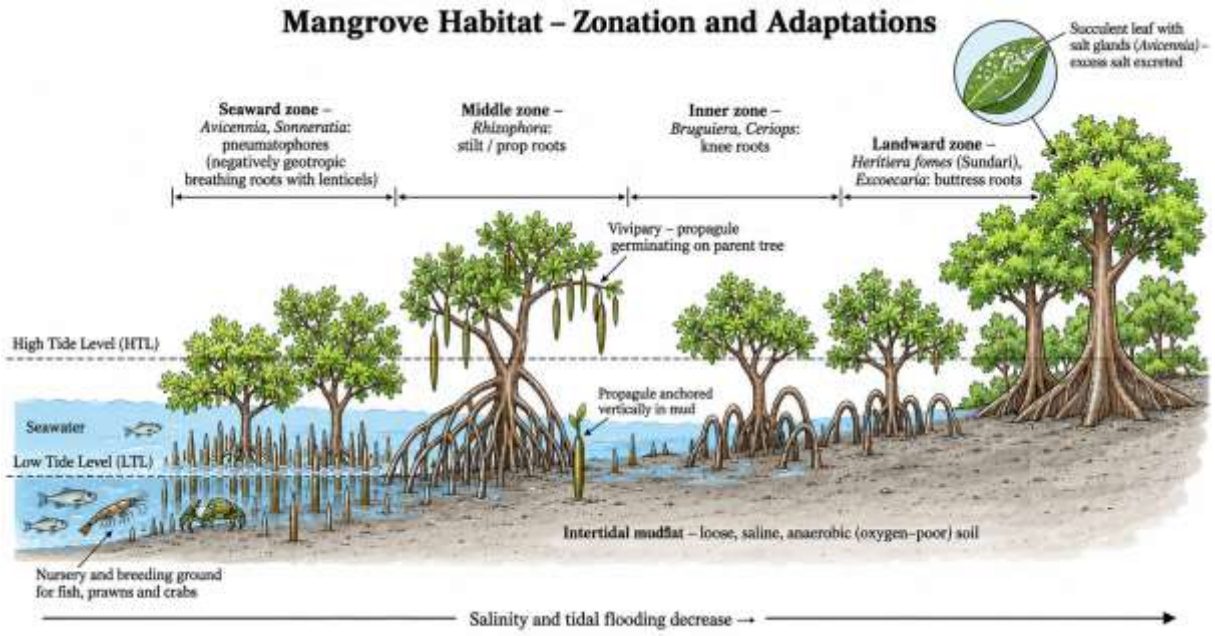


Fig.: Zonation and morphological adaptations of mangrove vegetation

3. ECOLOGICAL VALUES

- ***Coastal bio-shield***: Dense vegetation reduces the impact of cyclones, storm surges, coastal flooding and tsunamis.
- ***Shoreline stabilisation***: Complex roots reduce water velocity, trap sediments, check erosion and promote ***land accretion***.
- ***Blue-carbon storage***: Mangroves are highly efficient carbon sinks and store substantial carbon in woody biomass and waterlogged sediments; the module notes sequestration about **3–5 *times*** greater than many terrestrial forests.
- ***Fish nursery***: Mangrove creeks provide spawning, nursery and feeding habitats for fish, prawns, molluscs and other aquatic fauna.
- ***Biodiversity conservation***: They support diverse birds, reptiles, mammals and aquatic organisms.
- ***Water purification***: Mangrove roots and sediments trap pollutants, suspended matter and heavy metals, improving coastal water quality.
- ***Nutrient cycling***: High litter production and decomposition support detritus-based coastal food webs and maintain ecosystem productivity.

Mangroves are uniquely adapted to ***salinity***, ***tidal inundation***, ***anaerobic soils*** and unstable substrates. These same adaptations enable them to function as ***coastal bio-shields***, *blue-carbon sinks*, ***biodiversity refuges*** and *nursery grounds*, making them indispensable for *coastal ecological security*.

3 (c) : Write the distribution and economic importance of Dalbergia sissoo and Emblica officinalis. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants, for ***both species****, their* ***natural distribution and planted range*** *(with climate and soil) and their* ***economic importance****. Each species carries* ***≈ 5 marks****.*

❶ ***Introduction :*** *Introduce both as multipurpose trees: a timber species and a fruit/NTFP species.*

❷ ***Main Body :*** ❖ *Dalbergia sissoo: distribution and economic importance* ❖ *Emblica officinalis: distribution and economic importance*

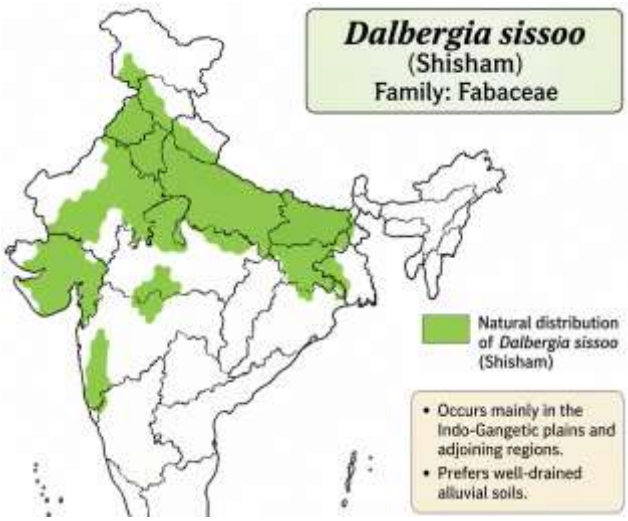
❸ ***Conclusion :*** *Their role in agroforestry and rural livelihoods.*

1. DALBERGIA SISSOO (SHISHAM)

Dalbergia sissoo (**Family: Fabaceae**), commonly called **Shisham**, prefers **well-drained alluvial soils**. It is frost-hardy when mature but seedlings are frost-sensitive, fire-sensitive, and possesses strong coppicing and root-suckering ability.

Distribution

- ***Natural range*:** The *Sub-Himalayan* ***tract and outer*** *Himalayan valleys* ***from the Indus to*** *Assam*, usually *below* 900 *m*, occasionally up to ≈ **1,500 *m***.
- ***Climate*:** Rainfall ≈ **75–450 *cm***.
- ***Habitat*:** A ***pioneer on fresh riverine alluvium***, sand and gravel along streams, where it forms *gregarious riverain stands*.
- ***Planted range*:** Widely planted on *canal banks, roadsides, farm bunds and in agroforestry*, especially in *Punjab, Haryana, UP and Bihar*.



Economic Importance

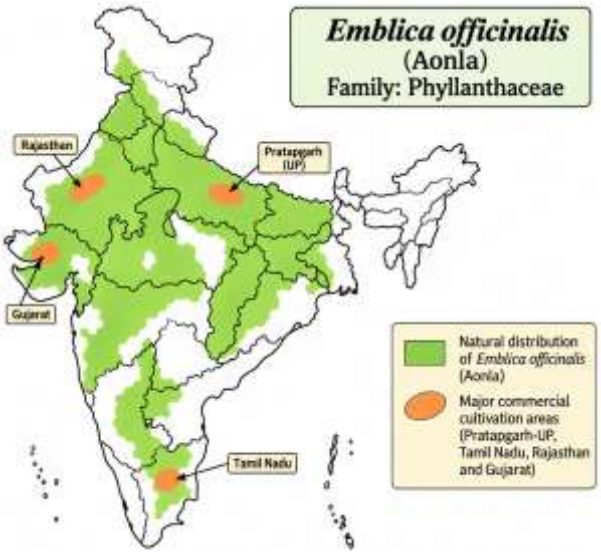
- ***Timber*:** *Furniture, cabinetry, carving, doors and windows, railway sleepers and coaches, carts, agricultural implements and tool handles.*
- ***Handicrafts*:** The *Saharanpur and Jodhpur* wood-craft industries depend on it. *Easing of CITES trade restrictions on D. sissoo (CoP19, 2022)* helped exports.
- ***Others*:** *Fuelwood and leaf fodder*. Its *nitrogen fixation* improves farm soils.
- ***Concern*:** *Dieback and mortality* (linked to *Fusarium* and *Ganoderma*) have reduced plantation stock.

2. EMBLICA OFFICINALIS (AONLA)

Emblica officinalis (***Family*: *Phyllanthaceae***), commonly called ***Aonla***, grows on varied soils including *dry and poor sites*. It is *frost- and fire-resistant*, drought hardy, and possesses *strong coppicing ability*, enabling rapid vegetative recovery after disturbance.

Distribution

- ***Natural range*:** *Tropical and subtropical deciduous forests across India*, up to ≈ **1,200 *m***.
- ***Climate*:** Rainfall ≈ **70–150 *cm***. It is *hardy and drought-tolerant*.
- ***Soils*:** It tolerates *saline–sodic soils (pH up to ≈ 9.5)*, which makes it suitable for *wasteland and usar reclamation*.
- ***Commercial cultivation*: *Pratapgarh* (UP)**, Tamil Nadu, Rajasthan and Gujarat. Main varieties are *NA-7, Krishna, Chakaiya and Banarasi*.



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Economic Importance

- ***Fruit:*** One of the ***richest natural sources of*** *vitamin C* ***(≈ 500–700 mg/100 g)***.
- ***Ayurveda:*** A key ingredient of *Triphala and Chyawanprash*, and used for hair and skin products.
- ***Processed products: Murabba, candy, pickle, juice and powder***. These create *rural enterprises and SHG income.*
- ***Tannin and dye:*** From the ***bark,*** *leaves and fruit*.
- ***Wood:*** Fuel and charcoal. The wood is ***durable under water***, so it is used in ***well-lining***.

Thus, ***Shisham*** is a key ***timber and agroforestry*** tree, while ***Aonla*** is a valuable ***fruit–medicinal NTFP*** suited to ***degraded and sodic lands***. Together they support ***farm income,*** *rural industry and livelihoods*.

4 (a) : Write the major characteristics of cold deserts. Describe two cold deserts of India. **[15 M]**

Approach

Understanding the Question !!

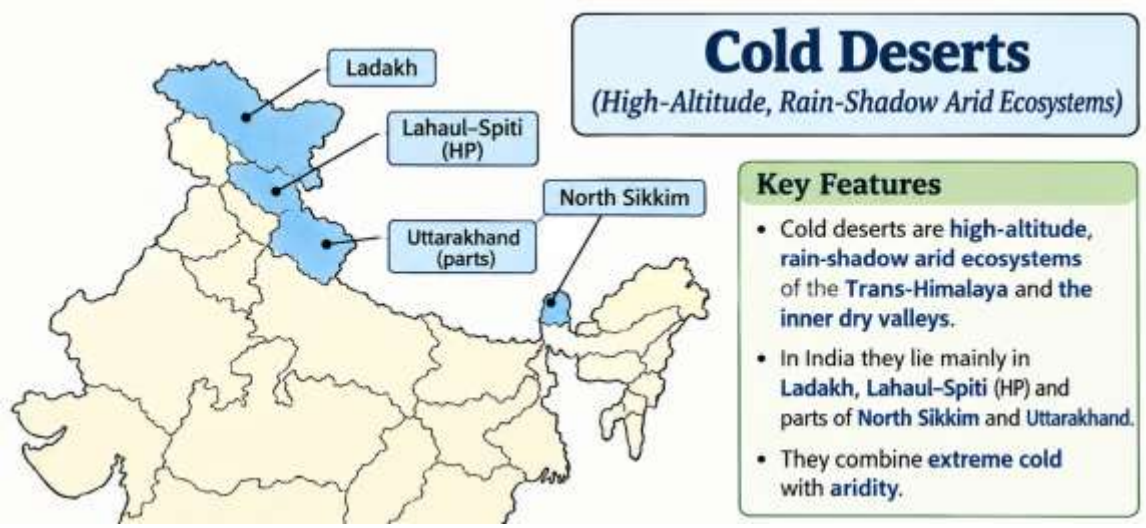
*Here, the examiner wants **(i)** the **major characteristics** of cold deserts (climate, soil, vegetation, adaptations) and **(ii)** a **description of two Indian cold deserts**, covering **location, climate, vegetation, fauna, protected areas and forestry interventions**.*

❶ ***Introduction :*** *Define cold deserts as high-altitude rain-shadow arid ecosystems.*

❷ ***Main Body :*** ❖ *Characteristics: climate, soil, vegetation, adaptations* ❖ *Ladakh cold desert* ❖ *Lahaul–Spiti cold desert*

❸ ***Conclusion :*** *Fragility and site-specific afforestation.*

Cold deserts are *high-altitude, rain-shadow arid ecosystems* of the *Trans-Himalaya and the inner dry valleys*. In India they lie mainly in *Ladakh, Lahaul–Spiti (HP)* and parts of *North Sikkim and Uttarakhand*. They combine *extreme cold with aridity*.



1. MAJOR CHARACTERISTICS

- ***Climate:***
  - Annual precipitation is *below ≈ 40–60 cm*, mostly as *snow*, and is often *below 10 cm* in the driest parts.
  - Winters are *long, with sub-zero temperatures*, and *diurnal ranges are large*.
  - *Intense UV and insolation, low air pressure*, and *strong desiccating winds*.
- ***Physiological drought:*** Water stays ***frozen*** for much of the year, so plants face drought despite moisture being present. The ***growing season is only 3–5 months***.

- **Soils:**
  - *Shallow, coarse, skeletal and sandy–gravelly, low in organic matter and microbial activity,* often *alkaline or saline.*
  - *Freeze–thaw (cryoturbation)* and *wind and water erosion* make the slopes unstable.
- ***Vegetation:*** Closed forest is ***absent***. The cover is ***sparse dry alpine scrub, cushion plants and steppe grasses***, with *willow–poplar* along streams.
  - Champion & Seth ***Group 16: Dry Alpine Scrub***: *Juniperus, Ephedra gerardiana, Hippophae rhamnoides, Artemisia, Caragana.*
- *Plant adaptations: Dwarf and cushion habit, hairy, waxy or reduced leaves, deep or spreading roots,* a *short life cycle, vegetative spread,* and *anthocyanins* for UV protection.
- *Fauna: Snow leopard, Himalayan ibex, Tibetan wild ass (kiang), blue sheep (bharal).*

2. **LADAKH COLD DESERT**

- ***Location:*** The *Trans-Himalayan* ***UT of*** *Ladakh*: *Leh, Kargil, Nubra, Zanskar and Changthang.* Altitude is about 3,000–5,500 *m.*
- ***Climate: Leh receives about 100 mm*** of rainfall a year. Winter temperatures fall ***below −20 °C***, and the area is ***windy, with*** *intense sunlight*.
- ***Vegetation:***
  - *Seabuckthorn (Hippophae), Caragana, Artemisia, Ephedra and Juniper.*
  - *Salix and Populus* are planted along streams.
  - *Changthang* has *wetlands and high-altitude steppe.*
- ***Protected areas:*** *Hemis National Park* (snow leopard) and ***Changthang WLS*** (***black-necked crane, kiang***). ***Tso Moriri*** is a ***Ramsar site***.
- ***Interventions:***
  - *Willow–poplar plantations* for fuel and timber.
  - *Seabuckthorn value chains* ("Leh Berry").
  - *Ice stupas / artificial glaciers* for spring irrigation.

3. **LAHAUL–SPITI COLD DESERT (HIMACHAL PRADESH)**

- ***Location:*** Lies in the *rain-shadow of the Pir Panjal and Great Himalaya*. Spiti is *drier and higher* than Lahaul.
- ***Climate:*** *Very low rainfall*, mostly as ***snow***, and a *short growing season. Upper Spiti has ground frost for more than 200 days.*
- ***Vegetation:*** *Juniper scrub*, *Seabuckthorn, Caragana, Ephedra* and *alpine herbs,* including *medicinal plants*. *Willow and poplar* grow along irrigation channels (*kuhls*).
- ***Protected areas:***
  - The ***Cold Desert Biosphere Reserve (2009)*** was added to UNESCO MAB ***in 2020***.
  - It includes *Pin Valley NP* and ***Kibber WLS***.
  - ***Chandratal*** is a ***Ramsar site***.
- ***Interventions:*** *Willow–poplar block and boundary plantations, pasture management* and *soil–moisture conservation.*

Indian cold deserts are ***fragile,*** *slow-recovering and physiologically dry*, and they face *climate change*, *overgrazing and tourism pressure*. Their management needs *locally adapted species (Salix, Populus, Hippophae), water harvesting, pasture regulation and community participation*, together with *conservation of their unique biodiversity.*

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4 (b) : Describe the regeneration of: (i) Shorea robusta (ii) Azadirachta indica (iii) Hardwickia binata. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants, for ***each species****, the* ***natural regeneration*** *(seed behaviour, vegetative means, problems) and the* ***artificial regeneration*** *(method, timing, practices). The three species carry* ***equal marks (≈ 5 each)****.*

❶ ***Introduction*** **:** *Define regeneration and state that it depends on species biology.*

❷ ***Main Body*** **:** ❖ *Sal: seed biology, problems, artificial methods* ❖ *Neem: seed, coppice, suckers, nursery* ❖ *Anjan: seed, taproot, direct sowing, stumps*

❸ ***Conclusion*** **:** *Comparative summary table.*

Regeneration is the *renewal of a forest crop* by *seed, coppice, root suckers or planting*. The method suited to a species depends on its *seed behaviour, coppicing power, root habit and site*.

1. SHOREA ROBUSTA (SAL)

Sal (***Shorea robusta***), belonging to *Dipterocarpaceae*, is a major timber tree of northern and central India, thriving best on *deep, moist, well-drained loamy soils*. It is a *light-demanding* and *fire-hardy species*; however, young seedlings are particularly susceptible to frost and drought.



Natural Regeneration

- ***Seed:*** Ripens in ***May–June*** and falls at the ***onset of the monsoon***. It is ***recalcitrant*** (viable for ***≈ 1 week***) and germinates ***almost at once***.
- ***Establishment:*** Seedlings show repeated ***die-back*** of shoots for several years before a vigorous shoot "establishes".
- ***Coppice:*** Sal ***coppices well***.
- ***Problems:*** *Dense canopy, weeds, raw humus, poor drainage (waterlogging), frost, drought, fire and grazing.*
- ***Regional picture:*** Regeneration is *adequate in Siwalik and Central Indian Sal,* and *deficient in moist Bhabar, Terai and Dun Sal.*

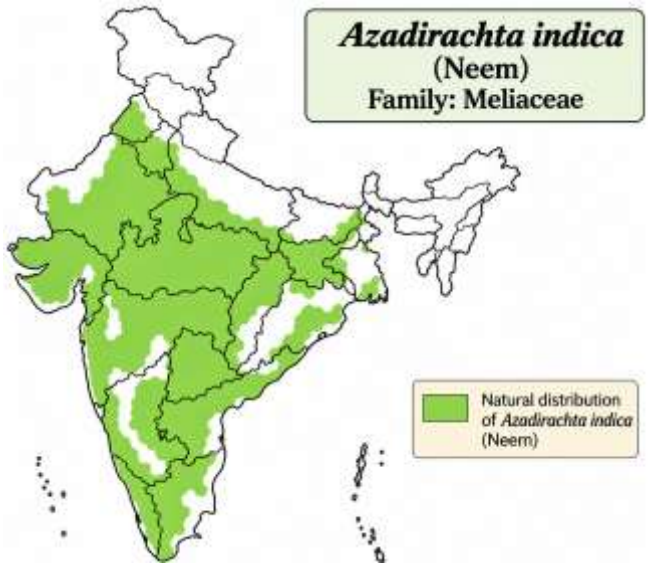
Artificial Regeneration

- *Direct sowing* of *fresh seed in lines* just after seed fall is the *most successful* method.
- ***Taungya*** is used for plantation Sal.
- ***Transplants*** do poorly because of the ***long taproot***.

System: *Indian Irregular Shelterwood* (and Uniform) with *soil working, weeding, controlled burning and fire protection.*

2. AZADIRACHTA INDICA (NEEM)

Azadirachta indica (Neem), belonging to the family ***Meliaceae,*** is widely distributed in ***tropical*** and ***subtropical*** India, especially in dry regions. It grows well on ***well-drained sandy*** to ***loamy soils***, is ***highly drought tolerant*** and ***light demanding***, moderately fire resistant, but comparatively sensitive to severe ***frost,*** especially when young.



Natural Regeneration

- **Seed:** Fruits ripen in *June–August*. Seed *loses viability within a few weeks*. *Birds and bats* disperse the seed widely, so regeneration is common *under hedges and trees*.
- **Vegetative:** *Coppices vigorously* and produces *root suckers*.
- **Habit:** *Light demander* but *tolerates side shade* when young. *Drought-hardy* but *frost-tender*.

Artificial Regeneration

- ***Direct sowing*** of ***fresh, depulped seed*** in the ***monsoon***.
- ***Nursery seedlings*** (container or bare-root) and ***stump planting*** both give ***high success***.
- ***Vegetative:*** ***Root suckers, cuttings and air-layering***, and ***tissue culture*** for elite clones.
- ***Spacing:*** ***≈ 5 × 5 m*** in plantations and agroforestry.

3. HARDWICKIA BINATA (ANJAN)

Hardwickia binata (***Anjan***), belonging to the family ***Fabaceae,*** is a characteristic tree of the ***dry deciduous forests of central and peninsular India***. It thrives on *shallow, rocky and well-drained soils,* is highly *drought hardy* and *light demanding*, shows good *fire resistance,* but young plants are comparatively ***sensitive to severe frost***.

Natural Regeneration

- **Seed:** Winged, single-seeded pods ripen in ***April–June***. Seed germinates with the ***first monsoon rains***.
- ***Root habit:*** Seedlings develop a ***very long taproot early***, while ***shoot growth is slow***. This makes them ***drought-hardy***.
- ***Problems:*** Natural regeneration is ***often scanty*** because of ***grazing, browsing, fire and weeds***.

ARTIFICIAL REGENERATION

- *Direct sowing* in *lines, patches or ridges* at the *onset of the monsoon* is the *best method*.
- *Stump planting* suits the long taproot. *Nursery transplants* do poorly because of *taproot damage*.
- *Protection* from *grazing* for several years is essential.
- *Agroforestry spacings*: *10 × 3 m or 5 × 3 m*. The tree is also *pollarded for fodder*.

Thus, ***Sal*** *needs* ***careful microsite management***, ***Neem*** *regenerates* ***easily by seed and vegetative means***, *and* ***Anjan*** *relies on* ***direct sowing and stumps with strict protection from grazing***.

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4 (c) : Explain any two of the following: (i) Periodic Blocks (ii) Felling Cycle (iii) Felling Series (iv) Taungya. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants ANY TWO of the four terms explained. Attempt exactly two; extra parts are not evaluated.

❶ ***Introduction*** **:** *Name the two terms chosen and state their role in forest management.*

❷ ***Main Body*** **:** ❖ *Term 1: definition, working and example* ❖ *Term 2: definition, working and example*

❸ ***Conclusion*** **:** *End with one line on their importance.*

A ***Periodic Block*** and ***Taungya*** are two important forestry devices used respectively for organising ***natural regeneration*** under ***shelterwood systems*** and for establishing ***plantations*** economically through temporary integration of ***agricultural crops***.

1. PERIODIC BLOCKS

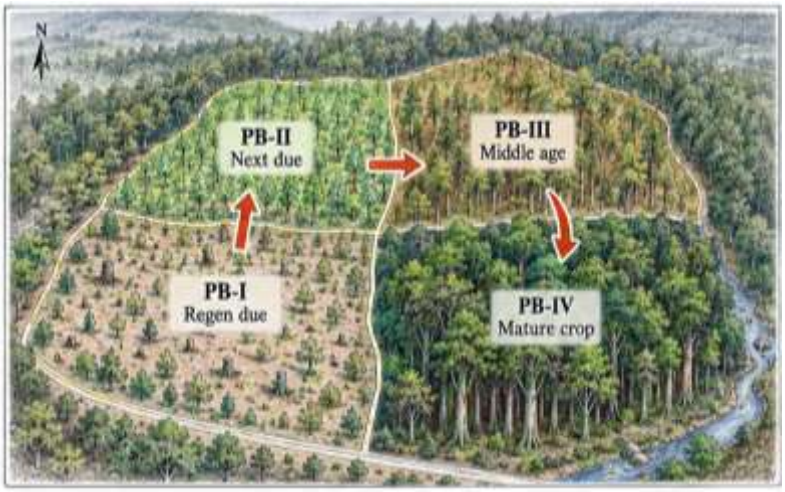
A ***Periodic Block*** (PB) is a part of a ***working circle*** set aside for regeneration during a specified ***regeneration period*** under a ***shelterwood system***. It is necessary because natural regeneration develops gradually over several years and therefore cannot be organised conveniently through ***annual coupes***.

Number of PBs = Rotation Period ÷ Regeneration Period.

For example, in Sal, a ***120-year*** rotation and ***30-year*** regeneration period give ***4 periodic blocks***.

Each PB is divided into smaller ***equi-productive compartments***, where regeneration fellings are carried out progressively:

Seeding felling → Secondary fellings → Final felling.



The time from seeding felling to final felling in a particular compartment is the ***regeneration interval***, whereas the time required to regenerate the whole PB is the ***regeneration period***. Where regeneration is uncertain, as in the ***Indian Irregular Shelterwood System***, periodic blocks may be ***floating*** rather than rigidly fixed, depending on the presence of established ***advance growth***.

2. FELLING CYCLE

Felling cycle is the ***period of time that elapses between two successive main fellings on the same forest area***.

It is especially important in the ***Selection System***, where the entire forest is generally too extensive to be worked annually. The working area is therefore divided into a number of coupes; one coupe is worked each year and, after all coupes have been treated, felling returns to the first coupe.

Example:

Coupe I → II → III → IV → V → back to Coupe I

If the same coupe is revisited after ***20 years***, the felling cycle is ***20 years***.

***Silvicultural significance*:**

- regulates the periodic removal of exploitable trees;
- provides sufficient time for ***regeneration and growth of residual trees***;
- helps maintain the ***uneven-aged structure*** characteristic of selection forests; and
- facilitates sustained and organised harvesting.

Thus, unlike ***rotation***, which relates to the age of the crop at maturity, felling cycle refers to the ***interval between successive main fellings on the same area***.

3. FELLING SERIES

A ***Felling Series*** is a forest area forming the whole or part of a ***Working Circle***, delimited so as to:

1. distribute ***felling and regeneration*** according to local conditions, and
2. maintain or create a ***normal distribution of age classes***.

Each felling series is treated as an *independent unit for yield regulation*, and yield is calculated separately for it. It should therefore possess an independent representation of age classes.

Where a working circle contains widely separated or ecologically and socio-economically different forest areas, it may be divided into several felling series for better control and distribution of silvicultural operations.

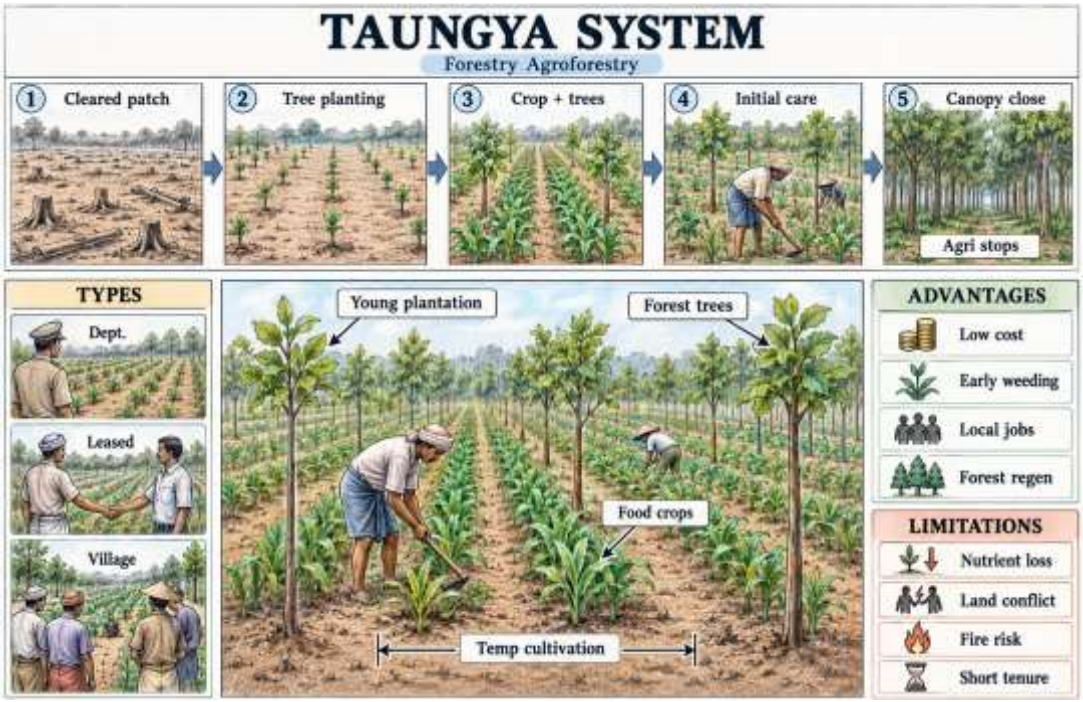
***Silvicultural significance*:**

- ensures orderly distribution of annual fellings;
- facilitates ***sustained yield***;
- improves administrative and silvicultural control;
- accommodates differences in local forest conditions; and

helps safeguard ***local socio-economic and ecological interests***

4. TAUNGYA

Taungya is a method of ***plantation establishment*** in which ***agricultural crops*** are temporarily cultivated between rows of young forest trees until ***canopy closure***. The method originated in ***Burma***, where ***U Pan Hla***, a ***Karen forester***, proposed allowing local cultivators to grow crops between young ***teak plantations*** while also assisting in ***plantation protection*** and tending; ***Dietrich Brandis*** later supported the approach.



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Main Types

- ***Departmental Taungya*** — both forest and agricultural crops are raised by the Forest Department.
- ***Village Taungya*** — local families cultivate food crops between tree rows, usually about **0.8–1.7 *ha*** per family for roughly **3–5 *years***.
- ***Leased Taungya*** — cultivation rights are given on payment of lease charges.

Another classification recognises ***Partial Taungya*** and ***Integral Taungya***, the latter associated with ***forest villages***.

MERITS AND LIMITATIONS

- ***Merits***: reduces ***weeding*** and ***establishment cost***, provides ***plantation protection***, creates ***rural employment*** and produces ***food crops*** during early plantation years.
- ***Limitations***: possible ***soil exhaustion***, dependence on ***labour availability***, risk of ***inequitable labour arrangements*** and potential conflict over ***land and tenure***.

SECTION – B

5 (a) : Write the scientific names and uses of eight tree species suitable each for temperate and arid climate agroforestry plantations. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants ***eight temperate and eight arid agroforestry species*** *with* ***correct scientific names and uses****. The species must be* ***genuinely used in agroforestry*** *in those climates; adding the* ***agroforestry system*** *for each is good value addition.*

❶ ***Introduction*** **:** *Site-matched species selection for each climate.*

❷ ***Main Body*** **:** ❖ *Temperate species table* ❖ *Arid species table*

❸ ***Conclusion*** **:** *Multipurpose benefits and research support.*

Agroforestry species must match ***climate, soil and local needs***. ***Temperate*** systems need ***cold- and frost-hardy*** multipurpose trees, while ***arid*** systems need ***deep-rooted***, ***drought-hardy***, ***often nitrogen-fixing*** trees that ***do not compete with crops***.

1. TEMPERATE AGROFORESTRY SPECIES

Species (local name)	***Major uses***	***AF system***
Populus ciliata (Himalayan poplar)	Matchwood, plywood, fuel	Boundary / block
Salix alba (Willow)	***Cricket bats***, fodder, fuel	Riparian / boundary
Juglans regia (Walnut)	***Edible nuts***, gunstock and furniture timber	Agri-horticulture
Prunus armeniaca (Apricot)	Fruit, ***kernel oil***	Agri-horticulture
Morus alba (Mulberry)	***Sericulture***, fodder, fruit, sports goods	Silvi-pasture / bunds
Grewia optiva (Bhimal)	***Winter leaf fodder***, bark fibre	Fodder bank on terrace risers
Celtis australis (Kharik)	Leaf fodder, fuel, tool handles	Agri-silviculture
Alnus nepalensis (Utis)	***N-fixation***, shade, fuel	***Large-cardamom*** agroforestry (Sikkim)

2. ARID AGROFORESTRY SPECIES

Species (local name)	***Major uses***	***AF system***
Prosopis cineraria (Khejri)	Fodder (loong), ***sangri pods***, N-fixation	***Agri-silviculture*** in Thar

Tecomella undulata (Rohida)	"***Marwar teak***" timber, shelterbelts	Boundary / shelterbelt
Acacia senegal (Kumat)	***Gum arabic***, edible seeds, fuel	Silvi-pasture
Acacia nilotica (Babul)	Fuel, tannin, pod fodder	Boundary / agri-silviculture
Acacia tortilis (Israeli babul)	***Dune stabilisation***, fuel, pod fodder	Shelterbelt / silvi-pasture
Ziziphus mauritiana (Ber)	***Fruit***, leaf fodder (pala)	***Hortipasture***
Azadirachta indica (Neem)	Timber, oil, ***biopesticide***	Boundary / windbreak
Ailanthus excelsa (Ardu)	***Goat fodder***, matchwood, plywood	Boundary / farm woodlot

Thus, ***site-matched multipurpose trees*** provide ***food, fodder, fuel, timber and income*** along with ***soil and water conservation***; research by **CAZRI (Jodhpur)** for arid systems and **ICAR–CAFRI** supports their wider adoption.

5 (b) : What are the characteristics of trees suitable for watershed management? **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***desirable traits of tree species*** *used for* ***soil and water conservation*** *in watershed treatment — **root, crown/litter, hardiness, regeneration, water-use and socio-economic** traits — each backed by an **example species**.*

❶ **Introduction** : *Define a watershed and the aims of its management.*

❷ **Main Body** : ❖ *Soil-binding traits* ❖ *Hydrological traits* ❖ *Biological and socio-economic traits*

❸ **Conclusion** : *Biological measures complement engineering works on a ridge-to-valley basis.*

A ***watershed*** is a ***geo-hydrological unit*** draining to a ***common outlet***. Its management aims to ***increase infiltration and recharge, reduce runoff and erosion, moderate floods*** and ***sustain base flow***; trees used must therefore ***bind soil and conserve water***.

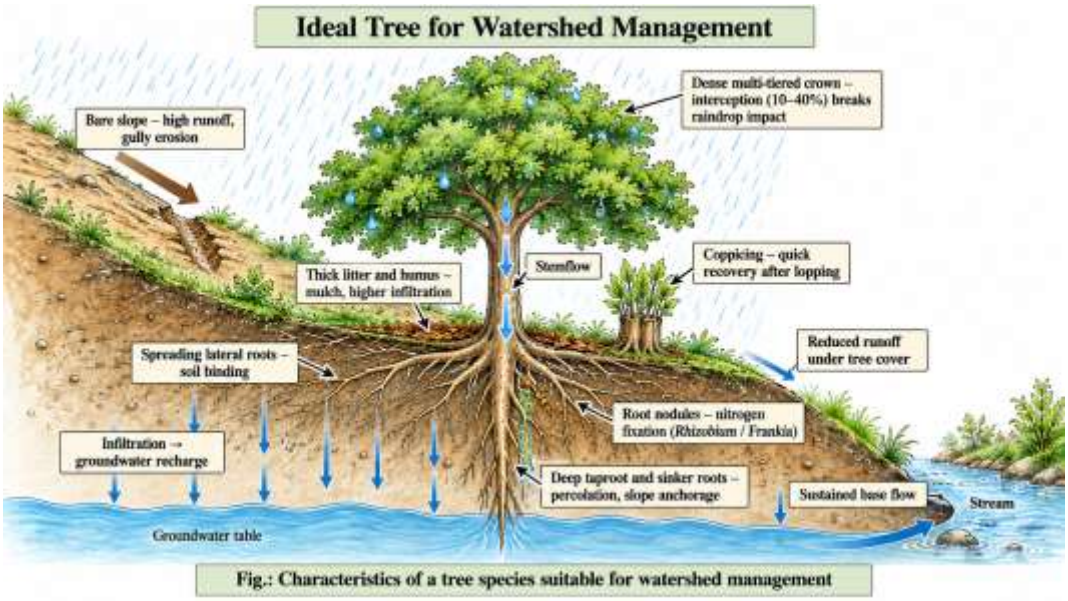


Fig.: Characteristics of a tree species suitable for watershed management

A. SOIL-BINDING TRAITS

1. ***Deep and extensive root system:*** taproots and spreading laterals ***anchor slopes*** and ***open channels for infiltration***, *e.g. Dendrocalamus strictus, Acacia catechu.*
2. ***Strong soil-binding ability:*** fibrous roots check ***sheet, rill and gully erosion***, *e.g.* **Salix** and **Alnus** on stream banks; **Vetiver** on contours.

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B. HYDROLOGICAL TRAITS

1. ***Dense, multi-layered crown*: *intercepts rainfall*** and ***reduces splash erosion***.
2. ***Abundant litter*:** forms ***mulch and humus***, ***improves soil structure*** and ***cuts evaporation***, *e.g.* ***Sal, Oak (Quercus)***.
3. ***Moderate water use*:** should ***conserve rather than deplete*** soil moisture; ***heavy users*** such as ***Eucalyptus*** should be avoided near recharge zones.

C. BIOLOGICAL AND SOCIO-ECONOMIC TRAITS

1. *Hardiness and quick establishment* on *shallow, degraded, dry* sites, *e.g. Acacia nilotica, Prosopis cineraria.*
2. ***Good regeneration:*** easy propagation and ***strong coppicing*** to recover after lopping, *e.g. Grewia optiva, Bauhinia.*
3. ***Soil improvement: nitrogen fixation*** and nutrient-rich litter, *e.g. Alnus nepalensis, Leucaena.*
4. ***Multipurpose and locally acceptable:*** *fodder, fuel and fruit* value wins *community protection, e.g. Grewia, Mango, Aonla.*

Thus, ideal watershed trees are *deep-rooted, soil-binding, litter-producing, hardy, quick-regenerating and water-efficient*. Planted on a *ridge-to-valley* basis, as under WDC–PMKSY, they *complement engineering structures* and make the watershed *stable and productive*.

5 (c) : Write in brief: (i) Objectives of Social Forestry (ii) Multipurpose trees and their characteristics. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants ***brief notes*** *on* ***(i)*** *the* ***objectives of social forestry*** *(origin and components are value addition) and* ***(ii)*** *the* ***definition, examples and characteristics of multipurpose tree species (MPTS)****. Both parts carry* ***≈ 4 marks each****.*

❶ ***Introduction*** **:** *Define social forestry, with Westoby (1968) and the NCA (1976).*

❷ ***Main Body*** **:** ❖ *Components and objectives of social forestry* ❖ *MPTS: definition, examples, characteristics*

❸ ***Conclusion*** **:** *Link both to livelihoods and to reducing pressure on forests.*

Social forestry means *raising and managing trees outside traditional forests*, with ***people's participation***, to meet *local needs*. The term was coined by *Jack Westoby* (1968), and the *National Commission on Agriculture* (1976) recommended it to ***reduce pressure on forests***.

***(i)* OBJECTIVES OF SOCIAL FORESTRY**

Components*: *Farm forestry, ***Community forestry*** (village woodlots), ***Extension forestry*** (roadside, canal-bank and railway strips) and ***Rehabilitation of degraded lands***.

- ***Basic needs*:** *fuelwood, fodder, small timber and* NTFPs for rural people.
- ***Reduce pressure*** on natural forests.
- ***Livelihoods*:** *employment and income*, especially for *women and landless* households.
- ***Land rehabilitation:*** greening *wastelands, ravines and degraded commons*.
- ***Soil and water conservation:*** check *erosion and runoff*; improve *recharge*.
- ***Environment*:** *shelterbelts, carbon sequestration*, and checks on *desertification and pollution*.
- ***Participation:*** strengthen *Panchayats and local institutions* through *benefit sharing*.
- ***Policy goal*:** help achieve the NFP 1988 *target of 33% forest and tree cover*.

***(ii)* MULTIPURPOSE TREES (MPTS)**

MPTS are *woody perennials grown deliberately for more than one product or service — food, fodder,*

fuel, timber, fibre, green manure or soil improvement. **Examples:** *Gliricidia sepium* (fodder, green manure, live fence), *Leucaena leucocephala, Sesbania grandiflora, Moringa oleifera, Grewia optiva, Prosopis cineraria.*

CHARACTERISTICS:

- *Fast growth and early yield.*
- ***Easy propagation*** by seed or cuttings; *strong coppicing and pollarding.*
- ***Deep roots*** and a *light, narrow or deciduous crown*, so there is *little competition with crops.*
- *Nitrogen fixation* and *good litter.*
- *Palatable, non-toxic fodder* and *marketable produce.*
- *No allelopathy; tolerance of drought, pests and lopping.*
- *Social acceptability* and *suitability to the local agro-climate.*

Thus, ***social forestry built on well-chosen MPTS*** meets ***rural biomass needs***, supports ***livelihoods*** and ***restores land***, while ***sparing natural forests***.

5 (d) : Enumerate the various measures to control noise pollution. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants an ***enumerated list of control measures****, organised as* ***source → path → receiver****, plus* ***legal, planning and green-belt*** *measures.* ***Legal standards*** *and the* ***forestry angle (green belts)*** *are the expected value addition.*

❶ **Introduction** : *Define noise pollution and the source–path–receiver approach.*

❷ **Main Body** : ❖ *Source control* ❖ *Path control and green belts* ❖ *Receiver protection* ❖ *Legal and planning measures (Rules 2000)*

❸ **Conclusion** : *The need for an integrated approach.*

Noise pollution is *unwanted or excessive sound*, measured in ***dB(A)***, from *traffic, industry, construction, aircraft and loudspeakers*. It causes *hearing loss, stress, sleep disturbance and disturbance to wildlife*. Control is most effective at the *source, along the path and at the receiver*.

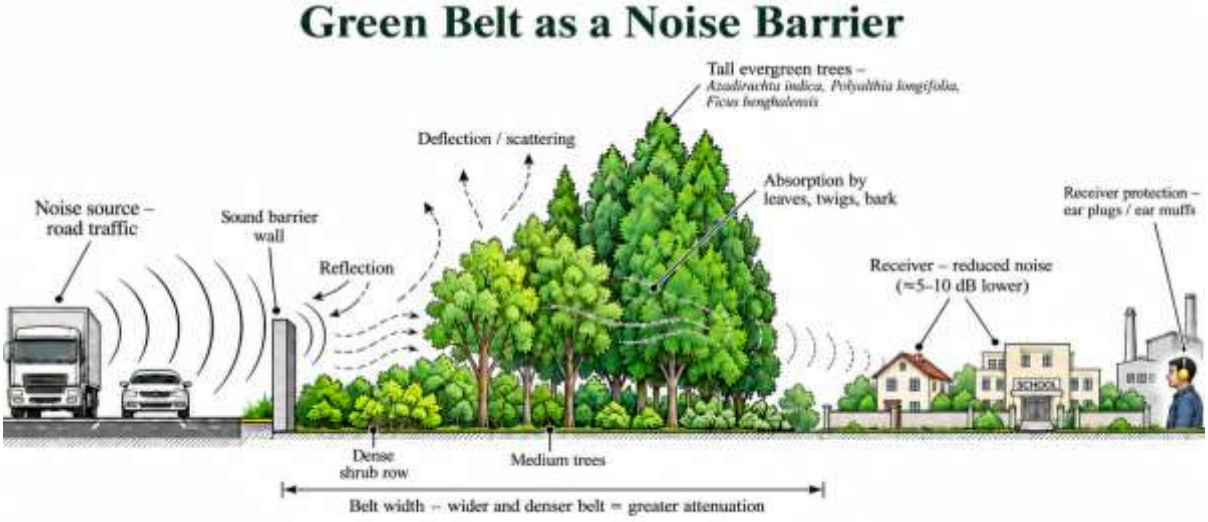


Fig.: Source–path–receiver control of noise using barriers and a green belt

1. ***Control at source***
   - ***Lo****w-noise machinery* with proper *lubrication and maintenance.*
   - *Silencers, mufflers and vibration isolators; acoustic enclosures* around noisy machines.
   - *Electric vehicles, no-honking* zones and *quieter road surfaces.*

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2. ***Control along the path***
   - *Noise barriers and acoustic walls* along highways and flyovers.
   - *Sound insulation* in buildings — double glazing and absorbent materials.
   - ***Distance and zoning*:** keep *industries and airports* away from *residential areas and silence zones*.
3. ***Green belts and urban forestry***
   - *Dense, multi-row belts* of trees and shrubs *absorb, deflect and scatter* sound; wide belts can cut noise by roughly **5–10 dB(A)**.
   - ***Suitable species*:** *evergreen, dense-crowned, broad-leaved* trees such as *Polyalthia longifolia, Azadirachta indica, Ficus* spp., *Alstonia scholaris, Syzygium cumini* and *Mangifera indica*, with ***bamboo or Thuja hedges*** below.
4. ***Receiver protection***
   - *Ear plugs and ear muffs, acoustic cabins, job rotation* and *audiometric check-ups* for workers.
5. ***Legal and planning measures***

   The ***Noise Pollution (Regulation & Control) Rules, 2000***, under the ***Environment (Protection) Act, 1986***, set ambient standards:
   - ***Silence zones*** of ***at least 100 m*** around ***hospitals, schools and courts***.
   - ***No loudspeakers or public address systems between 10 pm and 6 am*** (Supreme Court, 2005).
   - ***Monitoring and awareness*** through ***CPCB's ambient noise monitoring network*** and public campaigns.

Zone	*Day (6 am–10 pm)*	*Night (10 pm–6 am)*
Industrial	75 dB(A)	70 dB(A)
Commercial	65 dB(A)	55 dB(A)
Residential	55 dB(A)	45 dB(A)
Silence zone	50 dB(A)	40 dB(A)

Thus, effective noise control needs an ***integrated source–path–receiver strategy***, combining ***engineering, land-use planning, legal enforcement and green belts***.

5 (e) : Define tree improvement. What are the basic steps involved in the genetic improvement of a given tree species? **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants **(i)** *a* ***precise definition*** *of tree improvement and* **(ii)** *the* ***sequential steps*** *of a genetic improvement programme, from* ***objectives to deployment****. The* ***genetic gain formula*** *and an* ***Indian example*** *are good value addition.*

❶ **Introduction** : *Define tree improvement as genetics combined with silviculture.*

❷ **Main Body** : ❖ *Objectives and variation* ❖ *Selection and testing* ❖ *Seed orchards and deployment* ❖ *Flowchart*

❸ **Conclusion** : *Genetic gain in productivity, with an Indian example.*

Tree improvement is the *application of forest genetics and tree breeding, together with good silviculture*, to produce *genetically superior trees* with *higher yield, better form and wood quality, wider adaptability, and resistance to pests and stress* (Zobel & Talbert). It works on ***heritable variation***; the expected genetic gain is:

$$\Delta G = h^2 \times S \quad (h^2 = \textbf{heritability; S = selection differential})$$

BASIC STEPS

1. ***Fix breeding objectives*:** choose target traits *growth, straight bole, wood density, pulp yield, drought tolerance, disease resistance* and the *target environment*.

2. ***Study variation:*** *species and provenance trials* identify the *best seed sources* for the planting zone.
3. ***Plus-tree selection:*** select *phenotypically superior trees* by *comparison-tree* or *individual-tree grading* methods.
4. ***Genetic testing:*** *progeny tests* (half-sib → **GCA**; full-sib → **SCA**) and *clonal tests* separate *genetic worth* from *environmental effect*.
5. ***Elite trees:*** plus trees *proved superior genetically* become *elite trees*.
6. ***Mass production of improved material:*** *Seed Production Areas* (SPA) as a short-term source; *Clonal or Seedling Seed Orchards* (CSO/SSO) with *rouging* of poor families.
7. ***Deployment and advanced breeding:*** *clonal forestry* (cuttings, tissue culture), *hybridization* (*e.g. Eucalyptus* hybrids) and *recurrent selection* for later generations.

Objectives → Provenance trials → Plus trees → Progeny/clonal tests → Elite trees → Seed orchards / Clones → Plantations → Next-generation breeding
Indian example:* IFGTB (Coimbatore)** and **ITC Bhadrachalam** have produced ***high-yielding Eucalyptus and Casuarina clones, which have ***substantially raised plantation productivity*** for ***pulpwood farmers***.

Thus, tree improvement turns ***natural genetic variation*** into ***lasting gains in productivity, quality and adaptability***.

6 (a) : Describe an agroforestry model suitable for hill farming system. How does it increase the productivity of degraded hills? **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants **(i)** *a* ***specific, named agroforestry model*** *for hill farming — its* ***layout, components and species*** *— and* **(ii)** *an* ***explanation of how it restores the productivity*** *of degraded hills through* ***ecological, soil, water and economic mechanisms***.

❶ **Introduction** : *The constraints of hill farming, and the model chosen.*

❷ **Main Body** : ❖ *Model: slope-zoned layout (ICAR-NEH) with SALT* ❖ *Components and species in each zone* ❖ *How productivity increases*

❸ **Conclusion** : *A stable watershed and diversified farm income.*

Hill farming faces *steep slopes, shallow soils, high runoff, landslides, shifting cultivation (jhum)* and *little cultivable land*. A suitable model is the *slope-zoned land-use model* of the *ICAR Research Complex for NEH Region (Umiam, Meghalaya)*, combined with *SALT (Sloping Agricultural Land Technology)*, developed by the *Mindanao Baptist Rural Life Centre, Philippines*.

1. THE MODEL: SLOPE-ZONED LAND USE

Slope position	Land use	Components / species
Upper slopes (steep, ≈ top third)	***Protective forestry / silvipasture***	*Alnus nepalensis*, *Grewia optiva*, *Celtis*, *Quercus*, bamboo, with fodder grasses (*Setaria*, Napier)
Middle slopes	***SALT / contour hedgerow alley cropping*** and ***agri-horticulture***	***Double hedgerows*** of *Leucaena*, *Flemingia*, *Tephrosia*, *Gliricidia* along ***contours***, with crops in alleys; fruit trees — ***citrus***, ***pear***, ***peach***, ***apple***, ***guava*** — with ginger, turmeric and pulses
Lower slopes / valleys (≈ bottom third)	***Intensive agriculture***, homegardens, ***fishery and livestock***	Paddy, vegetables, ***multi-tier homegarden*** (areca, banana, black pepper, spices), farm ponds

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Key practices*: hedges are *lopped 3–4 times a year and the loppings spread in alleys as ***mulch and green manure***; ***minimum tillage***, ***half-moon terraces*** around fruit trees, and ***contour trenches*** with ***farm ponds***.

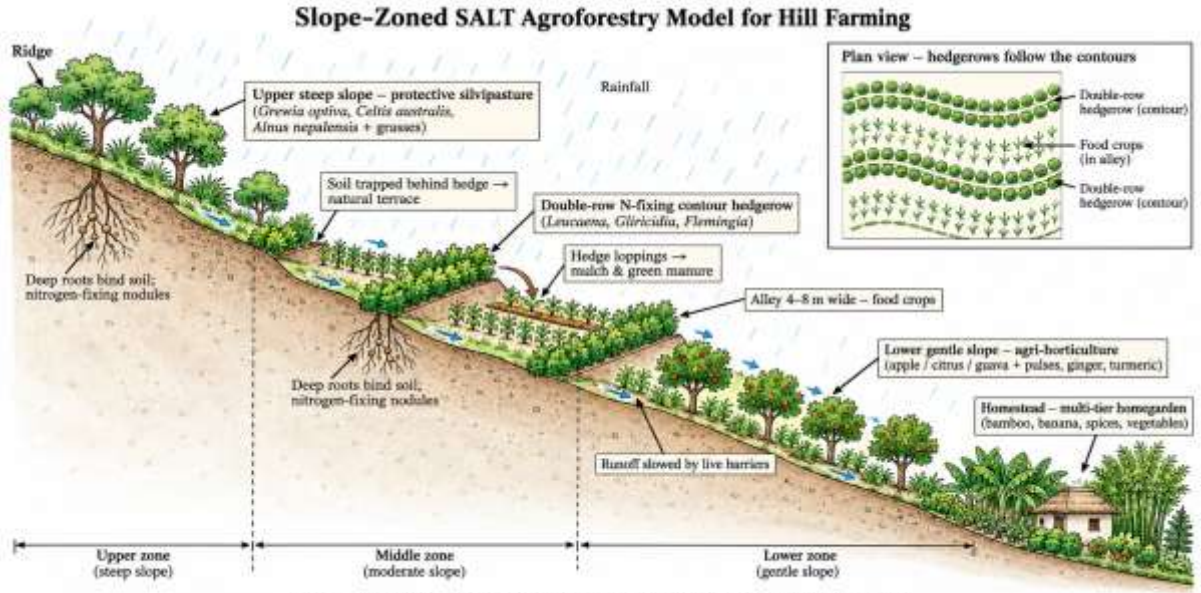


Fig.: Slope-zoned SALT model – land use matched to slope steepness

2. HOW IT INCREASES PRODUCTIVITY OF DEGRADED HILLS

- ***Erosion control***: contour hedges *slow runoff and trap sediment*, forming *natural terraces* at low cost over time.
- ***Slope stability***: *deep tree and shrub roots* bind the soil and *reduce landslides*.
- ***Soil fertility***: *N-fixing hedges* and *leaf litter* recycle nutrients and add *organic matter*, so *less fertiliser* is needed.
- ***Moisture conservation***: *mulch*, *trenches and ponds* increase *infiltration*, give *lifesaving irrigation* and *sustain springs*.
- ***Higher land-use efficiency***: *multi-tier canopies* use *light and soil layers* more fully, raising *total biomass*.
- ***Diversified income***: *fruit*, *spices*, *fodder*, *fuel*, *timber*, *milk and fish* together cut risk and raise *farm income*.
- ***Alternative to jhum***: *permanent, productive cultivation shortens or replaces shifting cultivation* and lets *fallows recover*.
- ***Climate resilience***: carbon sequestration and *buffering against drought and erratic rain*.

Thus, a ***slope-zoned SALT model*** turns ***erosion-prone, low-yield hills*** into a ***stable, fertile and diversified production system***, improving ***watershed health*** and ***livelihoods*** and offering a sustainable ***alternative to jhum***.

6 (b) : Discuss in brief the mechanical composition of soil **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants an account of ***soil texture*** *–* *the* ***soil separates with their size limits***, *the* ***textural classes (USDA triangle)***, *the* ***methods of determination (mechanical analysis, Stokes' law)*** *and the* ***significance of texture for forestry***.

❶ ***Introduction*** **:** *Define mechanical composition as a permanent soil property.*

❷ **Main Body** : ❖ *Soil separates (USDA/ISSS)* ❖ *Textural classes* ❖ *Determination* ❖ *Significance in forestry*
❸ **Conclusion** : *Basis of site–species matching.*

Mechanical composition (soil texture) is the *relative proportion of sand, silt and clay* in the *fine-earth fraction (< 2 mm)* of a soil. Ordinary management *does not change particle size*, so texture is a *permanent, fundamental property* that governs *water, air and nutrient relations* and *root growth*.

1. SOIL SEPARATES

Separate	***USDA (mm)***	***International / ISSS (mm)***	***Key property***
Gravel	> 2.0	> 2.0	Coarse fragment; not part of texture
Sand	2.0 – 0.05	Coarse 2.0–0.2; Fine 0.2–0.02	Gritty; ***large pores, drainage, low water retention***
Silt	0.05 – 0.002	0.02 – 0.002	Smooth, floury; ***moderate retention***; crust-prone
Clay	< 0.002	< 0.002	***Colloidal***, plastic; ***very high surface area and CEC***

2. TEXTURAL CLASSES

The percentages of sand, silt and clay are plotted on the **USDA *textural triangle***, which gives **12 *classes*** — from ***sand, loamy sand and sandy loam***, through ***loam, silt loam and clay loam***, to ***silty clay and clay***. ***Loam*** shows a ***balanced expression*** of the properties of all three fractions; it does ***not*** mean equal percentages.

3. DETERMINATION

(a) Feel method (field): grittiness, smoothness and stickiness, plus ***ball and ribbon*** formation between the fingers.

(b) Mechanical analysis (laboratory):

- ✓ ***Organic matter*** is removed with H_2O_2.
- ✓ The soil is ***dispersed*** with ***sodium hexametaphosphate (Calgon)***.
- ✓ ***Sand*** is separated by ***sieving***.
- ✓ ***Silt and clay*** are determined by the ***pipette (International) or hydrometer (Bouyoucos) method***.

4. SIGNIFICANCE IN FORESTRY

Texture	***Properties***	***Forestry implications***
Sandy (light)	Good aeration and drainage; ***low water and nutrient retention***	*Casuarina, Acacia, Prosopis*; needs ***mulch*** and ***moisture conservation***
Loamy	***Best balance*** of aeration, moisture and nutrients	***Nurseries***; ***Teak*** (deep, well-drained loam), ***Shisham***, most species
Clayey (heavy)	***High retention*** but poor aeration; ***waterlogging***, cracking (vertisols)	***Sal avoids stiff clays***; ***Babul, Arjun*** tolerate heavy black soils

Texture also controls ***porosity, bulk density, infiltration, erodibility, workability*** and ***fertiliser response***. Thus, ***mechanical composition*** is a ***stable physical attribute*** governing ***soil–water–air relations***, and a ***key basis*** for ***site–species matching, nursery siting and forest soil management***.

6 (c) : Define the following: (i) Seed orchard (ii) Exotics (iii) Plus tree (iv) Progeny test (v) Elite tree. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants ***precise definitions*** *of five tree-improvement terms, each with* ***one key feature or type and an example****. Each term carries* ***≈ 2 marks****, so all five need* ***equal, crisp treatment****.*

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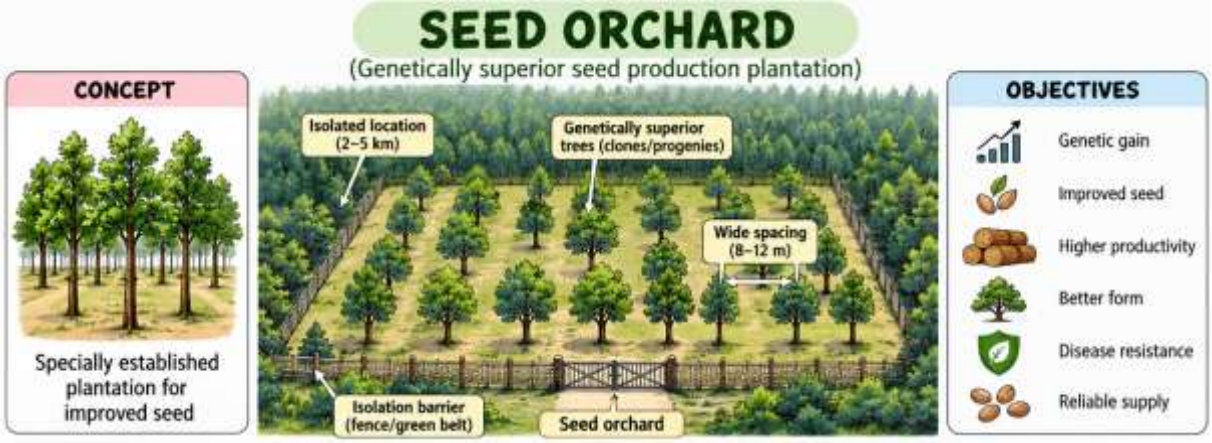
❶ **Introduction** : *Place the terms in the tree-improvement sequence.*
❷ **Main Body** : ❖ *Seed orchard* ❖ *Exotics* ❖ *Plus tree* ❖ *Progeny test* ❖ *Elite tree*
❸ **Conclusion** : *Flow from candidate tree to improved planting stock.*

These terms describe the ***materials and stages of tree improvement — selecting superior genotypes, testing them and multiplying them***.

(i) SEED ORCHARD

A ***plantation of selected superior clones or families***, ***isolated from outside pollen*** by a ***pollen-dilution zone*** (≈ 100–300 m, depending on species) and ***managed intensively*** for ***frequent, abundant, easily harvested, genetically improved seed***.

- ***Clonal Seed Orchard (CSO):*** raised from ***grafts or cuttings*** of plus trees.
- ***Seedling Seed Orchard (SSO):*** raised from ***seedlings of selected parents*** and later ***rogued***.

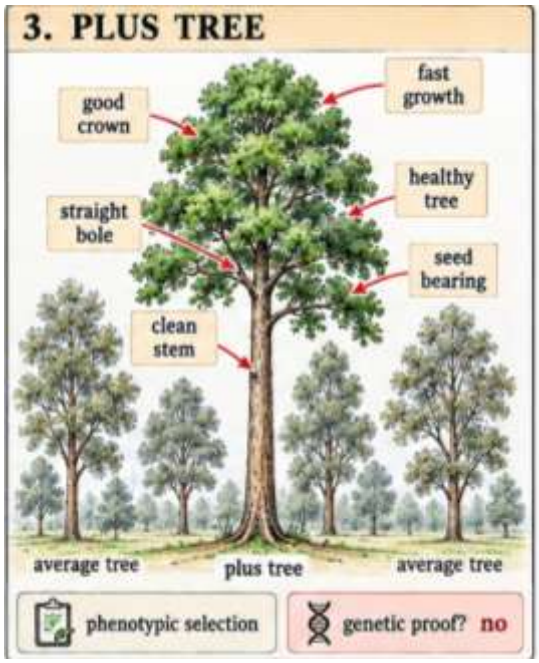


(ii) EXOTICS

Species grown outside their natural range of distribution, introduced after *quarantine and species trials*. Examples: *Eucalyptus* and *Casuarina equisetifolia* (Australia), *Populus deltoides* (North America). ***Caution:*** some become ***invasive***, *e.g. Prosopis juliflora.*

(iii) PLUS, TREE

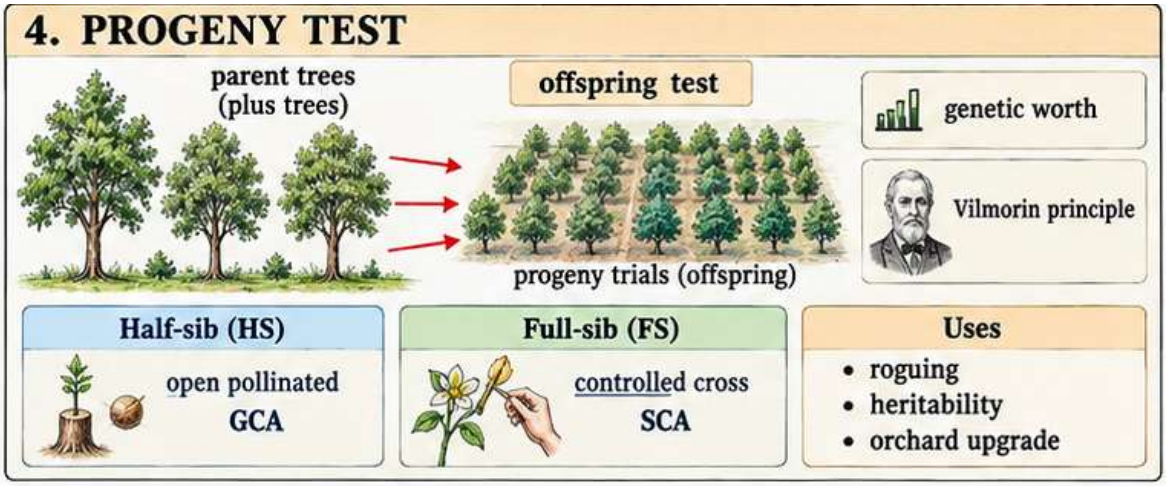
A *phenotypically outstanding tree* selected for *growth, a straight clean bole, a good crown, health and seed production*. It is chosen from *candidate trees* by *comparison with neighbouring check trees*; its *genetic superiority is not yet proved*.



(iv) PROGENY TEST

A test that *evaluates a parent's genetic worth* from the *performance of its offspring* (the *Vilmorin principle*).

- ***Half-sib (open-pollinated)*** progeny → ***General Combining Ability (GCA)***.
- ***Full-sib (controlled cross)*** progeny → ***Specific Combining Ability (SCA)***.
- ***Use: roguing*** inferior parents from seed orchards and estimating ***heritability***.



(v) ELITE TREE

A *plus tree whose genetic superiority has been confirmed* through *progeny or clonal tests*. It is the *foundation material* for *second-generation seed orchards, clonal forestry and advanced breeding*.

7 (a) : What do you mean by Forest Genetic Resources (FGR)? How do you conserve them? **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants **(i)** *the* ***meaning of FGR****, with its levels and importance, and* **(ii)** *the* ***methods of conservation – in-situ and ex-situ*** *– with* ***examples, institutions and the policy framework****.*

❶ ***Introduction*** **:** *Define FGR and its levels.*

❷ ***Main Body*** **:** ❖ *Importance and threats* ❖ *In-situ conservation* ❖ *Ex-situ conservation (seed biology)* ❖ *Institutions and policy*

❸ ***Conclusion*** **:** *Complementary conservation.*

Forest Genetic Resources (FGR) are the *heritable variation* in *forest trees and woody plants* — at the level of *genes, individuals, provenances, populations and species* — with *actual or potential economic, ecological or scientific value*. They are the *raw material for tree improvement and adaptation to climate change*.

1. IMPORTANCE AND THREATS

- *Importance*: breeding for *growth, quality and resistance; adaptation to changing climates; food, medicine and NTFP security*.
- *Threats: deforestation, fragmentation, fire, overgrazing, over-harvesting, invasive species, climate change* and *genetic pollution* from planting non-local seed.

2. IN-SITU CONSERVATION

Genetic resources are protected *within natural habitats*, so that *evolution and natural selection continue*.

- *Protected areas: National Parks, Wildlife Sanctuaries, Biosphere Reserves, Conservation and Community Reserves*.
- *Gene Conservation Units / Preservation Plots, seed stands, sacred groves* and *wildlife corridors*.

3. EX-SITU CONSERVATION

Genetic material is maintained ***outside its natural habitat***.

Material	***Method***	***Example***

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Orthodox seed (tolerates drying)	*Seed banks* at low moisture and low temperature	*Teak*, *Acacia*, *Pinus*
Recalcitrant seed (dies on drying)	*Clone banks*, *field gene banks*, *cryopreservation* of embryos	*Sal*, *Neem*, *Hopea*
Living collections	*Arboreta*, *botanical gardens*, *provenance trials*, *seed orchards*	FRI Dehradun arboretum
Tissues	*In-vitro culture*, *cryopreservation* (–196 °C) of pollen and embryos	Elite clones

4. INSTITUTIONS AND POLICY

- *Institutions*: NBPGR *National Gene Bank* (New Delhi); ICFRE *institutes* (*e.g.* IFGTB *Coimbatore*, *TFRI*, *IWST*).
- *Global*: *Svalbard Global Seed Vault*; *FAO Global Plan of Action for FGR* (2013).
- *Law*: *Biological Diversity Act*, 2002, providing for *Access and Benefit Sharing* (ABS).

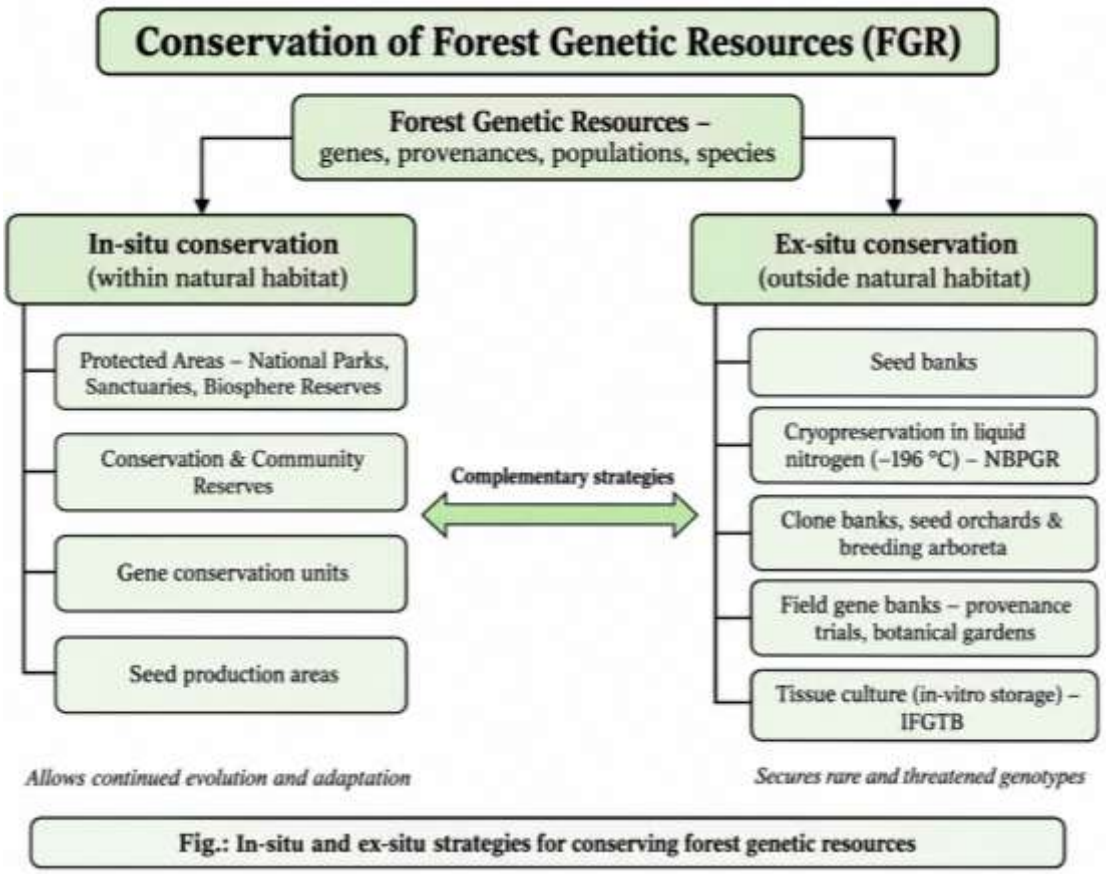


Fig.: In-situ and ex-situ strategies for conserving forest genetic resources

Thus, FGR conservation needs a ***complementary in-situ + ex-situ strategy***, safeguarding both ***natural evolutionary diversity*** and ***selected elite genotypes*** for ***future forestry and climate resilience***.

7 (b) : Enumerate the guiding principles to finalize the choice of tree species for afforestation of denuded areas where soil conservation measures are implemented. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants an ***enumerated set of guiding principles*** *for* ***choosing species*** *for* ***denuded lands*** *treated with* ***soil-conservation works***, ***grouped*** *and backed by* ***Indian site examples*** *(ravines, choes, dunes, mine spoils).*

❶ **Introduction** : *The condition of denuded lands and the role of engineering measures.*
❷ **Main Body** : ❖ *Ecological principles* ❖ *Protective (soil–water) principles* ❖ *Silvicultural principles* ❖ *Socio-economic and risk principles* ❖ *Indian examples table*
❸ **Conclusion** : *A self-sustaining protective cover.*

Denuded lands — ravines, eroded hill slopes (choes), shifting sand dunes and mine spoils — have lost their *vegetation and topsoil* and suffer from *low fertility, low moisture, heavy runoff and erosion, and heavy biotic pressure. Engineering measures* (contour trenches, bunds, check dams, gully plugs) give *initial stability*, but *lasting protection* comes only from the *right vegetation.*

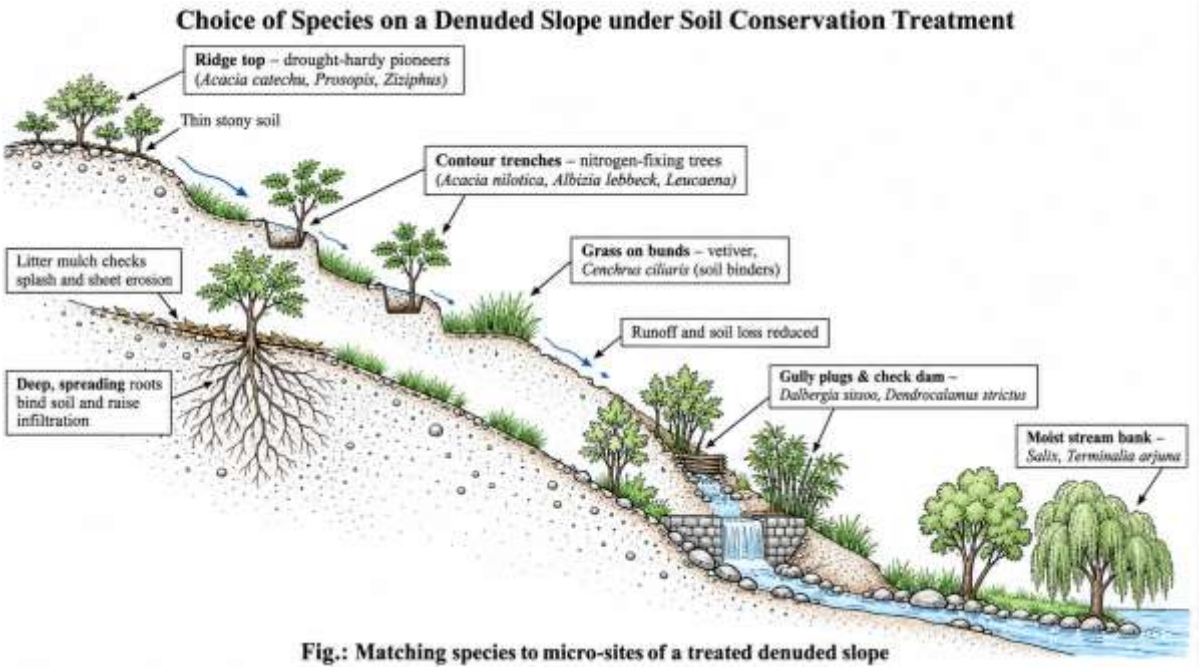


Fig.: Matching species to micro-sites of a treated denuded slope

1. ECOLOGICAL PRINCIPLES

- ***Site–species matching*:** species should suit the local *rainfall, temperature, soil depth, pH, salinity, drainage and altitude.*
- ***Pioneer, light-demanding, hardy species*** able to establish on ***exposed, poor soils***.
- ***Succession-based sequence*:** *grasses → shrubs → trees*; grasses and shrubs *stabilise the surface first.*
- ***Prefer native species***; use ***exotics*** only where natives fail.

2. PROTECTIVE (SOIL–WATER) PRINCIPLES

- *Deep and spreading root systems* that *bind soil, stabilize gully sides* and *increase infiltration.*
- *Good crown cover and abundant litter* to cut *raindrop impact* and build *humus.*
- ***Compatibility with structures*:** roots should *strengthen, not damage, bunds and check dams*; grasses such as *Cenchrus* and *Eulaliopsis* on *bund faces.*

3. SILVICULTURAL PRINCIPLES

- ***Site-improving ability*: *N-fixing*** species, *e.g. Acacia, Albizia, Leucaena, Alnus, Casuarina.*
- *Rapid establishment and early canopy closure*, with *strong coppicing or root-suckering* for recovery.
- *Tolerance to the dominant stress: drought, frost, salinity–alkalinity, calcareous or toxic spoils.*
- *Resistance to grazing, fire and pests.*
- *Mixed planting rather than monoculture* for *resilience.*

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4. SOCIO-ECONOMIC AND RISK PRINCIPLES

- *Multipurpose value* (fodder, fuel, fruit) to win *community protection*.
- *Avoid invasive or heavy water-using species* near *recharge zones*.

INDIAN EXAMPLES

Denuded site	Suitable species
Chambal ravines	*Acacia nilotica*, *Prosopis juliflora*, *Dendrocalamus strictus*, *Azadirachta indica*
Shivalik choes	*Acacia catechu*, *Dalbergia sissoo*, Bhabar grass (*Eulaliopsis binata*), *Vitex negundo*
Thar dunes	*Acacia tortilis*, *Prosopis cineraria*, *Calligonum polygonoides*, *Ziziphus nummularia*, *Lasiurus sindicus*
Mine spoils	*Acacia auriculiformis*, *Cassia siamea*, *Leucaena*, *Dendrocalamus*
Cold desert	*Salix*, *Populus*, *Hippophae*

Thus, the ideal species for denuded lands are *site-matched*, *pioneer*, *deep-rooted*, *soil-binding*, *site-improving*, *hardy and useful to local people*. *Biological and engineering measures together* build a *stable*, *self-sustaining protective forest*.

7 (c) : Describe the serious effects of global warming. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***serious, multi-sectoral effects*** *of global warming —* ***physical, ecological and socio-economic*** *— backed by* ***data (IPCC/WMO)***, ***Indian examples*** *and a* ***clear forestry angle***.

❶ **Introduction** : *Define global warming and give the key warming data.*

❷ **Main Body** : ❖ *Physical effects* ❖ *Effects on forests and biodiversity* ❖ *Socio-economic effects*

❸ **Conclusion** : A *"threat multiplier", and India's response.*

Global warming refers to the *long-term rise in Earth's average surface temperature*, primarily due to the enhanced *greenhouse effect caused by anthropogenic emissions* of CO_2, CH_4 and other greenhouse gases. Its impacts are no longer confined to temperature rise alone; they are increasingly visible through *climate extremes*, *ecosystem disruption*, *sea-level rise*, *water stress and socio-economic losses.*



A. PHYSICAL EFFECTS

1. ***Cryosphere and water*:** *Himalayan glaciers are retreating*, altering flows of *perennial rivers* (Ganga, Indus, Brahmaputra) and raising the risk of *glacial lake outburst floods* (*GLOFs*), *e.g. South Lhonak, Sikkim* (2023).
2. ***Sea-level rise*:** *thermal expansion and melting land ice* raised sea level about 20 *cm* (1901–2018), driving *coastal erosion, salinity intrusion and loss of islands, e.g.* the *Sundarbans*.
3. ***Extreme events*:** more *heatwaves, droughts, cloudbursts, flash floods and intense cyclones*, and an *erratic monsoon*.
4. ***Oceans*:** *marine heatwaves, acidification, coral bleaching* (Lakshadweep, Gulf of Mannar) and *falling dissolved oxygen*.

B. EFFECTS ON FORESTS AND BIODIVERSITY

1. ***Range shifts*:** species and *tree lines move upslope and poleward, e.g. Chir pine moving into Banj oak zones* in Uttarakhand.
2. ***Phenological change*:** *earlier bud-burst and flowering* cause *mismatches with pollinators*.
3. ***Forest fires*:** *hotter, drier seasons* increase fires, as in *Uttarakhand and Odisha*.
4. ***Pests and diseases*:** more frequent *bark-beetle and defoliator outbreaks*.
5. ***Mortality and biodiversity loss*:** *drought stress, dieback* and *extinction risk for endemic and alpine species*.
6. ***Weaker carbon sink*:** stressed forests may switch from *carbon sinks to sources*.

C. SOCIO-ECONOMIC EFFECTS

1. ***Agriculture*:** *lower yields* (especially *wheat* under terminal heat), *pest outbreaks* and *livestock heat stress*.
2. ***Health*:** *heat stroke* and the spread of *vector-borne diseases* (malaria, dengue) to new areas.
3. ***Economy and society*:** *damage to infrastructure, lost labour productivity, climate migration* and *greater vulnerability of the poor*.

Thus, global warming is a *"threat multiplier"* affecting *water, forests, biodiversity, food, health and livelihoods* at the same time. India responds through its **NDC** — including an *additional carbon sink of 2.5–3 billion t CO_2e through forest and tree cover* — along with the *Green India Mission, Mission LiFE* and *climate-resilient adaptation*.

8 (a) : Explain the various classes of threat to biodiversity. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***classes (categories) of threat*** *to biodiversity, organised under a* ***recognised framework*** *(direct vs indirect drivers;* ***HIPPO / IPBES****), each with an* ***explanation and Indian examples****.*

❶ **Introduction** : *Define biodiversity and give the IPBES (2019) data.*

❷ **Main Body** : ❖ *Direct threats (HIPPO + climate change)* ❖ *Indirect (underlying) drivers* ❖ *Natural threats and intrinsic vulnerability*

❸ **Conclusion** : *Cumulative and synergistic effects; the extinction vortex.*

Biodiversity is **the *variety of life at the genetic, species and ecosystem levels*. The *IPBES Global Assessment* (2019) warns that *about 1 million species face extinction*, driven mainly by *human activity*. Threats can be grouped into *direct, indirect and natural/intrinsic*** classes.

A. DIRECT THREATS (HIPPO + CLIMATE CHANGE)

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- *Habitat loss, degradation and fragmentation* (the *leading driver*): conversion for *agriculture, mining, dams, roads and urbanisation*; *fragmentation* causes *edge effects, isolation, inbreeding and loss of gene flow, e.g.* grassland loss for the *Great Indian Bustard*, fragmented *elephant corridors*.
- ***Invasive alien species***: *outcompete natives, change fire regimes* and *block regeneration, e.g. Lantana camara, Prosopis juliflora, Parthenium, Chromolaena odorata.*
- ***Pollution:*** *pesticides, heavy metals, plastics, acid rain and eutrophication; e.g. diclofenac* caused a >95% *crash in Gyps vulture* populations.
- *Population pressure and over-consumption*, which intensify every other threat.
- ***Over-exploitation:*** *over-harvesting, poaching and illegal wildlife trade*, and *unsustainable NTFP collection, e.g. pangolin, tiger, Red Sanders*, medicinal plants such as *Nardostachys*.
- ***Climate change:*** *range shifts, phenological mismatch, coral bleaching, more fires and droughts; alpine and endemic species* are most at risk.

B. INDIRECT (UNDERLYING) DRIVERS

- *Demographic and economic growth, consumption patterns* and *poverty*.
- *Policy and market failures* (perverse subsidies, undervalued ecosystem services) and *weak governance and enforcement*.

C. NATURAL THREATS AND INTRINSIC VULNERABILITY

- ***Natural disturbances***: *cyclones, floods, landslides, droughts, wildfires, disease and pest outbreaks*.
- ***Intrinsically vulnerable species*** — *narrow range, small populations, low reproductive rates, specialised habitats, poor dispersal — e.g. island endemics, Pygmy hog, Lion-tailed macaque*.
- ***Extinction vortex***: in small populations, *genetic, demographic and environmental stochasticity reinforce each other*, pushing the population towards extinction.

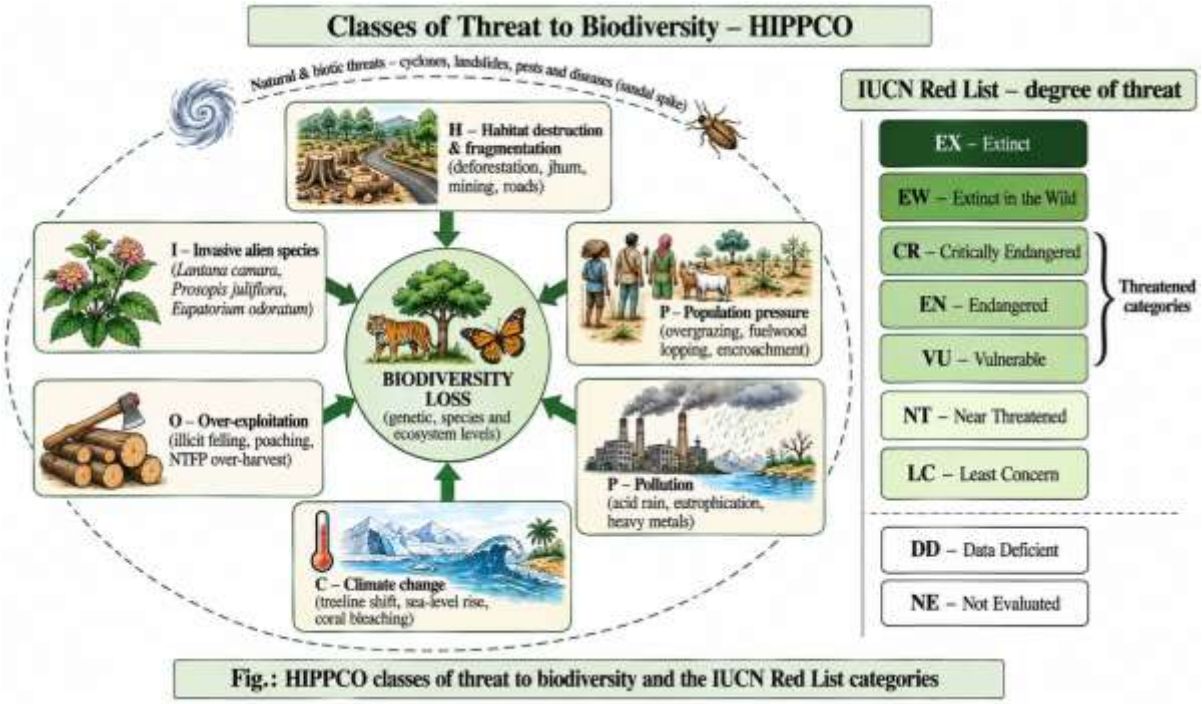


Fig.: HIPPCO classes of threat to biodiversity and the IUCN Red List categories

Thus, threats to biodiversity act *cumulatively and synergistically*: *habitat loss and invasives* combine with *climate change* to push *small, isolated populations* into an *extinction vortex*. This calls for *landscape-level conservation*, in line with the *Kunming–Montreal GBF* "30×30" *target* and India's *NBSAP*.

8 (b) : Describe the significance of plant introduction as one of the major methods of tree improvement. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***significance of plant introduction*** *in tree improvement, shown through* ***Indian examples****, completed by a* ***systematic introduction procedure*** *and its* ***limitations****.*

❶ ***Introduction*** **:** *Define plant introduction (species, provenance, genotype).*

❷ ***Main Body*** **:** ❖ *Significance with examples* ❖ *Procedure for safe introduction* ❖ *Limitations and risks*

❸ ***Conclusion*** **:** *Value of introduction, subject to careful screening.*

Plant introduction is the *transfer of a species, provenance or genotype from its native range to a new area* for *direct use, testing or breeding*. It is the *quickest method of tree improvement*, because it uses *variation already evolved elsewhere*. *Acclimatization* is the plant's *adjustment to the new environment*; *naturalization* is when it *reproduces and spreads on its own*.

1. SIGNIFICANCE

- ***Wider species choice*****:** fills gaps where *native species cannot meet the objective Casuarina equisetifolia* for coastal sands, *Acacia tortilis* for the Thar dunes (from Israel, 1958), *Eucalyptus* for pulpwood (first planted at *Nandi Hills, c. 1790*).
- ***Rapid gain in productivity*****:** *fast-growing exotics* give *high MAI on short rotations, e.g. Populus deltoides* (North America) in Tarai farm forestry.
- ***Specific industrial needs*****:** *rubber* (*Hevea brasiliensis*), *pulp and resin* (tropical pines — *P. caribaea, P. patula*), *matchwood and plywood* (poplar), *fodder* (*Leucaena*).
- ***Germplasm for breeding*****:** a *wider genetic base* for *provenance testing, hybridisation* (*e.g. Eucalyptus* hybrids such as *E. tereticornis* × *E. camaldulensis*) and *seed orchards*.
- ***Escape from native pests*****:** introduced species may grow better *without their natural enemies*, at least for a time.
- ***Restoration of degraded sites*****:** hardy exotics such as *Acacia auriculiformis* and *Prosopis juliflora* on *mine spoils, saline and dune lands*.
- ***Saves time and cost*****:** *proven international material and research gains* are adopted instead of starting from scratch.

2. PROCEDURE FOR SAFE INTRODUCTION

- *Climatic and site matching* using *homoclimes*.
- *Procurement of seed or clones* through NBPGR, under the *Plant Quarantine (Regulation of Import into India) Order, 2003*.
- *Quarantine and pest screening.*
- *Species elimination trials* in small plots to screen out unsuitable species.
- *Species and provenance testing trials* to measure *growth and adaptability*.
- *Species proving / pilot plantations* at plantation scale.
- *Large-scale release*, with *monitoring for invasiveness*.

3. LIMITATIONS AND RISKS

- ***Invasiveness*****:** *Prosopis juliflora, Lantana camara*.
- ***Ecological concerns*****:** *high water use, allelopathy* and *loss of biodiversity* (*e.g.* the *Eucalyptus* debates).

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- ***New pests*:** imported *pests and diseases*, *e.g.* the *Leucaena psyllid.*
- ***Biological failure*:** *failure to flower or set seed*, and *narrow genetic bases.*

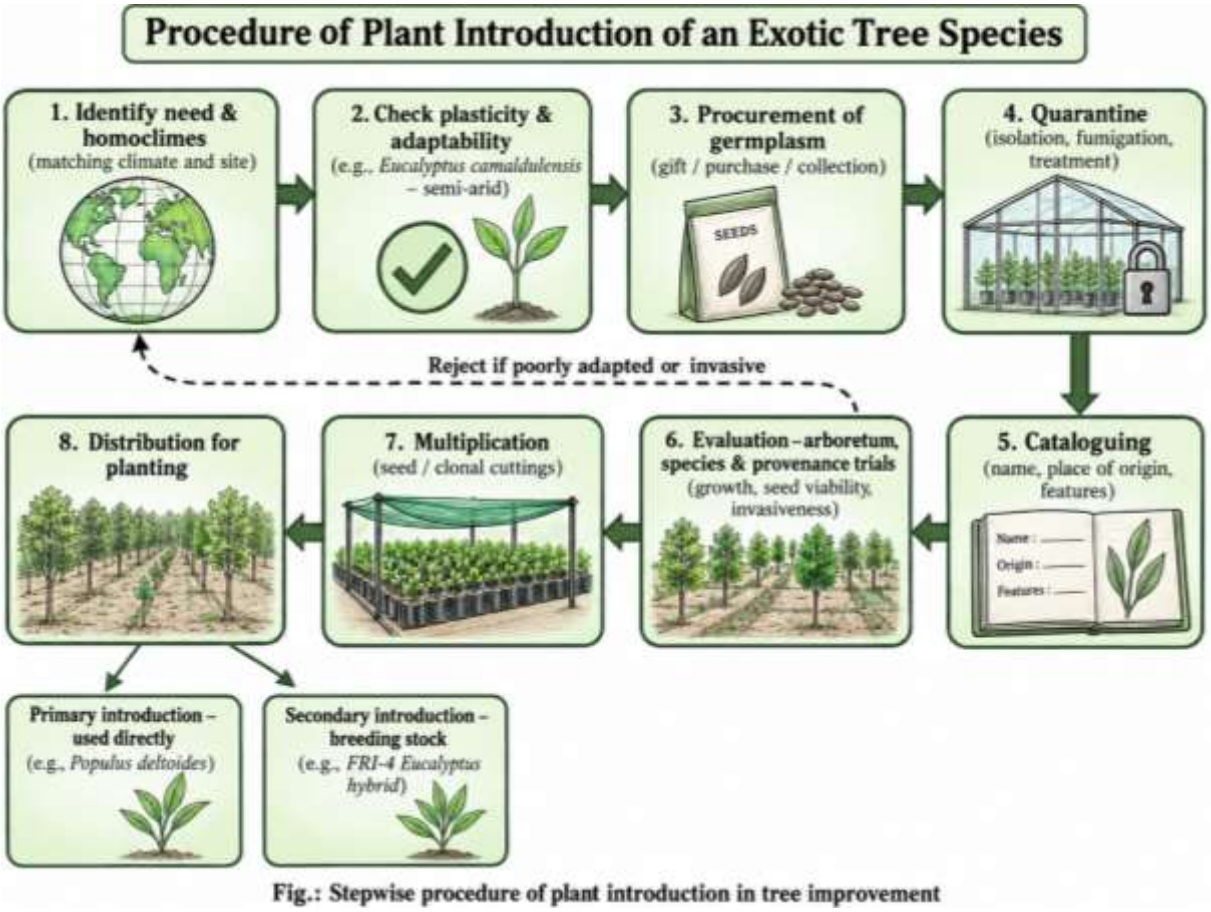


Fig.: Stepwise procedure of plant introduction in tree improvement

Thus, plant introduction is a ***powerful, quick method*** of tree improvement for obtaining *productive, specialised planting material*; its success depends on *site matching, quarantine, staged trials and screening for ecological risk.*

8 (c) : Describe the significance of plant introduction as one of the major methods of tree improvement. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants **(i)** *the* ***benefits of JFM****, grouped as* ***ecological, economic and institutional****, and* **(ii)** *the* ***specific guidelines*** *for women's participation (mainly the* ***2000 guidelines****). The word "****meaningful****" means* ***real decision-making****, not just numbers.*

❶ ***Introduction*** **:** *Define JFM and give its policy base (NFP 1988, 1990 circular).*

❷ ***Main Body*** **:** ❖ *Benefits of JFM* ❖ *Guidelines for women: representation, office-bearers, practical measures*

❸ ***Conclusion*** **:** *Substantive participation, and the link with FRA.*

Joint Forest Management (JFM) is a *partnership between the Forest Department and local communities* to *protect and regenerate forests* and *share their benefits*. Rooted in the *National Forest Policy, 1988*, it was launched by the *MoEF circular of 1 June 1990, strengthened by the 2000 and 2002 guidelines*, and now works through *over 1 lakh JFM Committees (JFMCs).*

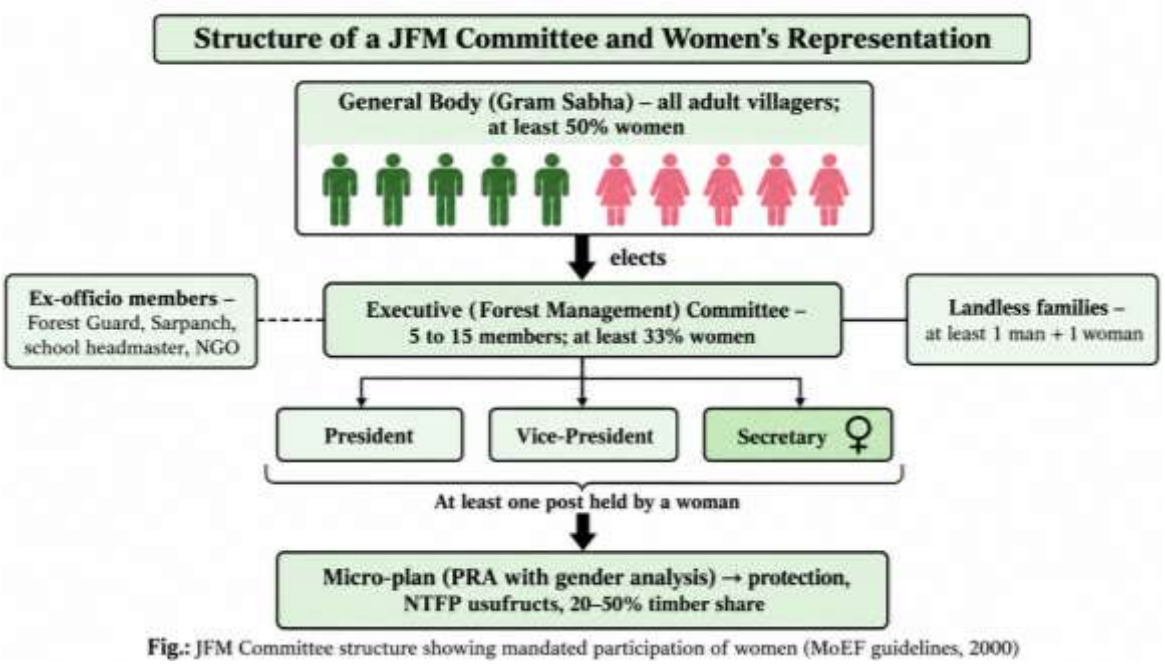


Fig.: JFM Committee structure showing mandated participation of women (MoEF guidelines, 2000)

5. BENEFITS OF JFM

***Ecological*:**

- *Better protection* against *fire, grazing and illicit felling*.
- *Regeneration of degraded forests*, with gains in *soil and water conservation and biodiversity*.

***Economic*:**

- *Usufruct rights to NTFPs*, fodder and fuelwood, and a *share of timber revenue* (often 25–50%, depending on the state).
- *Local employment* and *micro-plans* for village development.

***Institutional and Social*:**

- *Less conflict* between the Forest Department and people, and *mutual trust*.
- *Decentralised, participatory planning* through *JFMCs and micro-plans*.
- *Transparency, accountability* and *social capital*, including *women's SHGs*.

6. GUIDELINES FOR MEANINGFUL PARTICIPATION OF WOMEN (2000)

***Representation*:**

- ***General Body*:** *at least 50% women; one man and one woman from every household* should be members.
- ***Executive / Managing Committee*:** *at least 33% women*.
- ***Office-bearers*:** *at least one of the President, Vice-President or Secretary* must be a woman.

***Practical measures for meaningful participation*:**

- **Quorum** for meetings should require *women's presence*.
- *Meetings* at *times and places convenient for women*.
- *Separate women's sub-groups or SHGs*, and *PRA with gender analysis* of who *uses, works on and benefits from* forests.
- *Entry-point activities* that reduce women's drudgery — *fuel-efficient chulhas, LPG, fodder banks*.
- *Capacity building* and *NTFP-based enterprises* run by women.

Thus, JFM links *forest conservation with livelihoods and participatory governance*; it is effective only when *women have real voice in planning, decisions and benefit sharing*, and when it is *aligned with community forest rights under FRA 2006*.

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