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Forestry Optional

IFoS | 2025 | Paper - 2	
Date	
Syllabus	

SECTION – A

1 (a) : What are the challenges in implementing traditional forest working plans in tribal and forest-dependent communities? Enlist the steps to overcome these challenges. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***key challenges*** *that traditional, timber-centric* ***working plans*** *face in* ***tribal and forest-dependent areas****, followed by a list of* ***practical remedial steps****.*

❶ ***Introduction*** **:** *Define a working plan and its traditional timber-oriented focus.*

❷ ***Main Body*** **:** ❖ *Challenges (legal, socio-economic, technical, institutional)* ❖ *Steps to overcome them*

❸ ***Conclusion*** **:** *People-centric, FRA-compliant working plans ensure both conservation and livelihoods.*

A *working plan* is the *principal instrument of scientific forest management* of a division, prescribed under the ***National Working Plan Code (2014, revised 2023).*** Traditional plans were *timber- and revenue-centric*, designed with little input from the *tribal communities* who depend on the forest.

A. Challenges

1. ***Top-down approach:*** Prescriptions drafted by the *Working Plan Officer* with negligible *community consultation*, creating alienation and non-cooperation.
2. ***Overlap with rights regimes:*** **FRA 2006** grants ***Community Forest Resource (CFR) rights*** and ***Gram Sabha*** management powers; **PESA 1996** gives ownership of **MFP**, often conflicting with working-plan prescriptions.
3. ***Livelihood mismatch:*** Plans ignore *NTFP, grazing, shifting cultivation* (e.g., *jhum* in North-East) and fuelwood needs, leading to *illicit felling* and *encroachment.*
4. ***Neglect of traditional knowledge:*** Sacred groves and customary practices are rarely recognized.
5. ***Institutional and technical gaps:*** Shortage of staff, weak data, *delayed revision*, and difficult terrain or *LWE-affected areas.*

B. Steps to Overcome

1. ***Participatory planning:*** Mandatory *Gram Sabha consultation*, integrating *JFMC micro-plans* and *CFR management plans* into the working plan.
2. ***Overlapping working circles:*** *JFM, NTFP, bamboo* and *eco-development* overlapping working circles with *sustainable harvest protocols*; use the plan for preparing *JFM micro-plans* and *community development plans.*

3. *Recognize customary practices* and *traditional ecological knowledge*, e.g., protecting *sacred groves*.
4. *Capacity building* of communities and frontline staff; *benefit-sharing* mechanisms.
5. ***Technology:*** *GIS, remote sensing* and *community-based monitoring* for transparent, timely planning.

Thus, shifting from ***timber-centric*** to ***people-centric, rights-compliant*** working plans is the key to sustainable management in tribal landscapes.

1 (b) : What do you mean by tree height? Explain diagrammatically the method of height estimation on level as well as on sloping grounds using tangent method. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants a precise ***definition of tree height*** *and a* ***diagram-supported derivation*** *of the* ***tangent (trigonometric) method*** *for* ***level ground*** *and the* ***three cases of sloping ground****.*

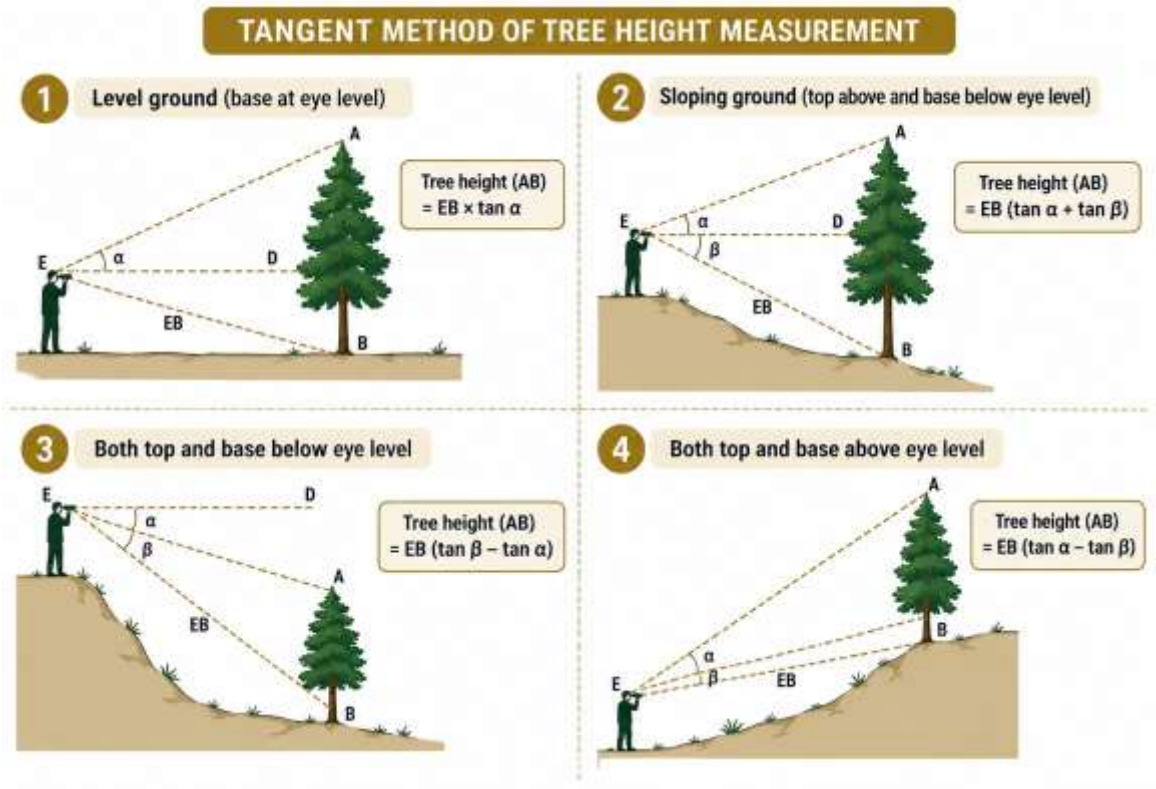
❶ ***Introduction*** **:** *Define tree height and the principle of the tangent method.*

❷ ***Main Body*** **:** ❖ *Definition* ❖ *Level ground case* ❖ *Sloping ground cases (top above/base below eye, both below eye, both above eye)*

❸ ***Conclusion*** **:** *The tangent method gives accurate height when horizontal distance and angles are measured correctly.*

Tree height is the *straight-line vertical distance* from *ground level* to the *tip of the leading shoot*. The *tangent method* is a *trigonometric principle* in which the observer measures the *horizontal distance* to the tree and the *angles of elevation/depression* to its top and base using an *Abney's level* or *clinometer*.

Notation: **AB** = tree height (A = top, B = base), **E** = observer's eye, **ED** = horizontal distance to the tree, **EB** = slope distance to the base, α = angle to top, β = angle to base.



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A. On Level Ground

The observer stands at C at horizontal distance BC; eye height EC is measured with a staff.

$$AB = AD + DB = ED \tan \alpha + EC = BC \tan \alpha + EC$$

B. On Sloping Ground

Situation	Angles	Formula
Top above eye, base below eye	α elevation, β depression	AB = ED (tan α + tan β) = EB cos β (tan α + tan β)
Top and base both below eye (observer upslope)	α, β both depression (β > α)	AB = ED (tan β − tan α) = EB cos β (tan β − tan α)
Top and base both above eye (observer downslope)	α, β both elevation (α > β)	AB = ED (tan α − tan β) = EB cos β (tan α − tan β)

Since the horizontal distance **ED** is difficult to measure on slopes, it is replaced by **EB cos *β***, where EB is the ***slope distance*** to the base.

Common *errors* are *instrumental* (defective instruments), *personal* (wrong distance in undergrowth), *observational* (base not visible) and due to *lean of trees*; measuring with the lean to the side, or from *two opposite sides* and averaging, minimises them.

Thus, the *tangent method* is the most widely used and accurate field method of *tree height estimation* on all terrains.

1 (c) : Discuss the concept of sustained yield. How is it different from progressive yield on the basis of arguments given against sustained yield? **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***concept of sustained yield****, the* ***criticisms*** *levelled against it, and how* ***progressive yield*** *answers those criticisms in a* ***comparative*** *manner.*

❶ **Introduction** : *Define sustained yield as the backbone of forest management.*

❷ **Main Body** : ❖ *Concept of sustained yield* ❖ *Arguments against it* ❖ *Sustained vs progressive yield table*

❸ **Conclusion** : *For India, a blend with progressive yield orientation is needed.*

Sustained yield (first documented by *Hans Carl von Carlowitz, Sylvicultura oeconomica, 1713*) is the *continuous, regular and approximately equal annual (or periodic) yield* of forest produce *in perpetuity*, achieved by harvesting no more than the *increment* of the forest. It requires a *normal forest* with *normal age-class distribution, normal increment* and *normal growing stock,* and is a core principle of the *National Forest Policy 1988.*

A. Arguments Against Sustained Yield

1. ***Static concept*:** Can be practiced in a *stagnant economy* but has no justification in a *growing or developing economy*; no nation accepts a static economy.
2. ***Ignores rising demand*:** India's *timber demand–supply gap* keeps widening.
3. ***Rigid supply hinders economic growth***; no incentive to invest in *forest technology* and does not attract the *private sector.*
4. ***Inelastic felling*:** A fixed annual yield cannot respond to high demand and rising prices, so it *fails to work as a price moderator;* changing demand and new competing products make 80-year predictions (e.g., teak) unreliable.

5. ***Practically difficult in natural forests*** owing to *insect-pest attacks, drought, frost, forest fire, El Niño*, etc.

B. Progressive Yield as the Answer

Progressive (increasing) yield, propounded by ***Hartig***, aims at an *ever-increasing yield* by replacing ***inferior species*** with *superior ones, enrichment planting, tending, protection against increment loss* and *quick regeneration.*

Basis	Sustained Yield	Progressive Yield
Nature	Regular but fixed (static)	Regular and increasing (dynamic)
Economy suited	Stagnant/developed	Developing, e.g., India
Investment and R&D	Discouraged	Encouraged (clonal forestry, remote sensing)
Suitable for	Protection forests (Himalaya), public multiple-use forests	Production and private forestry; faster planting for carbon targets
Limitation	Hinders growth and investment	Needs technology and skilled workforce; market volatility

Thus, with India's widening *timber demand–supply gap*, the aim should be ***progressive yield***, while combining it with ***sustained yield*** for renewable resources so they are not depleted.

1 (d) : Describe Von Mantel's formula of yield regulation. Enlist its advantages and disadvantages **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***derivation and description of Von Mantel's formula*** *(growing-stock based yield regulation) along with its* ***advantages*** *and* ***disadvantages****.*

❶ **Introduction** : *Introduce yield regulation by growing stock and the normal forest concept.*

❷ **Main Body** : ❖ *Derivation of formula* ❖ *Description and application* ❖ *Advantages* ❖ *Disadvantages*

❸ **Conclusion** : *A simple but approximate method best suited to even-aged crops.*

Von Mantel's formula (identical to *Messon's formula*, which the French claim was developed independently by **Masson**) is a *growing-stock-based method* of *yield regulation* in *even-aged forests,* known for its "*glorious simplicity*".

A. Derivation

In a ***normal forest***, the ***normal growing stock*** equals the ***mean annual increment (I)*** multiplied by ***half the rotation***:

$$NGS = I \times r/2$$

For ***sustained yield***, annual yield equals the increment, so I becomes the yield. Replacing the normal growing stock with the ***actual growing stock (GS)***:

$$Ya = GS \div (r/2) = 2GS \,/\, r$$

where Ya = annual yield, **GS** = actual growing stock of the felling series, r = rotation. E.g., GS = 60,000 m^3 and r = 60 years gives $Ya = 2{,}000\ m^3/year$. Expressed as a percentage, $Y = 200/r$ % of GS — the ***exploitation percentage (Masson's ratio)***, e.g., 2½% for r = 80 years.

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B. Advantages

1. *Simple and easy* – needs only *growing stock* and *rotation*.
2. Based on *actual measured growing stock*; *over-stocked* forests are felled heavily and *under-stocked* ones lightly.
3. Complete enumeration yields a *stock map* showing understocked and failed areas needing *enrichment*.
4. Suitable for *regular*, *even-aged* crops.

C. Disadvantages

1. Requires *complete enumeration* of the growing stock from seedlings to rotation age – *costly and impractical*.
2. *Ignores age-class distribution* and *rate of growth/site quality*.
3. Enumeration down to *seedlings and saplings*, a small part of the growing stock, is *expensive and time-consuming*.
4. ***Inelastic*** – surplus or deficit is spread over *half the rotation*, slowing normalisation.

Thus, Von Mantel's formula is a *quick*, *conservative* yield regulation tool, whose enumeration burden is reduced by *Howard's*, ***Simmon's, Smythies' and Burma modifications***.

1 (e) : Differentiate between yield tables and stand tables. Give objectives of stand table. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants a ***point-wise distinction*** *between* ***yield tables*** *and* ***stand tables***, *followed by the* ***objectives*** *of preparing a* ***stand table***.

❶ **Introduction** : *Define both tables as mensurational tools.*

❷ **Main Body** : ❖ *Definitions* ❖ *Differences table* ❖ *Objectives of stand table*

❸ **Conclusion** : *The stand table complements the yield table for financial and silvicultural decisions.*

A *yield table* is a tabular statement of the *growth and yield* of *even-aged*, *fully stocked stands* by *age and site quality*. A *stand table* shows the *distribution of stems by diameter classes* for each of a series of *crop diameters*; in India it is usually *appended to the yield table*.

A. Differences

Basis	Yield Table	Stand Table
Content	Volume, basal area, MAI, CAI, top height, stems/ha by age and site quality	Number/percentage of stems by diameter classes (e.g., 10 cm classes)
Independent variable	Age and site quality	Crop (mean) diameter
Information	Average diameter of main crop and thinnings	Range of diameters and their proportion in the crop
Main uses	Site quality, rotation, increment, stock map by site quality, thinning guide	Money yield table, financial valuation, assortment estimation
Status	Independent primary table	Supplementary to yield table

B. Objectives of Stand Table

1. To know the *range of diameter classes* and their *percentage of the total crop*, which a yield table (giving only average diameter of main crop and thinnings) cannot give.

2. To give the *percentage of trees over given diameter limits* in crops of various diameters.
3. To give the *number of trees per hectare over given diameter limits* in a crop.
4. To give the *number of trees by 10 cm diameter classes*.
5. To prepare *money yield tables* and determine the *financial value of crops*.

Thus, the *yield table* gives stand averages, while the *stand table* reveals *diameter distribution*, together supporting sound *management and valuation*.

2 (a) : Critically examine the effectiveness of joint forest management in reconciling the goals of forest conservation and community livelihood security, in India. What institutional, ecological and socio-political challenges limit its long-term sustainability and scalability? **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants a ***critical (balanced) assessment*** *of* ***JFM's success and shortcomings*** *in reconciling* ***conservation*** *with* ***livelihood security***, *followed by* ***institutional, ecological and socio-political challenges*** *to its* ***sustainability and scaling up***.

❶ ***Introduction*** **:** *Trace JFM origin from NFP 1988 and the 1990 MoEF guidelines.*

❷ ***Main Body*** **:** ❖ *Achievements in conservation* ❖ *Achievements in livelihoods* ❖ *Critical gaps* ❖ *Institutional, ecological, socio-political challenges* ❖ *Way forward*

❸ ***Conclusion*** **:** *JFM must evolve into rights-based community forest governance.*

Joint Forest Management **(JFM)** is a *co-management partnership* between the *Forest Department* and ***local communities***, inspired by the *Arabari experiment* **(West Bengal, 1971)** and **NFP 1988**, and formalised by *MoEF guidelines of 1 June 1990* (strengthened in 2000 and 2002). JFM has since spread to almost all States through a large network of *JFMCs/VFCs* and is reflected in working plans through the *JFM overlapping working circle*.

A. Effectiveness in Forest Conservation

1. *Regeneration of degraded forests*, e.g., ***sal coppice*** recovery in ***Arabari*** and ***Harda (MP)***.
2. Reduced *illicit felling, fire and grazing* through *community patrolling*.
3. Contributed to stable/increasing *forest and tree cover* reported by **ISFR**.

B. Effectiveness in Livelihood Security

1. ***Usufruct rights*** over *NTFP, fuelwood, fodder* and *share of final harvest* (proportion varies by State).
2. *Wage employment* in plantations; *village development funds*; e.g., *Andhra Pradesh Community Forest Management*.
3. Women's participation through **SHGs** and mandatory membership norms.

C. Critical Gaps

1. ***Unequal partnership***: Forest Department dominates; JFMC often headed or controlled by the ***Forester as Member-Secretary***.
2. ***Benefit-sharing delayed*** as timber harvests come after decades and ***green felling*** is restricted (Supreme Court, **1996**).
3. ***Donor-driven*** expansion (World Bank, JICA projects) led to dormant committees after funds ended.

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D. Challenges to Sustainability and Scalability

Type	Challenges
Institutional	No ***statutory backing*** (executive order only); overlap with **FRA 2006** ***Gram Sabha*** and **PESA**; weak accountability; elite capture; poor ***micro-plan*** integration with working plans
Ecological	Focus on *plantation of fast-growing exotics* reduces diversity; ***over-extraction of NTFP***; ***invasives*** like *Lantana camara*; climate stress and fire
Socio-political	*Gender and caste exclusion*; distrust of Forest Department; conflicts over ***tenure***; dependence on *political patronage*; marginalization of nomadic grazers

E. Way Forward

1. Give JFM ***statutory status*** and ***converge with FRA CFR*** management under Gram Sabhas.
2. *Assured, timely benefit-sharing* including *NTFP value chains* (*PM Van Dhan Yojana*) and *carbon finance*.
3. *Native, mixed-species* restoration; ***ecological monitoring*** with GIS.
4. Strengthen *women's leadership*, *social audit* and *capacity building*.

Thus, JFM has partially reconciled ***conservation and livelihoods***, but its long-term success depends on transition to *rights-based, democratic community forest governance*.

2 (b) : Discuss the field work to be carried out by a Working Plan Officer for the preparation of Working Plan. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants a ***systematic account of the field operations*** *of the* **Working Plan Officer (WPO)** *–* ***examination of territorial units, resource assessment, growing stock, regeneration, socio-economic and biodiversity surveys*** *– as prescribed by the* **National Working Plan Code**.

❶ **Introduction** : *Place WPO field work after approval of PWPR in the working plan preparation sequence.*

❷ **Main Body** : ❖ *Examination of territorial units* ❖ *Forest resource assessment* ❖ *Growing stock, NTFP and biodiversity* ❖ *Regeneration, bamboo and socio-economic surveys* ❖ *Consultation and data verification*

❸ **Conclusion** : *Field work forms the factual foundation (Part I) of the working plan.*

Under the **National Working Plan Code (NWPC), 2023**, preparation of a working plan is a systematic and time-bound exercise involving forest-resource assessment, stakeholder consultation, formulation of management prescriptions, approval and monitoring. Modern tools such as **remote sensing, GIS, GPS and digital databases** supplement field surveys.

A. Examination of Territorial Units

1. Inspect range, beat, sub-beat, block, *compartment and sub-compartment* and villages; ensure the extent of forest cover is maintained.
2. Record area under *legal classes* (*RF, PF, UF*), *site quality*, area under each *working circle*, *land use change* and *forest types*; *mark compartment boundaries*.

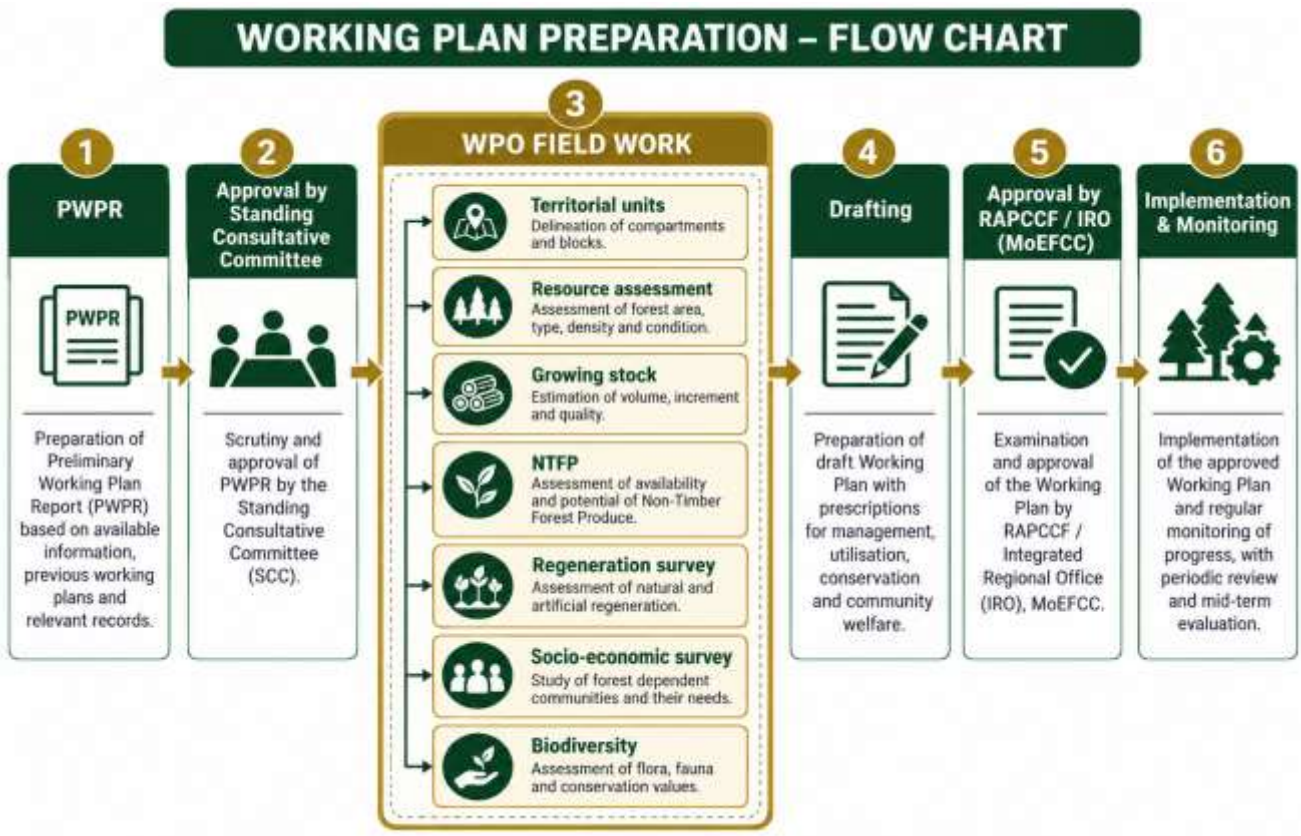
B. Forest Resource Assessment

1. Assess past performance against criteria: ***biodiversity conservation***, ***forest health and vitality*** (regeneration, fire, grazing, lopping, ***invasive weeds***, pests and diseases), ***soil and water conservation***, and ***productivity*** (growing stock, increment, ***carbon stock***).

2. ***Social, economic and cultural benefits*** — number of **JFMCs** and area protected, use of ***indigenous knowledge***, ***sacred groves***, ***FRA compliance***, rights and concessions, ecotourism.

C. *Growing Stock, NTFP and Biodiversity Assessment*

1. ***Growing stock estimation*:** enumeration in sample plots; *diameter class-wise distribution* of stems used to compute plot volume and interpolated for the compartment, using *volume table equation*, *volume table or yield table*.
2. **NTFP *(including* MAPs):** from old records, local enquiry and plot data; for tree NTFP, harvest from *at least three trees of different diameter classes over two consecutive seasons*; *10–20 individuals* per herb species.
3. ***Biodiversity assessment*:** species counts and DBH to derive ***basal area, density and frequency***.



D. *Regeneration, Bamboo and Socio-economic Surveys*

1. *Regeneration survey*: *2–4% enumeration*, in ***strips*** on flat terrain and by *topographical units* in hills; categories ***e***, ***w***, ***u+***, ***u***, ***s+***, ***s***, ***r***, **0**; prepares the *regeneration stock map* for correct silvicultural treatment.
2. *Bamboo/rattan*: *two-stage random sampling*; classified as ***luxuriant***, ***degraded***, ***culturable*** and non-clump forming.
3. *Socio-economic survey* of *fringe villages within 3 km* — dependence on timber, fuelwood, fodder, grazing, NTFP — by *stratified multistage random sampling* (villages, then households).
4. Assessment of *wildlife habitats and species* and *trees outside forests* (TOF).

E. *Consultation and Data Verification*

1. *Stakeholder consultation* on draft *management objectives* with **PRIs**, civil society, *wood-based industries* and research institutions; *minutes and video recording* are annexed to the draft plan.

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2. Collection of *secondary data*, *verification of primary data*, expert consultation and *short-term studies* where needed; preparation of *GIS* ***maps*** at the scale prescribed in the PWPR.

Thus, meticulous ***field work*** by the WPO provides the *scientific and social foundation* of a working plan, ensuring *sustainable, participatory forest management*.

2 (c) : What are cantilever bridges? Discuss the stability of cantilever bridges along with their disadvantages. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants a ***definition and structure*** *of the cantilever bridge, the* ***factors governing its stability***, *and its* ***disadvantages***, *ideally with a labelled sketch.*

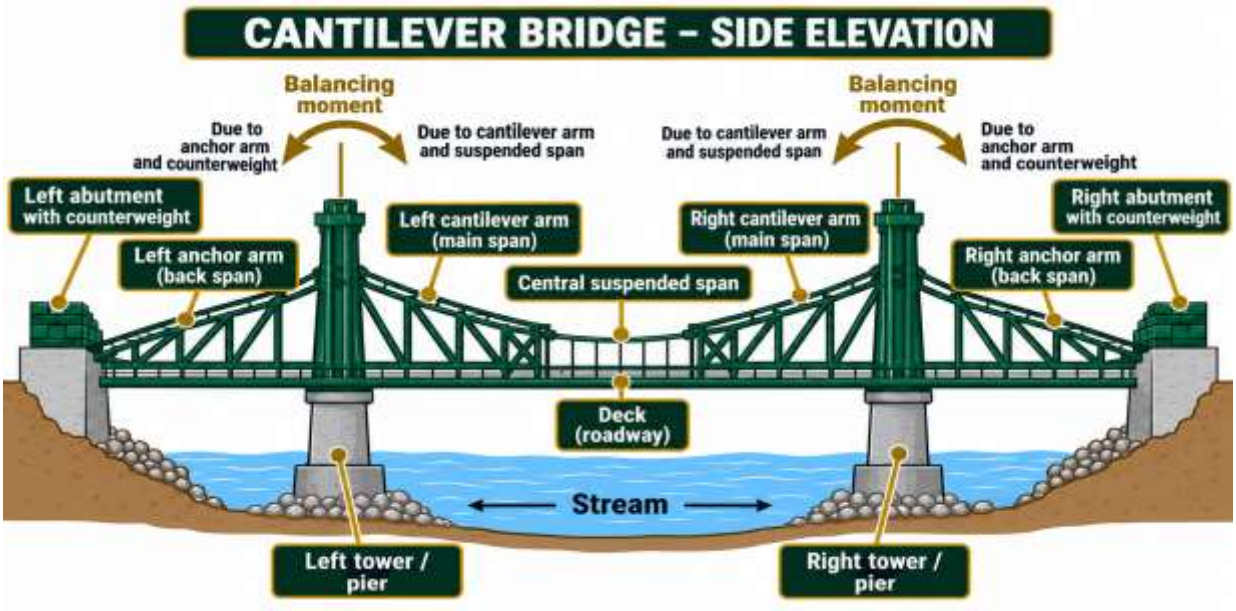
❶ **Introduction** : *Define a cantilever bridge as a counterpoised-beam structure.*

❷ **Main Body** : ❖ *Structure and working* ❖ *Factors of stability* ❖ *Disadvantages* ❖ *Forest relevance*

❸ **Conclusion** : *Suitable for wide gaps where intermediate piers are impossible.*

A ***cantilever bridge*** is built from *two systems of counterpoised beams* (*cantilevers*) built out from the ***abutments*** towards each other, *supporting the road bearers in the middle*; the *span gap is kept short* where the two parts connect, often closed by a short *suspended span*. Each arm is fixed (anchored) at one end only, its load being balanced by an *anchor arm/counterweight* on the shore side.

1. Structure



- ***Anchor arm:*** shore-side beam held down by masonry or ballast to balance the load.
- ***Cantilever arm:*** beam projecting over the gap from the *tower/pier*.
- ***Suspended span:*** short central beam resting on the tips of the two cantilever arms.
- ***Deck and road bearers:*** carry the traffic; e.g. the *Howrah Bridge* (Kolkata) is a classic cantilever design.

2. Stability of Cantilever Bridges

Stability depends mainly on the *length of beams, counterweight, centre of gravity and size of the beam*:

1. ***Length of beams:*** longer cantilever arms increase *bending moment* and deflection; hence the *span gap is kept short* where both parts are connected.

2. ***Counterweight:*** adequate *anchor arm, ballast or masonry* must balance the projecting arm, i.e. the ***overturning moment*** of arm plus live load must be less than the *resisting moment* of the counterweight.

   Resisting moment (counterweight × anchor length) > Overturning moment (load × cantilever length)

3. ***Centre of gravity:*** should lie within the *base of the support*; loads kept symmetrical.
4. ***Size of the beam:*** *depth, cross-section and durability* of the timber/steel beams decide load capacity.
5. ***Foundation:*** stable abutments free from ***scour*** and slope failure.

3. *Disadvantages*

1. *Difficult and cumbersome construction*, needing heavy anchorage.
2. *Wastage of material* – large counterweights and deep beams.
3. Requires a *high level of technical knowledge* and precise design.
4. Timber cantilevers are prone to *deflection, decay and termite attack*, needing anti-termite and preservative treatment.
5. Higher ***maintenance cost***; failure of anchorage causes total collapse.

Thus, cantilever bridges are stable only when *anchorage, beam length and load* are balanced, and they suit ***wide hill streams*** where intermediate piers cannot be built.

3 (a) : Elucidate the scope and importance of forest management. How does choice of forest management objectives vary with ownership, locality, quality of forest produce and financial benefits? **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***scope*** *and* ***importance*** *of forest management, and a reasoned analysis of how* ***objectives change with ownership, locality, produce quality and financial benefits****, with Indian examples.*

❶ ***Introduction*** : *Define forest management as application of technical and business principles to forests.*

❷ ***Main Body*** : ❖ *Scope* ❖ *Importance* ❖ *Variation of objectives with four factors (table)*

❸ ***Conclusion*** : *Objectives must balance ecology, people and economics.*

Forest management is the practical application of *scientific, technical and economic principles* to the administration of a forest estate for *specified objectives* on a *sustained basis.* In India it is guided by the *National Forest Policy 1988* and executed through *working plans* under the *National Working Plan Code 2023.*

A. *Scope of Forest Management*

1. ***Controlling composition and structure of growing stock:*** site-selective *tending, choice of species, regeneration methods*, stand manipulation and *protection* (fire, grazing, pests, encroachment).
2. ***Harvesting to marketing of produce:*** proper *logging plan*, suitable *transport methods, marketing/auction* and *revenue management.*
3. ***Administration of forest property:*** *monitoring and control of works, labour management and welfare,* economic efficiency.
4. ***Yield regulation and inventory:*** *rotation, annual cut, sustained yield*, growing-stock assessment (e.g. Von Mantel, Brandis methods).
5. ***Social and protective functions:*** *JFM, FRA 2006* rights, *biodiversity, watershed* and *carbon sequestration.*

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B. Importance

- Primary aim: *maximum benefits to the greatest number of people for all time*; ensures *sustained yield* and moves the forest towards ***normality***.
- Maintains **ecological security** – soil, water, climate (NFP target: **33% *forest cover***).
- Meets ***bona fide needs*** of local communities and improves ***rural livelihoods*** through community participation.
- Meets *special objectives – industrial demand* (Chir pine forests for ***resin***, ***poplar*** in the ***Tarai*** for paper), ***private sector participation*** in logging and processing, ***wasteland management*** (Chambal ravines, abandoned mines), ***urban forestry*** (Delhi), **CAMPA** and mangrove plantations.
- Promotes ***protective roles*** – soil erosion control, flood prevention, habitat, ***carbon sequestration***; helps meet the *INDC carbon sink target* (additional **2.5–3 *bn t CO2e*** by 2030) and **26 *m ha land restoration*** target by 2030.

C. Variation of Objectives

Factor	***Variation in objectives***	***Indian example***
Ownership	State (**~96%** of India's forests): *multipurpose, ecological forestry*, welfare of whole society, long investment return (*40–150 yrs*); Private: ***single, market-oriented timber forestry***, rotation of *maximum volume or highest net return*, may harvest *earlier than design time* (6–40 yrs); Community: ***subsistence (fuel, fodder, NTFP)***	Reserved forests vs *Eucalyptus* farm forestry in Punjab vs ***Van Panchayats*** of Uttarakhand
Locality	Hill slopes/catchments: *protection, soil and water*; plains: *production*; near towns: *recreation, amenity*; tribal areas: *NTFP*	Shivalik protection forests; teak plantations of Kerala; urban ***Nagar Van***
Quality of produce	High-value timber: *long rotation, large sizes*; low-grade: *pulpwood, fuel, short rotation coppice*	Teak at 60–80 years; *Eucalyptus/Leucaena* for pulp at 5–8 years
Financial benefits	Private owners judge by *return on invested capital*, choose *financial rotation* and simple, low-cost prescriptions; public forestry seeks *sustainable financial* ***returns*** (harvest, ecotourism, ecosystem services, *carbon credits*) but returns are *not the primary metric*; operations should still be *commercially sustainable*	Plantation corporations (FDCs) vs national parks

Other modifying factors include ***legal status***, ***market demand***, ***infrastructure*** and ***people's rights***. Objectives therefore form a ***hierarchy*** – ***protection first, then needs of local people, then production for industry*** (NFP 1988).



Thus, forest management is a ***multi-objective science*** whose goals must be tailored to ***ownership, site, produce and economics***, while keeping ***sustainability*** as the non-negotiable core.

3 (b) : Discuss the objectives and scope of Forest Working Plan. Give the characteristics of a good working plan. Enlist the summary of facts on which proposals are based for their preparation. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***objectives and scope*** *of a working plan, the* ***characteristics of a good plan****, and a list of the* ***summary of facts (Part I)*** *on which proposals rest.*

❶ ***Introduction*** **:** *Define working plan as the key document for scientific management for a fixed period.*

❷ ***Main Body*** **:** ❖ *Objectives* ❖ *Scope* ❖ *Characteristics* ❖ *Summary of facts (Part I)*

❸ ***Conclusion*** **:** *A good plan links facts to prescriptions.*

A ***working plan*** is a ***written scheme of management*** aimed at continuity of policy and action, controlling treatment of a forest for a *fixed period (normally 10 years).* Its preparation is mandatory under the *Supreme Court order in T.N. Godavarman (1996)* and follows the *National Working Plan Code 2023.*

A. Objectives

1. Make the *National Forest Policy effective at all levels* of management; prevent *ad-hoc, uncoordinated decisions.*
2. Define *clear aims* with *realistic methods* resulting from careful study of all relevant factors; maintain *continuity of management* despite change of staff.
3. Provide *guidelines and standards* and a ***framework for sustainable management***, balancing *development and conservation*; make forest practices *environmentally responsible, socially beneficial and economically viable.*
4. Ensure ***orderly and economic development*** of the forest; make all *supervisory staff aware* of intended future development.
5. Bring together in *readily accessible form* all information needed for management; improve *growing stock* towards the *normal forest.*

B. Scope

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- Covers *all forests of a division* – silviculture, *grazing, watershed, biodiversity, wildlife, recreation, utilization*, organized into *working circles* and *compartments*.
- Basis for *JFM micro-plans, forest certification* (C&I of SFM), *climate-mitigation assessment*, EIA/SIA and poverty alleviation in fringe areas.
- (Ram Prakash) survey of *past results and present facts*, analysis against policy, and a *plan of future action* for a definite period.

C. Characteristics of a Good Working Plan

1. ***Simple and brief***, self-contained and practicable for field staff.
2. ***Based on thorough knowledge*** of the area – inventory, *GIS maps*, growth data.
3. ***Realistic, not idealistic*** objectives, consistent with NFP 1988.
4. ***Does not unduly limit the discretion*** of executive staff, especially in silvicultural matters.
5. ***Recognises practical difficulties*** – marketing, transport, technical ability of staff.
6. ***Records past work*** (control forms, *compartment histories*) for future plans.
7. Prefers *indigenous and miscellaneous species* over exotics in plantations.
8. ***Participatory*** – stakeholder consultation with *PRIs, JFMCs*; PWPR approved by the *Standing Consultative Committee*, plan approved by the *MoEFCC Integrated Regional Office* (deemed approval if no decision in **45 days**).

D. Summary of Facts (Part I)

Chapter	Facts recorded
Tract dealt with	*Name, situation, configuration, geology, soil, climate, water supply*
Territorial units and area	*Area under legal classes* (RF, PF, UF), site quality, area under *working circles*, land-use change, *distribution of forest types*, compartment boundaries, rights and concessions
Flora and fauna	*Forest types (Champion & Seth),* composition, condition, wildlife
Utilization of produce	*Demand, markets, lines of export,* methods of exploitation, rates
Staff and labour	Strength of staff, *labour supply,* JFMCs
Past systems of management	*History, results of previous plans*, deviations
Growing stock, NTFP and regeneration	*Growing stock* (volume equation, volume table, yield table), *increment*, NTFP assessment, *regeneration survey/stock map*, socio-economic and wildlife habitat survey
Forest resource assessment	***Biodiversity, forest health*** (fire, pests, invasives), ***soil and water,*** productivity, ***carbon***, socio-economic benefits, FRA compliance

These facts, compiled from the **PWPR** (initiated **28 *months*** before expiry of the current plan) and field survey, form the basis of ***Part II – Future Management (prescriptions)***.



Thus, a good working plan converts a reliable ***summary of facts*** into ***realistic, participatory prescriptions*** for sustainable forest management.

3 (c) : Explain stratified sampling and variable radius sampling methods. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***principle, procedure, merits and limitations*** *of* ***stratified random sampling*** *and* ***variable radius (point/Bitterlich) sampling*** *in forest inventory.*

❶ **Introduction** : *Introduce sampling as estimating forest parameters from part of the population.*

❷ **Main Body** : ❖ *Stratified sampling – concept, procedure, merits* ❖ *Variable radius sampling – concept, BAF, procedure, merits* ❖ *Comparison*

❸ **Conclusion** : *Both improve efficiency of forest inventory.*

Complete enumeration is costly; hence *forest inventory* relies on *sampling*, which estimates parameters (volume, basal area, stems/ha) from a part of the population with known *precision*.

A. Stratified Random Sampling

The forest is divided into *homogeneous sub-populations (strata)* – by *forest type, site quality, density, age class* – and *sampling units are selected randomly* within each stratum *in proportion to its size*; strata may be formed horizontally (site quality) or vertically.

1. ***Stratify*** using maps, *satellite imagery* or past records.
2. ***Allocate samples*** – proportional or *optimum (Neyman) allocation* (more plots in variable strata).
3. ***Estimate*** stratum means and combine as a *weighted mean*.

$$\textbf{Overall mean} = \Sigma\,(N_h / N) \times \textbf{mean of stratum } h$$

- ***Merits:*** lower ***variance*** for same effort, separate estimates for each stratum, administratively convenient.
- ***Limitations:*** needs prior knowledge for stratification; wrong strata reduce gains. e.g. **FSI** stratifies by forest type and density.

B. Variable Radius (Point) Sampling

Developed by the Austrian forester **Bitterlich (1948)**; also called *angle-count, plotless, variable plot or PPS sampling*. Trees are selected on the basis of *size rather than frequency*; principle – the *ratio of tree diameter to plot radius is constant*, so each tree counted represents the *same basal area/ha*.

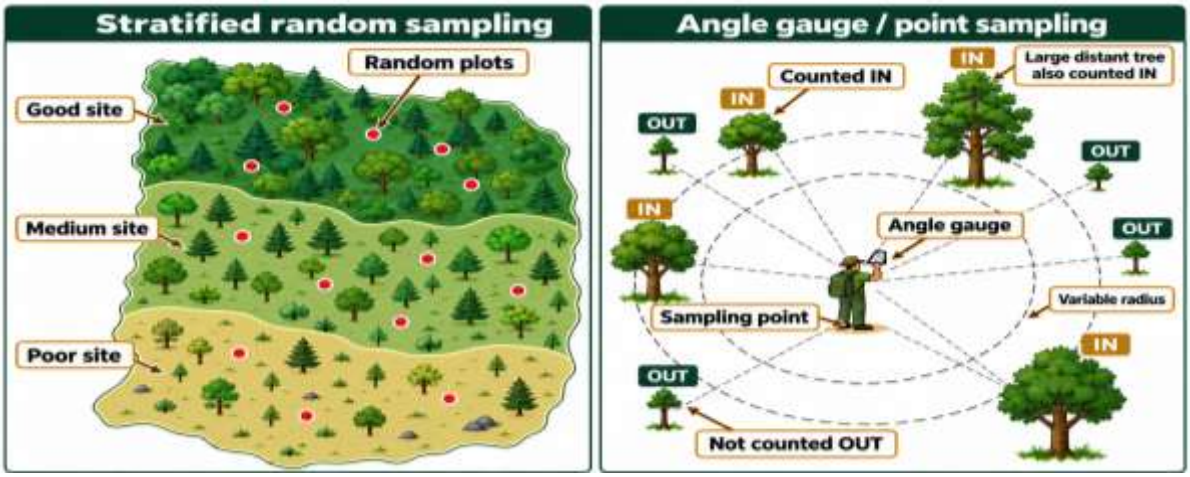
1. Sampling points are located *randomly or systematically*; at each, the observer sweeps 360° with a *simple angle gauge, wedge prism or Spiegel relaskop* (known **BAF**) at breast height.
2. Trees forming an angle *bigger than the critical angle* are counted (***full tally*** = **1**), ***border trees*** = **0.5**, out trees = 0; inclusion depends on *tree size and distance* from the point.
3. Each tree's plot radius ***varies with its diameter*** – hence "variable radius".

$$K = 2\sin(\theta/2) = d/R\ ;\ \ BAF\ (F) = 2500\ k^2$$

$$\textbf{Basal area per ha} = BAF \times \textbf{Number of tally trees}\ ;\ \ \textbf{Volume/ha} = \textbf{Basal area} \times \textbf{Stand form height}$$

- ***Merits:*** fast, no plot laying, directly gives ***basal area/ha***; efficient for volume.
- ***Limitations:*** errors from ***hidden trees, slope***, borderline trees; less suitable for ***dense, young stands***.
- ***Types: horizontal*** point sampling (Bitterlich – basal area) and ***vertical*** point sampling (***Hirata*** – tree height).

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Basis	Stratified sampling	Variable radius sampling
Unit	Fixed-area plot	Point (plotless)
Selection	Random within strata, ∝ stratum size	Probability ∝ ***tree size***
Main output	Mean volume, stems/ha	***Basal area/ha***

Thus, ***stratification*** reduces variance while ***point sampling*** reduces field effort; combined, they give efficient forest inventory.

4 (a) : Give objectives of diameter and girth measurement. Discuss the comparison between tape and calliper measurements. How are tree diameter classes formed in India? **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***objectives*** *of measuring diameter/girth, a* ***point-wise comparison of tape and calliper****, and the* ***system of diameter/girth classes*** *used in Indian forestry.*

❶ ***Introduction*** **:** *State that dbh at 1.37 m is the most basic tree measurement.*

❷ ***Main Body*** **:** ❖ *Objectives* ❖ *Tape vs calliper comparison table* ❖ *Formation of diameter classes in India*

❸ ***Conclusion*** **:** *Choice of instrument and classes affects accuracy of estimates.*

Diameter at breast height (dbh) measured at *1.37 m* above ground and *girth (circumference)* are the most frequently measured and easily obtained tree parameters.

A. Objectives of Diameter and Girth Measurement

1. Estimate *quantity of timber*, *firewood* and other produce *volume* via *volume tables*.
2. Compute *basal area* ($g = \pi d^2/4$) of trees/crop; measure *taper, form and log shape* to judge ***timber quality***.
3. Determine ***increment*** and ***growth*** (periodic, MAI).
4. Decide *exploitable size*, marking for *thinning and felling*.
5. Prepare *stand tables* and *diameter distributions* for yield regulation (e.g. *Brandis/Hufnagel methods*).
6. *Inventory of growing stock*; correlate *height–volume–age–increment*; carbon stock and valuation.

B. Tape vs Calliper

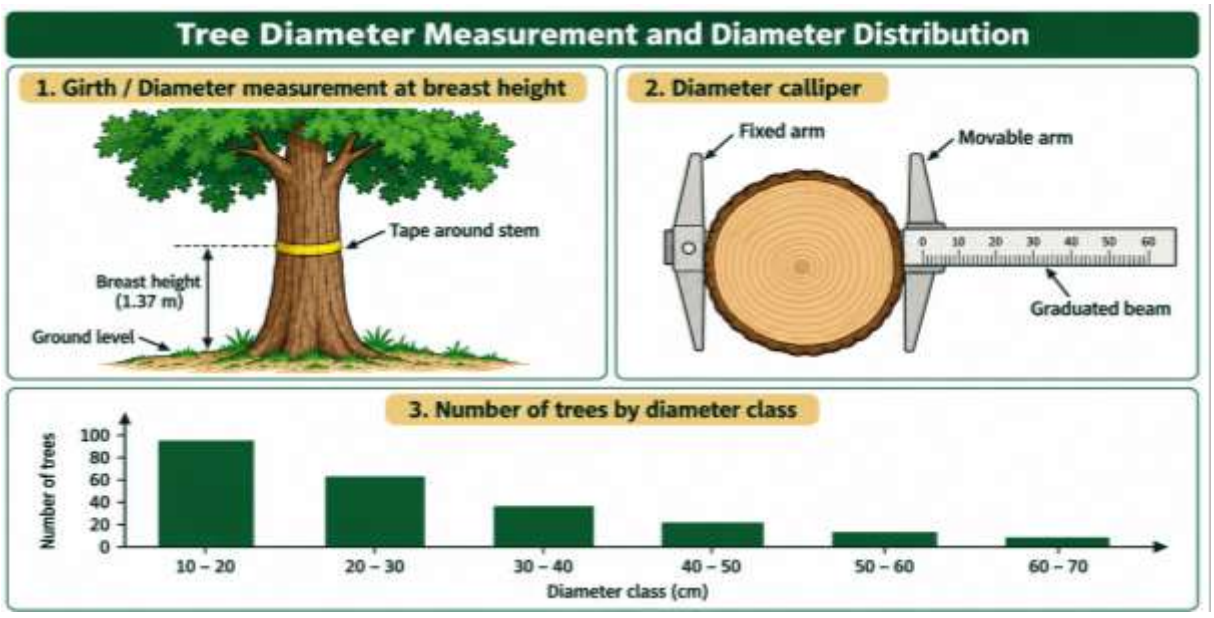
Basis	Tape	Calliper
Measures	***Girth*** (converted to diameter: $d = g/\pi$)	***Diameter*** directly
Number of readings	***One*** reading enough even for elliptical stems	***Two*** perpendicular readings for elliptical stems

Error magnitude	1 cm girth error = only ***~1/3 cm*** diameter error	1 cm error = 1 cm diameter error
Direction of error	Only *positive errors* (overestimates on elliptical, rough-barked stems)	± ***errors*** tend to cancel – better accuracy
Bias with irregular stems	Over-estimates basal area of ***elliptical/fluted stems***	Smaller basal-area error
Portability and use	Easy to carry, *no adjustment*; easy on *felled logs*	Cannot measure *large trees*; second diameter hard on *hill slopes and logs on ground*; wooden arms stick in *rain*
Sources of error	Tape *elasticity*, twisting, not perpendicular to axis; *rough bark exaggerates* girth	Calliper *forced on tree*, arm not at *right angle*; but *crushes loose bark*, easy for *unskilled labour*

Hence the ***caliper*** is preferred for research plots and small trees; the ***tape*** for large trees, ***repeated measurements*** (permanent plots) and felled logs.

C. *Formation of Diameter Classes in India*

1. ***Fix the exploitable size*** and ***felling cycle*** – e.g. ***Brandis*** fixed a ***girth limit of 6'*** for ***teak*** under Indian conditions, below which no tree was to be felled.
2. ***Fix the diameter (girth) classes*** at equal intervals – ***DBH classes spaced at 5 or 10 cm*** (stand tables commonly show trees by ***10 cm diameter classes***); for volume-table sample trees, trees are grouped into ***5 cm girth classes***.
3. ***Enumerate*** the trees class-wise – e.g. ***systematic strip enumeration*** (Brandis); Biolley's check method enumerated in ***5 cm diameter classes*** down to a minimum diameter.
4. ***Number the classes from the exploitable size downwards*** – trees above the exploitable size form ***Class I***, the next lower ***Class II***, and so on (as in ***Smythies' safeguarding formula***, which uses ***t = time for a Class II tree to pass into Class I***).
5. Find the ***rate of girth increment*** of each class by ***stump analysis*** and the ***transition period*** from each class to the next; adding these (plus an establishment period) gives the ***rotation*** for the exploitable girth (***Brandis' diameter class or Indian method***).
6. Class-wise counts form the ***stand table***, compared with the ***reverse-J-shaped*** distribution of uneven-aged (selection) forests to judge normality.



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Thus, accurate ***dbh measurement*** with the right instrument and a standard ***diameter-class system*** fixed by the working plan underpins ***volume, yield and growth*** estimation in Indian forestry.

4 (b) : Discuss the environmental impact of road, tunnel and bridge construction in forest ecosystems **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***ecological impacts*** *of* ***roads, tunnels and bridges*** *on forests – on land, water, biodiversity and people – with* ***Indian examples*** *and* ***mitigation measures****.*

❶ **Introduction** : *Note the need for linear infrastructure and its conflict with forests.*

❷ **Main Body** : ❖ *Impacts of roads* ❖ *Impacts of tunnels* ❖ *Impacts of bridges* ❖ *Common impacts* ❖ *Mitigation*

❸ **Conclusion** : *Green infrastructure reconciles development with conservation.*

Linear infrastructure is essential for access, protection and development, but in forests it is a leading cause of ***fragmentation***. Diversion of forest land for such projects is regulated under the *Forest (Conservation) Act* 1980 (now *Van (Sanrakshan Evam Samvardhan) Adhiniyam*, 1980).

A. Impacts of Road Construction

1. *Heavy felling, damage and erosion during construction; deforestation and fragmentation edge effects* penetrate deep into the forest; creates *barrier* to animal movement.
2. ***Road kills*** – e.g. NH-44 through ***Pench–Kanha***, NH-37 through ***Kaziranga***, NH-766 through ***Bandipur*** (night traffic ban).
3. ***Soil erosion and landslides*** from cut slopes and *muck dumping* – e.g. *Char Dham road* in Uttarakhand.
4. ***Altered drainage*** – roads endanger *water sources and watercourses,* block normal water flow and cause ***sedimentation*** of streams; *destabilize soil* and raise *landslide risk.*
5. ***Invasive species*** spread along road verges (*Lantana camara*, *Parthenium hysterophorus*).
6. ***Easier access*** to poachers, *illegal felling and transport, overexploitation, fire* and encroachment; threatens *habitats of rare and protected species.*
7. ***Noise*** (even in silent zones), *thermal (engine heat)* and *litter pollution* – polythene, glass, plastic bottles.
8. ***Socio-cultural impact:*** connectivity and migration erode *tribal society, culture and traditional knowledge.*

B. Impacts of Tunnel Construction

1. ***Blasting*** causes *vibration*, slope instability and cracks – e.g. *Joshimath subsidence* debate around *Tapovan–Vishnugad tunnel.*
2. ***Disruption of aquifers and springs*** – drying of springs in Himalaya.
3. Large ***muck/debris*** dumped in valleys and rivers.
4. Disturbance during construction, though tunnels *reduce surface forest loss* in operation (e.g. ***Atal Tunnel***).

C. Impacts of Bridge Construction

1. ***Riparian vegetation clearance*** and bank erosion.
2. ***Siltation and altered stream flow*** by piers – affects *aquatic fauna and fish breeding.*
3. ***Dredging and sand mining*** for materials.
4. Positive role when built as *elevated corridors*, replacing at-grade roads.

D. Cross-cutting Impacts

- *Loss of carbon sinks* and *micro-climate change*.
- *Human–wildlife conflict* and *habitat isolation* leading to genetic loss.
- *Displacement of forest dwellers* and loss of NTFP; *overexploitation* via illegal transport of timber.



E. Mitigation

1. *WII guidelines "Eco-friendly Measures to Mitigate Impacts of Linear Infrastructure on Wildlife"* **(2016)** – *underpasses, overpasses*, e.g. *NH-44 underpasses* in the *Pench–Kanha* landscape.
2. ***Avoid–minimise–compensate***: alignment away from *PAs and corridors*; *EIA* and *Compensatory Afforestation* (CAMPA).
3. ***Reconnaissance survey*** assessing effects on *forest, wildlife and watershed*; roads that *do not interfere with natural drainage, do not damage the landscape* and *take account of flora and fauna*; breast/retaining walls, catch-water drains, *bio-engineering, scientific muck disposal*.
4. ***Regular maintenance*** – drainage management, repair of retaining walls, cleaning sediment, *landslide remediation*.
5. ***Speed limits, night traffic regulation***, signage, fencing to guide animals.
6. Preference for *tunnels/elevated roads* in sensitive stretches.

Thus, roads, tunnels and bridges must be planned as "*green infrastructure*", integrating *wildlife passages, slope stabilisation and EIA,* so that connectivity for people does not cost connectivity for wildlife.

4 (c) : Discuss the importance of remote sensing and GIS in forest resource monitoring and their use for better checks and production of forest resources in long-term forest working. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***importance of RS and GIS*** *in* ***monitoring forests****, and how they help in* ***better control (checks)*** *and* ***enhanced production*** *under* ***long-term working plans****, with Indian applications.*

❶ ***Introduction*** **:** *Define RS and GIS briefly.*

❷ ***Main Body*** **:** ❖ *Importance in monitoring* ❖ *Use for checks* ❖ *Use for production and long-term working*

❸ ***Conclusion*** **:** *Geospatial tools make management evidence-based.*

Remote sensing (RS) acquires information about forests from *satellite/aerial sensors* without contact, while *GIS* stores, analyses and displays *spatial data in layers*. Together they provide *repetitive, synoptic and objective* data for forest management.

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A. Importance in Forest Resource Monitoring

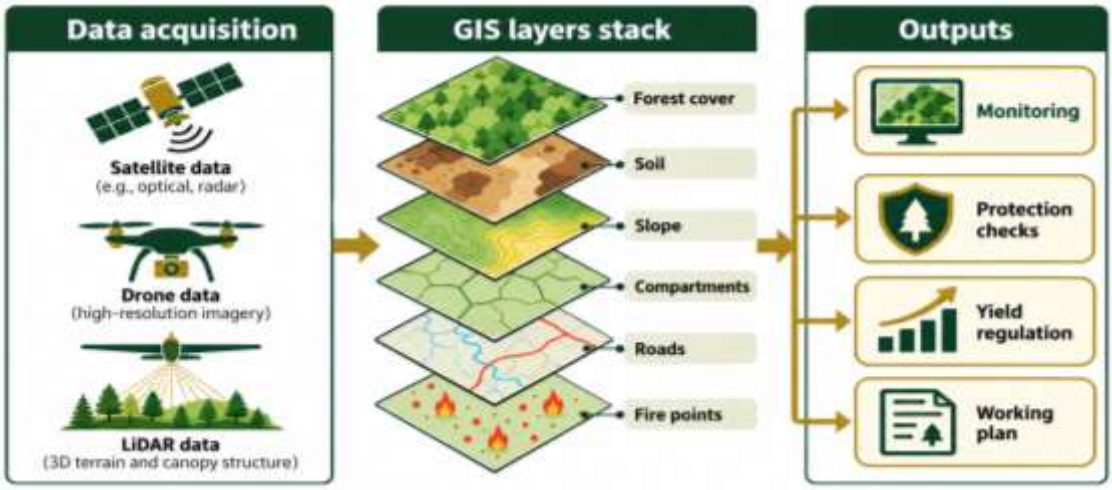
1. ***Forest cover mapping*** : *FSI's biennial* wall-to-wall mapping using *IRS Resourcesat-2 LISS-III* (23.5 *m*) at 1:50,000.
2. ***Forest type, density*** (VDF, MDF, OF) and *tree species classification* from canopy biophysical/biochemical parameters – cheaper than field survey.
3. ***Change detection*** : deforestation, degradation, *mining and shifting cultivation* areas.
4. ***Biomass and carbon*** estimation using *LiDAR*, SAR and NDVI.
5. ***Biodiversity and habitat*** mapping, *wildlife corridors, fragmentation analysis*; mapping *invasive species (Lantana camara, Parthenium hysterophorus)* by phenology.

B. Use for Better Checks (Control and Protection)

1. ***Forest fire alerts*** : *FSI's FAST 3.0* using *MODIS (1 km)* and *SNPP-VIIRS (375 m)* hotspots, sent directly to registered users; *Van Agni Geo-portal*.
2. ***Encroachment and illegal felling*** detection; *e-Green Watch* for CAMPA plantation monitoring.
3. ***Boundary demarcation*** with *DGPS* and digitised maps; FRA claim verification.
4. ***Monitoring compliance*** of working plan prescriptions and the *effects of silvicultural and management programs*; monitoring *social forestry*, *Green India Mission* plantations.
5. ***Pest/disease*** and drought stress detection.

C. Use for Production in Long-term Forest Working

1. *Stratification* for inventory – reduces sampling cost.
2. *Growing stock and increment* estimation for *yield regulation.*
3. *Site suitability, terrain evaluation and soil mapping* for plantations and species choice; *wetland/water* mapping.
4. *Compartment-wise database* (compartment history) and *GIS maps* prepared by the WPO under the ***National Working Plan Code 2023***.
5. *Planning road network*, harvest scheduling and *watershed treatment*.
6. *Decision support systems, ecosystem/landscape and carbon cycle modelling;* tracking the *INDC carbon sink* (2.5–3 *bn t* CO_2); limitation – features below 23.5 *m* and areas under *cloud/shadow* are missed, so ***ground truthing*** is needed.



Thus, RS and GIS turn forest management into a ***data-driven, transparent and adaptive*** process, making both ***protection*** and ***sustained production*** more effective over the ***long term***.

5 (a) : What are the functional characteristics of an ecosystem? Briefly explain the process of energy flow within an ecosystem. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***functional attributes of an ecosystem*** *listed and the* ***unidirectional energy flow*** *through* ***trophic levels*** *explained with laws and models.*

❶ ***Introduction*** : *Define ecosystem as a structural-functional unit.*

❷ ***Main Body*** : ❖ *Functional characteristics* ❖ *Energy flow steps* ❖ *Energy flow models*

❸ ***Conclusion*** : *Energy flows one way while nutrients cycle.*

An ***ecosystem*** is a *self-regulating functional unit* in which *biotic* and *abiotic* components interact through ***energy flow*** and ***material cycling***.

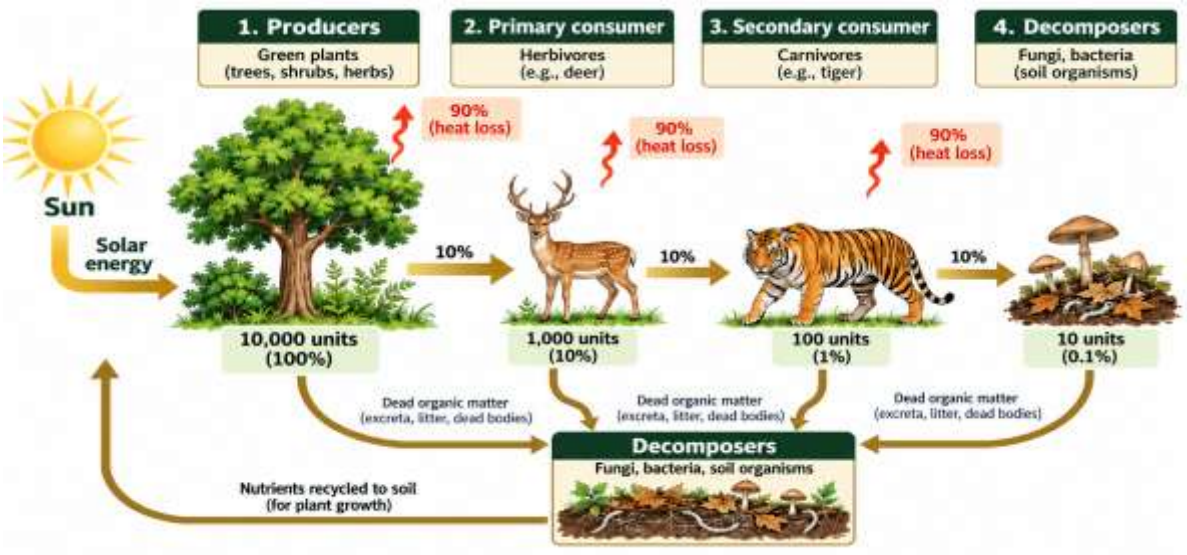
A. Functional Characteristics

1. ***Productivity:*** GPP and NPP by producers, e.g. tropical evergreen forests of the *Western Ghats* have high NPP.
2. ***Energy flow:*** *unidirectional* transfer along *food chains* and *food webs*.
3. ***Nutrient (biogeochemical) cycling***: C, N, P cycles; *litter decomposition* in forests.
4. ***Decomposition:*** *detritivores* and *microbes* release nutrients, e.g. termites in dry deciduous forests.
5. ***Ecological succession and homeostasis:*** *cybernetic regulation* towards *climax* stability.

B. Process of Energy Flow

Sun → Producers (≈1% fixed) → Herbivores → Carnivores → Top carnivores; heat lost at each step

- ***First law of thermodynamics*:** energy is transformed, not destroyed; ***second law*:** each transfer loses energy as ***respiratory heat***.
- ***Lindeman's 10% law*:** only about **10%** passes to the next ***trophic level***, limiting chains to ***4–5 links***.
- ***Grazing food chain*** (grass → deer → tiger) and ***detritus food chain*** (litter → earthworm → bird); in forests the ***detritus chain dominates***.
- *Pyramid of energy is always upright* (≈90% lost at each level), whereas the *pyramid of biomass is inverted in forests* because trees hold far more biomass than consumers; *single-channel and Y-shaped models* (Odum) depict the flow.



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Thus, ecosystems function through *one-way energy flow* and *cyclic nutrient movement*, which together sustain *productivity and stability*.

5 (b) : Why is proper nomenclature crucial in studying medicinal and aromatic plants? **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***importance of correct botanical (binomial) nomenclature*** *for* ***medicinal and aromatic plants (MAPs)*** *in terms of* ***identity, safety, trade, research and conservation****.*

❶ ***Introduction*** **:** *Define nomenclature under ICN and binomial system.*

❷ ***Main Body*** **:** ❖ *Scientific accuracy* ❖ *Safety and quality* ❖ *Trade, IPR and conservation*

❸ ***Conclusion*** **:** *Correct names are the foundation of safe herbal use.*

Nomenclature is the science of giving ***distinct, proper names*** to organisms under universal rules (**ICBN**), using the ***binomial system*** of ***Linnaeus*** (*Species Plantarum*, 1753), e.g. *Rauvolfia serpentina* Benth. MAPs carry many *vernacular names*; common names are *not universal*, one plant may have *hundreds of common names*, and *two plants may share one common name*, whereas each has *only one scientific name*.

A. Scientific Accuracy

1. ***Resolves synonymy and homonymy*****:** "Brahmi" refers to both *Bacopa monnieri* and *Centella asiatica*; "Shankhpushpi" to several species.
2. ***Universal communication*****:** a single name links *Ayurveda*, *Unani*, *Siddha* and modern *pharmacology* literature.
3. ***Chemotaxonomy*****:** related taxa share ***phytochemicals***, guiding search for new drugs, e.g. *Rauvolfia serpentina* (reserpine).

B. Safety and Quality

4. ***Prevents adulteration and substitution*****:** *Saraca asoca* bark substituted by *Polyalthia longifolia*.
5. ***Pharmacopoeial standards*****: *Ayurvedic Pharmacopoeia of India*** monographs and **GMP/AYUSH** quality control require exact identity.
6. ***Avoids toxicity*****:** confusing *Aconitum heterophyllum* (non-toxic) with toxic *Aconitum* species can be fatal.

C. Trade, IPR and Conservation

7. ***CITES, Biological Diversity Act 2002 and* ABS:** listing of species like *Nardostachys jatamansi*, *Taxus wallichiana* needs precise names.
8. ***IPR and biopiracy defence*****: TKDL** entries and patent challenges (neem, turmeric) rely on correct identity.
9. ***Herbarium vouchers and latest names*****:** identification against ***herbarium specimens*** and use of the ***latest accepted nomenclature*** (author citation, e.g. *Mangifera indica* L.) underpin Red List assessment and NMPB cultivation.

Thus, proper nomenclature ensures ***authenticity, safety, legal protection and conservation*** of India's medicinal plant wealth.

5 (c) : What are the most effective strategies for balancing biodiversity conservation with sustainable resource utilization in forest ecosystems, especially in the face of climate change and increasing anthropogenic pressures? **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants ***practical strategies*** *that reconcile* ***conservation*** *with* ***sustainable use****, explicitly addressing* ***climate change*** *and* ***anthropogenic pressures****, with* ***Indian examples****.*

❶ **Introduction** : *State the conservation–livelihood dilemma (≈ 30 crore forest-dependent people).*

❷ **Main Body** : ❖ *Landscape and protected-area strategies* ❖ *Sustainable utilisation* ❖ *Climate-adaptive and governance strategies*

❸ **Conclusion** : *Integrated, people-centric landscape management is the way forward.*

India's forests support high ***biodiversity*** and about 30 *crore forest-dependent people*, while facing *fragmentation*, *fire*, *invasives* and *climate shifts*. Balance demands an *integrated landscape approach*.

A. Conservation-centred Strategies

1. ***Protected Area network with zonation*****:** *core–buffer–transition* of *Biosphere Reserves*; *eco-sensitive zones*.
2. ***Corridors and connectivity*****:** tiger corridors (Kanha–Pench), aiding *climate-driven range shifts*.
3. ***Ex situ backup*****:** seed banks, *Medicinal Plant Conservation Areas* (MPCAs).

B. Sustainable Utilisation

4. ***Sustainable harvest of NTFP*****:** non-destructive tapping, rotational harvest, *MSP for MFP, Van Dhan Kendras.*
5. ***Participatory governance*****:** *JFM, FRA 2006 CFR rights* (Mendha-Lekha), *BMCs and PBRs.*
6. ***Working plans under NWPC 2023*** with biodiversity and *certification* (*FSC/PEFC-type*).

C. Climate-resilient and Pressure-reducing Measures

7. ***Climate-smart silviculture*****:** mixed native species, *assisted natural regeneration*, fire management.
8. ***Reduce pressure*****:** *agroforestry and Trees Outside Forests*, LPG/biogas, *Green India Mission*.
9. ***Economic incentives*****: PES, CAMPA**, carbon markets/REDD+, ***ecotourism*** (Periyar).

Thus, combining ***protection, participation, sustainable use and climate adaptation*** within landscapes best balances ***conservation and development***.

5 (d) : Explain (i) Water blister of teak, (ii) Gummosis of eucalyptus, (iii) Leaf crack, and (iv) Frost crack. **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants each of the ***four tree disorders/injuries*** *explained in terms of* ***nature, cause, symptoms and control****, with host examples.*

❶ **Introduction** : *Classify forest damage into biotic diseases and injuries due to climatic factors.*

❷ **Main Body** : ❖ *Water blister* ❖ *Gummosis* ❖ *Leaf crack* ❖ *Frost crack* ❖ *Comparison table*

❸ **Conclusion** : *Site-matching and good silviculture prevent most of these disorders.*

Forest damage arises from ***diseases*** (fungi, bacteria, mycoplasma) and *injuries due to climatic factors* such as *solar radiation, frost, flood, drought, snowfall and strong wind.* The four disorders below reduce *growth and timber quality*.

(i) Water Blister of Teak

- A *physiological (non-infectious) disorder* of *Tectona grandis*, associated with *excess soil moisture* on *ill-drained, waterlogged* sites unsuited to teak.

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- **Symptoms:** *blister-like swellings* on bark that hold ***watery sap***, later rupturing into ***cracks*** that admit ***secondary pathogens***.
- ***Control*: *site selection***, drainage, avoid stiff clayey soils.

(ii) Gummosis of Eucalyptus

- ***Gummosis* = *exudation of gum (kino)***; gum is a *degraded product of the cell wall*, produced as a *protective response to injury, stress or disease*.
- In eucalyptus it accompanies ***wounds*, *drought stress*** and diseases such as ***pink disease*** (*Corticium salmonicolor*, which also attacks teak, *Bombax ceiba* and neem) and ***stem cankers*** in humid Kerala and Karnataka plantations.
- ***Control*:** avoid injury, ***disease-tolerant clones***, remove cankered stems, ***Bordeaux paste*** on wounds.

(iii) Leaf Crack

- A ***mechanical/abiotic injury***: splitting or tearing of the ***leaf lamina*** by ***strong wind*, *hail*** or sudden *moisture and temperature change*; it lowers *photosynthetic area* and opens entry for *leaf pathogens*.
- ***Control*:** *windbreaks and shelterbelts*, balanced nutrition, healthy vigour.

(iv) Frost Crack

- A ***climatic injury***: a *longitudinal radial split* of the stem when sudden ***severe cold*** makes outer wood ***contract faster*** than inner wood; repeated opening and callusing forms a ***frost rib***.
- In timber it appears as ***frost shake***, where wood *splits inwards towards the centre* due to very cold weather, lowering timber grade.
- Seen in ***temperate Himalayan*** trees and *frost pockets*; *control*: retain ***overhead cover***, avoid frost hollows, frost-hardy species.

Disorder	*Nature*	*Key sign*
Water blister	Physiological (excess water)	Sap-filled bark blisters
Gummosis	Protective response to injury/disease	Gum exudation, cankers
Leaf crack	Mechanical (wind, hail)	Split lamina
Frost crack	Climatic (frost)	Radial stem split, frost rib/shake

Thus, most of these disorders are minimised by ***site-species matching*, *sound silviculture and timely protection***.

5 (e) : In the context of current environmental and developmental pressures, how effective are the Forest (Conservation) Act, 1980 and the Wildlife (Protection) Act, 1972? What are the changes needed to enhance their impact? **[8 M]**

Approach

Understanding the Question !!

Here, the examiner wants a ***balanced evaluation*** *of the* **FCA 1980** *and* **WPA 1972** *(including the* **2023 Adhiniyam** *and* **2022 Amendment***) and* ***specific reforms***.

❶ ***Introduction*** **:** *Introduce both Acts and their recent amendments.*

❷ ***Main Body*** **:** ❖ *Achievements* ❖ *Limitations under current pressures* ❖ *Reforms needed*

❸ ***Conclusion*** **:** *Strong laws need strong implementation and community partnership.*

The **FCA 1980** regulates *diversion of forest land*, and the **WPA 1972** protects *species and habitats*. Both were recently amended: *Van (Sanrakshan Evam Samvardhan) Adhiniyam, 2023* and *Wild Life (Protection) Amendment Act, 2022*.

A. Effectiveness

1. ***Diversion slowed*:** prior ***Central approval*** (Sec 2, in force from **25 Oct 1980**) for *dereservation* and *non-forest use* sharply cut the pre-1980 loss rate; *compensatory afforestation* via **CAMPA 2016**.
2. ***PA network*:** about **1,000+ PAs**, All India Tiger Estimation (5th cycle, 2022) **3,167** minimum (≈ ***70% of global tigers***), Asiatic lion and rhino recovery.
3. ***2022 amendment*:** enables **CITES** implementation (new Schedule IV), reduced schedules from *six to four*, higher penalties, ***invasive species*** control.

B. Limitations

5. ***2023 Adhiniyam concerns*:** limits coverage to *recorded/notified forests* (diluting **T.N. *Godavarman* 1996** "dictionary meaning"), exempts land within *100 km of borders/LoC/LAC*, strips along *rail lines and* ***roads***, plantations on ***private land***, zoos and safaris; Supreme Court (2024) ordered status quo on the definition.
6. ***Poor CA quality*** and unutilised CAMPA funds; **FRA 2006** consent often bypassed.
7. WPA: weak *conviction rates*, *human–wildlife conflict*, live-elephant transfer provision (2022) criticised.

C. Changes Needed

- ***Clear forest definition*** protecting *deemed and unclassed forests*; State expert committees for mapping.
- ***Landscape-level EIA***, cumulative impact assessment, *satellite monitoring* of CA plantations.
- ***Gram Sabha consent*** aligned with FRA; *community conserved areas*.
- ***Wildlife Crime Control Bureau*** strengthening, special courts, conflict compensation schemes.

Thus, both Acts remain India's ***conservation backbone***, but need ***precise definitions, transparency and community participation*** to match current pressures.

6 (a) : How do India's forest ecosystems influence the therapeutic use and conservation of medicinal and aromatic plants in Ayurveda and Unani, considering their habitat specificity, ecological distribution and botanical traits? **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***link between forest ecosystems and MAPs****, covering* ***habitat specificity****,* ***ecological distribution****,* ***botanical traits*** *influencing* ***therapeutic potency*** *in* ***Ayurveda and Unani****, and the resulting* ***conservation strategies****.*

❶ ***Introduction*** **:** *India has ~8,000 medicinal plant species; ~90% sourced from forests.*

❷ ***Main Body*** **:** ❖ *Forest types and MAP distribution* ❖ *Habitat specificity and potency* ❖ *Botanical traits and therapeutic use* ❖ *Conservation implications*

❸ ***Conclusion*** **:** *Conserving forest ecosystems is conserving traditional medicine.*

India, a *mega-diverse country*, has about *8,000 medicinal plant species*, of which nearly *90% of the raw drugs* used in ***Ayurveda and Unani*** are collected from ***forests***. Forest ecosystems shape ***where*** these plants grow, ***what chemicals*** they produce, and ***how*** they must be conserved.

A. Ecological Distribution across Forest Types

Forest ecosystem	Key MAPs	Use in Ayurveda/Unani
Alpine and sub-alpine Himalaya	*Picrorhiza kurroa*, *Aconitum heterophyllum*, *Nardostachys jatamansi*	Kutki (liver), Ativisha, Jatamansi (nervine)

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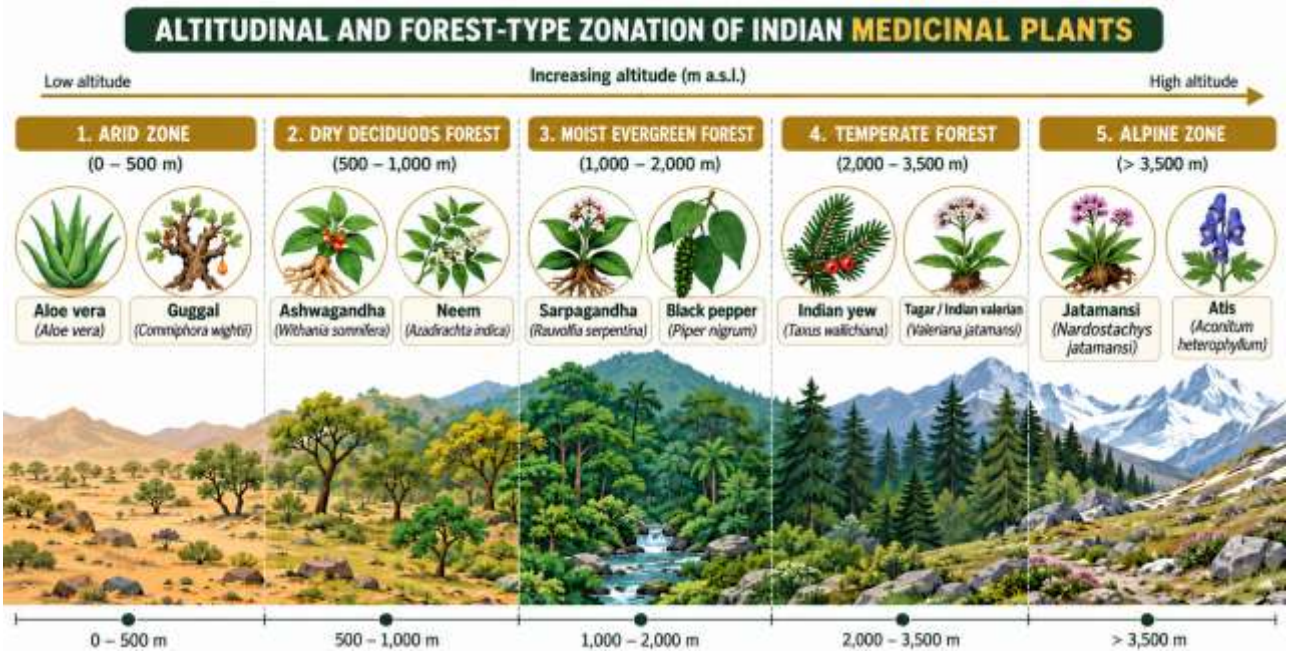
Temperate Himalaya	*Taxus wallichiana*, *Valeriana jatamansi*, *Berberis aristata*	Anticancer taxol, Tagar, Daruharidra
Tropical moist/evergreen (W. Ghats, NE)	*Saraca asoca*, *Garcinia indica*, *Coscinium fenestratum*	Ashoka (uterine tonic), Kokum
Tropical dry deciduous (Central India)	*Terminalia chebula*, *Phyllanthus emblica*, *Rauvolfia serpentina*	Triphala, Sarpagandha (hypertension)
Arid and semi-arid	*Commiphora wightii*, *Tecomella undulata*	Guggul (lipid, joints), Rohida

B. Habitat Specificity and Therapeutic Potency

1. ***Altitude and stress*:** high-altitude cold and UV raise *secondary metabolites*; *Picrorhiza* picrosides are higher above **3,000 m**.
2. ***Edaphic specificity*:** *Commiphora wightii* on *rocky arid* soils; *Rauvolfia* in *shaded moist* deciduous understorey.
3. ***Microclimate and association*:** shade-loving *Coscinium*, mycorrhiza-dependent ***orchids*** (*Dactylorhiza hatagirea*, Salam panja in Unani).
4. ***Collection stage and part*:** *Atropa belladonna* (Kashmir, Chakrata) leaves are collected at ***flowering***, when alkaloids peak (**0.9–1.2%**); *Rauvolfia* ***root bark*** yields ***reserpine***. ***Dravyaguna*:** classical texts specify *collection season, habitat and part* (e.g. *Kshetra* concept), reflecting ecological knowledge.

C. Botanical Traits and Use

1. ***Part used*:** roots/rhizomes (*Picrorhiza*), bark (*Saraca*), resins (*Guggul*), fruits (*Terminalia*), seeds; ***underground part harvest is destructive***.
2. ***Life form*:** slow-growing ***perennials and trees*** (*Taxus*) recover poorly; ***annual herbs*** regenerate faster.
3. ***Aromatic traits*:** essential oils of *Santalum album*, *Cymbopogon*, *Aquilaria malaccensis* (agarwood/Ood in Unani) depend on ***age and natural infection***.



D. Conservation Implications

- ***Threats: over-harvesting***, narrow endemism, habitat loss; *Saraca asoca*, *Nardostachys* are ***threatened*** (IUCN/CITES).

- ***In situ:*** *Medicinal Plants Conservation Areas* (MPCAs) of about **200 ha**, kept as '***hands-off***' sites with viable breeding populations and minimal forestry operations; PAs, sacred groves.
- ***Ex situ:*** herbal gardens, ***seed and gene banks*** (NBPGR), tissue culture of *Picrorhiza*.
- ***Policy*: NMPB** cultivation subsidies, *Good Agricultural and Collection Practices*, *Biological Diversity Act 2002* ABS, export restrictions.
- ***Community role*: Van Dhan**, JFM-based sustainable harvest, **PBR *documentation*** of traditional knowledge.

Thus, India's *forest ecosystems determine the availability, potency and sustainability* of Ayurvedic and Unani drugs; *habitat-based conservation and cultivation* are essential to secure this heritage.

6 (b) : Define carbon sequestration. Mention two natural methods and one artificial method of carbon sequestration. How does ocean water contribute to carbon sequestration? **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants a ***definition***, ***two natural*** *and* ***one artificial*** *method, and a clear explanation of the* ***ocean's role*** *via the* ***solubility pump*** *and* ***biological pump***, *with Indian context.*

❶ ***Introduction*** **:** *Define carbon sequestration and link it to climate mitigation and India's NDC.*

❷ ***Main Body*** **:** ❖ *Definition and types* ❖ *Natural methods* ❖ *Artificial method* ❖ *Ocean sequestration pumps*

❸ ***Conclusion*** **:** *Forests and oceans are the planet's twin carbon sinks.*

Carbon sequestration is the *long-term capture and storage of atmospheric CO2 in biomass, soils, oceans or geological formations*, reducing ***greenhouse warming***. India's **NDC** targets an *additional sink of 2.5–3 billion tonnes* CO_2 through forest and tree cover by 2030.

A. Natural Methods

1. ***Forest (terrestrial biological) sequestration*:** photosynthesis stores carbon in *biomass*, *deadwood and litter*; India's forest carbon stock ≈ *7,285 million tonnes* (ISFR 2023). Tools: *afforestation*, *Green India Mission*, *Nagar Van Yojana*, *agroforestry*.
2. ***Soil carbon sequestration*:** humus and *soil organic carbon* via root turnover and litter; enhanced by *conservation tillage*, *cover crops*, *biochar*, grassland management.
   - Other natural sinks: ***blue carbon*** in ***mangroves*** (Sundarbans), seagrasses and ***peatlands***.

B. Artificial Method

- ***Carbon Capture and Storage (CCS/CCUS):*** CO2 captured from power plants or industry, compressed and injected into *deep saline aquifers*, *depleted oil fields* or *basal***t** (mineralisation); e.g. NTPC and ONGC pilot projects, Norway's Sleipner. Other options: *Direct Air Capture*, *BECCS*.

Capture → Compression → Transport (pipeline) → Injection (≥ 800 m) → Monitoring

C. Role of Ocean Water

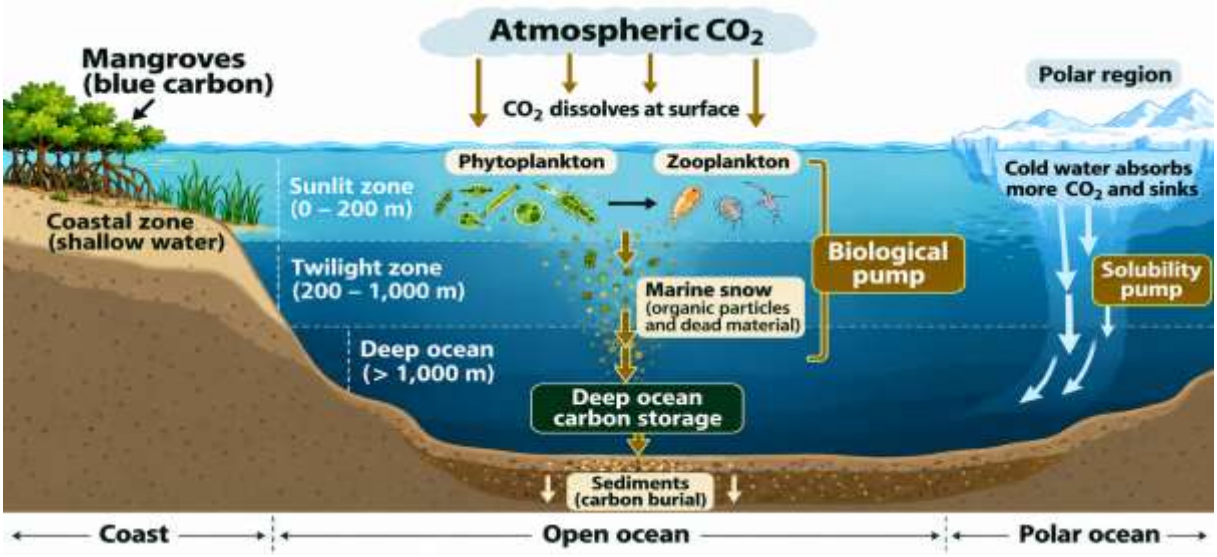
Oceans hold about **50 *times*** the atmospheric carbon and absorb nearly **25–30% *of anthropogenic* CO2** through two pumps:

1. ***Solubility (physical) pump*:** CO2 dissolves more in ***cold water***; in polar regions dense cold water ***sinks*** (thermohaline circulation), carrying dissolved inorganic carbon to the ***deep ocean*** for centuries.

$$CO2 + H2O \rightleftharpoons H2CO3 \rightleftharpoons H+ + HCO3- \rightleftharpoons 2H+ + CO3\ 2-$$

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2. ***Biological pump*: *phytoplankton*** fix CO2 by photosynthesis; dead organisms, *faecal pellets* and *marine snow* sink, exporting *organic carbon* to deep waters and sediments.
3. ***Carbonate pump*:** *coccolithophores, corals and foraminifera* form **CaCO3** shells that settle as sediments.
4. ***Coastal blue carbon*:** mangroves and seagrass store carbon in waterlogged soils up to **4 *times*** faster than terrestrial forests per unit area.



- ***Concerns*: *ocean acidification*** (pH fall ≈ 0.1 since industrialisation) and warming ***weaken the solubility pump*** and harm coral reefs.

Thus, ***forests, soils and oceans*** together form Earth's main carbon sinks; protecting them alongside **CCS** is vital for India's ***net-zero* 2070** goal.

6 (C) : How do production and consumption patterns of forest resources influence market structures? What methods can be employed to assess future projections for sustainable forest-based economic planning in India? **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***link between production/consumption patterns and market structure*** *(competition, pricing, channels) and the* ***demand-supply projection methods*** *usable for* ***forest sector planning*** *in India.*

❶ ***Introduction*** **:** *Define market structure and its components.*

❷ ***Main Body*** **:** ❖ *Production patterns and market structure* ❖ *Consumption patterns and market structure* ❖ *Projection methods*

❸ ***Conclusion*** **:** *Reliable projections enable sustainable, demand-led forest planning.*

Market structure means the *organizational characteristics of a market* its size, design and manner of operation – that affect the ***nature of competition and pricing***. Its components are *concentration of market power, degree of product differentiation, conditions of entry, flow of market information and degree of integration.*

A. Influence of Production Patterns

1. ***Concentrated state ownership*:** timber from *Forest Development Corporations* and depot ***auctions*** creates *monopoly/oligopoly* supply; few large paper mills create ***oligopsony*** for pulpwood; *mechanization and technology* further concentrate processing.

2. ***Agroforestry shift*:** the *bulk of industrial wood* now comes from ***trees outside forests*** (*Eucalyptus*, *Populus deltoides*, *Melia dubia*) – many small growers make the market *more competitive* but ***price-volatile*** (e.g. Yamunanagar poplar mandi).
3. ***NTFP production*:** scattered, perishable output and weak holding capacity cause *middlemen dominance*; *cooperative/group marketing*, *JFM*, *MSP for MFP* and *Van Dhan* increase the *number of sellers and buyers* and bargaining power.
4. ***Marketing costs*:** *transport*, *storage*, *financing and market information* costs shape whether markets stay local and thin or become integrated.

B. Influence of Consumption Patterns

5. ***Substitutes*:** *iron/aluminium doors and windows*, *plastics*, and *e-books*, *recycling and changing reading habits* lower demand for joinery timber and paper, changing product mix.
6. ***Changing income and habits*:** demand shifts in *form and quality* – *panels*, *plywood*, *MDF*, certified wood – raising *product differentiation* and import dependence.
7. ***Rural fuelwood/fodder*** consumption remains largely *non-monetized*, keeping local markets informal.

C. Methods for Future Projection

Method	Basis	Use
Trend extrapolation	Time-series of past production/consumption	Short-term timber demand
Econometric models	Demand linked to *GDP*, *population*, *price*, *income elasticity*	Industrial wood, paper
Input–output / end-use method	Wood per unit of housing, packaging, furniture	Sectoral demand
Delphi / expert opinion	Structured expert consensus	New products, policy scenarios
Scenario & GIS-inventory modelling	***FSI/ISFR growing stock***, NFI, growth rates	Supply potential, sustainable yield

- Supplemented by ***market intelligence systems*** and ***working-plan yield data***.

Thus, understanding production–consumption shifts and using *combined projection tools* allows India to plan *sustainable*, *market-responsive forest economies*.

7 (a) : Describe the process and importance of wood seasoning. How do air and kiln seasoning methods differ? **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***meaning and process of seasoning*** *(moisture movement, stacking, drying schedule), its* ***importance****, and a clear* ***comparison of air vs kiln seasoning****.*

❶ ***Introduction*** **:** *Define seasoning and moisture content of green and seasoned wood.*

❷ ***Main Body*** **:** ❖ *Water in wood and moisture content* ❖ *Process steps* ❖ *Importance* ❖ *Air vs kiln comparison*

❸ ***Conclusion*** **:** *Proper seasoning adds value and service life to timber.*

Seasoning is the *controlled removal of excess moisture* from green timber (MC **50–200%**) down to **10–12%** in well-seasoned timber (***ISI code***; **10–20%** for doors and windows), so that it is *dimensionally stable* and durable. Water is held as *free water* (capillary, in cell cavities), *bound water* (in cell walls) and ***water vapour***.

Moisture Content (%) = (Wet weight – Oven-dry weight) / Oven-dry weight × 100

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A. *Process of Seasoning*

1. ***Removal of free water*:** water in cell cavities evaporates first, down to the *fibre saturation point* **(~25–30%)**; no shrinkage occurs.
2. ***Removal of bound water*:** water in cell walls leaves next, causing *shrinkage* (tangential ~8–12%, nearly twice radial ~4–6%; longitudinal negligible ~0.1%).
3. ***Conversion and stacking*:** logs sawn into planks; *horizontal stacking* on *crossers/stickers* for air flow; *vertical stacking* for rapid surface drying of non-refractory woods.
4. ***Controlled drying*:** regulating *temperature, relative humidity and air circulation* (also governed by ***species, initial MC, grain direction and thickness***) as per the ***refractoriness class*** – Class A highly refractory (*Shorea robusta, Anogeissus latifolia*), Class B moderately refractory (*Tectona grandis, Dalbergia sissoo*), Class C non-refractory (conifers, *Bombax ceiba*).
5. ***Protection of stack*:** seasoning sheds – only rain protection for non-refractory, ***tight roof with ventilated walls*** for highly refractory woods; end-coating or ***salt seasoning*** to prevent ***cracks, splits and warping***.
    - Other methods: ***water seasoning*** (2–4 weeks in running water), ***chemical***, ***electrical*** (high-frequency, 5–8 hours) and ***solar kilns***.

B. *Importance of Seasoning*

- *Reduces fungal and insect attack* and sap stain.
- *Reduces weight* – lowers ***transport cost***.
- ***Dimensional stability*** – avoids *shakes, splits, warping* in service.
- Fits timber for ***painting*** and ensures proper ***preservative penetration***; controls drying rate to ***minimize damage***.
- Raises ***market value*** and allows use of ***secondary species***.

C. *Air vs Kiln Seasoning*



Basis	Air seasoning	Kiln seasoning
Heat source	***Air is the only medium*** carrying heat	***Steam*** (also furnace / solar) heat
Control	No control of T, RH, air flow	***Full control*** of T, RH, circulation
Time	Slow – months to a year	Fast – days to weeks

Final MC	Only up to ***air-dry* (~15–20%)**	Any desired MC (**8–12%**)
Weather dependence	Seasonal, interrupted by rain	***24×7, all year***
Insects and fungi	Timber ***more susceptible***	Less susceptible
Space	***More stacking space***	Less space
Strength	Gives ***stronger timber***	***Slightly weaker*** timber
Cost	***Simple and economical***	***High investment***, running cost, skilled labour
Suitability	Small users, rural depots	Furniture, plywood, export industry

Thus, seasoning – air for economy, kiln for *speed and precision*, and *solar kilns* as a low-cost hybrid – is essential for *efficient wood utilization*.

7 (b) : How do Indian forest policies address land use and resource management? What reforms are needed for sustainable and inclusive forest management? **[15 M]**

Approach

***Understanding the Question* !!**

Here, the examiner wants an evaluation of how the **NFPs of 1894, 1952, 1988** *(and the* **Draft NFP 2018***) handled* ***land use and resource management****, followed by* ***specific reforms*** *for* ***sustainability and inclusion****.*

❶ ***Introduction*** **:** *Forest policy as the guiding framework for land and resource use.*

❷ ***Main Body*** **:** ❖ NFP 1894 ❖ NFP 1952 ❖ NFP 1988 ❖ *Draft* NFP 2018 ❖ *Reforms*

❸ ***Conclusion*** **:** *Policy must move from control to co-management.*

A ***forest policy*** sets national goals for the ***allocation of land*** and ***use of forest resources***. India's policies show a shift from ***revenue*** to ***conservation*** to ***people-centred management***.

A. Policy-wise Approach to Land Use and Resources

Policy	Land use	Resource management
1894 (Voelker report, 1893)	Four classes – forests for ***climatic/physical protection***, ***commercial timber***, ***minor forests***, ***pastures***; ***no restriction on diversion*** for agriculture	***Revenue-oriented***, commercial timber (teak, sal, deodar); grazing rights very limited; silent on wildlife, shifting cultivation
1952	Target ***33% cover (60% hills, 20% plains)***; ***functional classification*** – protection, national, village forests, tree lands; ***balanced and complementary use of forest land***, preference to agriculture; ***silent on diversion*** (e.g. Shivalik fruit belt)	***Production-oriented*** – six national needs incl. defence, communication, industry and revenue; grazing with nominal fees; no people's participation; ignored rights and concessions; no coercive check on shifting cultivation
1988	***33% (66% hills)*** goal; ***strict control on diversion*** (CAMPA, mine management plans); ***steep slopes, catchments and sensitive areas*** severely protected; afforestation of ***degraded lands***, social, farm and extension forestry	***Ecological stability first***; local needs of fuel, fodder, MFP prioritised; ***no working without approved plan***; restricted ***clear-felling*** and ***exotics***; grazing as per ***carrying capacity***; ***shifting cultivation*** restricted to affected area; industries to raise ***own raw material***; ***wildlife corridors***; ***tribal cooperatives*** replace contractors; **JFM** (1990)
***Draft* NFP 2018**	More ***agroforestry, social forestry, captive plantations*** to relieve natural forests	***Climate change***, low productivity, ***human–wildlife conflict***, water crisis, pollution, declining investment; criticised for ***privatisation***, no

		mechanism for competing land demands, weak ***people's participation***, silence on ***mining and NE diversion***

B. Achievements

- Forest and tree cover at about **25% of GA** (ISFR 2023); **Forest (Conservation) Act 1980** curbed diversion; ***JFM committees*** across states; **FRA 2006** recognised community rights.

C. Reforms Needed

1. ***Adopt a new NFP:*** finalise the 2018 draft with *clear land-use targets* and *landscape restoration* (**26 Mha** degraded land by 2030, UNCCD COP-14 pledge).
2. ***Tenure security:*** convergence of *FRA 2006 CFR* with working plans; *Gram Sabha* as co-manager.
3. ***Statutory JFM*** with fair *benefit-sharing* and women's participation.
4. ***Agroforestry and TOF:*** liberal *felling/transit rules*, MSP and ***buy-back*** for farm wood.
5. ***Quality, not area:*** restore *open/degraded forests*, control ***invasives*** (*Lantana camara*), fire and grazing.
6. ***Valuation and finance:*** *PES, Green Credit*, transparent **CAMPA** use, ***carbon markets***.
7. ***Science and data:*** *National Working Plan Code 2023*, remote sensing, ***certification*** for market access.

Thus, Indian forest policy must evolve from ***state control*** to ***inclusive, landscape-level co-management*** that balances ***ecology, livelihoods and economy***.

7 (c) : How does air pollution lead to forest dieback? Mention its causes and visible effects. **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***mechanism*** *by which* ***air pollutants*** *cause* ***progressive forest decline (dieback)****, the* ***pollutant sources/causes****, and the* ***visible symptoms*** *on trees and stands.*

❶ ***Introduction*** **:** *Define forest dieback.*

❷ ***Main Body*** **:** ❖ *Causes (pollutants)* ❖ *Mechanism* ❖ *Visible effects*

❸ ***Conclusion*** **:** *Pollution control is part of forest protection.*

Forest dieback is the ***progressive death of twigs and branches from the tips backward***, leading to ***crown thinning*** and stand-level ***decline***, often triggered by chronic stress such as ***air pollution*** (e.g. *Waldsterben* in Central Europe).

A. Causes – Major Pollutants

Pollutant	Source	Main action
SO2, NOx	Thermal power, smelters, vehicles	***Acid rain***, leaf necrosis
Ozone (O3)	Photochemical smog	Stippling, reduced photosynthesis
Fluorides	Aluminium, brick kilns	Tip and margin burn
Heavy metals, dust	Mining, cement units	Stomatal blocking, root toxicity
NH3 / N *deposition*	Agriculture, industry	Nutrient imbalance

B. Mechanism of Dieback

1. ***Direct foliar injury:*** SO_2, NO_2 *and* O_3 damage leaf surfaces and disrupt *stomatal function* (abnormal closure); *dust fills stomatal cavities – reduced photosynthesis* and growth.
2. ***Acidification:*** sulphur pollution and *acid rain* damage *young shoot tips*, lichens and ferns; acidified soils leach **Ca, Mg, K**, injuring ***fine roots***.

3. ***Nutrient imbalance*:** *nitrogen deposition* from *NOx and NH3* disrupts the natural nutrient balance and cycling in soil.
4. ***Secondary attack*:** prolonged exposure weakens trees, making them susceptible to *pests*, *pathogens* and drought – *decline and mortality*.

Pollutant → Foliar & root injury → Carbon & nutrient stress → Secondary pests/drought → Dieback

C. Visible Effects

- *Discoloration (chlorosis)*, *stippling*, *necrotic lesions*, *tip burn*, premature *leaf fall*.
- *Crown thinning*, dead top branches, *reduced increment*.
- Loss of *lichens and mosses* (bio-indicators); sensitive species decline – change in ***composition***.
- Indian cases: mango *black-tip disease* caused by *CO2 and SO2 pollution*; vegetation stress around *thermal-power and mining hubs*.

Thus, forest dieback from air pollution needs ***emission control***, ***green belts of tolerant species*** and ***long-term monitoring***.

8 (a) : Define forest ecology. Briefly describe the key parameters of forest productivity and explain the methods used to determine ecosystem productivity. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants a precise ***definition of forest ecology****, the* ***parameters of productivity*** *(GPP, NPP, NEP, secondary productivity, biomass, factors) and the* ***measurement methods*** *for ecosystem productivity.*

❶ ***Introduction*** **:** *Define forest ecology and productivity.*

❷ ***Main Body*** **:** ❖ *Definition* ❖ *Parameters of productivity* ❖ *Factors* ❖ *Methods of measurement*

❸ ***Conclusion*** **:** *Productivity estimation guides management and carbon accounting.*

Forest ecology is the scientific study of the *interactions between forests and their living and non-living components* – trees, plants, animals, *soil*, *water*, *air and humans* – covering *structure*, *function*, *succession and energy/nutrient flow*.

Ecosystem productivity is the *rate of dry-matter (biomass) production* per unit area per unit time (***g m⁻² yr⁻¹*** or ***kcal m⁻² yr⁻¹***).

A. Key Parameters

1. ***Gross Primary Productivity (GPP)*:** total energy assimilated by producers – total rate of photosynthesis including respiration.
2. ***Net Primary Productivity (NPP)*:** biomass left after autotrophic respiration – available to the next trophic level.

$$NPP = GPP - Ra \text{ (autotrophic respiration)}$$

3. ***Net Ecosystem Productivity (NEP)*:** NPP minus *heterotrophic respiration* – net carbon gain of the ecosystem.
4. ***Secondary productivity*:** biomass accumulation by ***heterotrophs*** – transferred, not true productivity.
5. ***Standing crop/biomass*** and ***Mean Annual Increment (MAI)*** – practical forestry indicators.

B. Factors Influencing Productivity

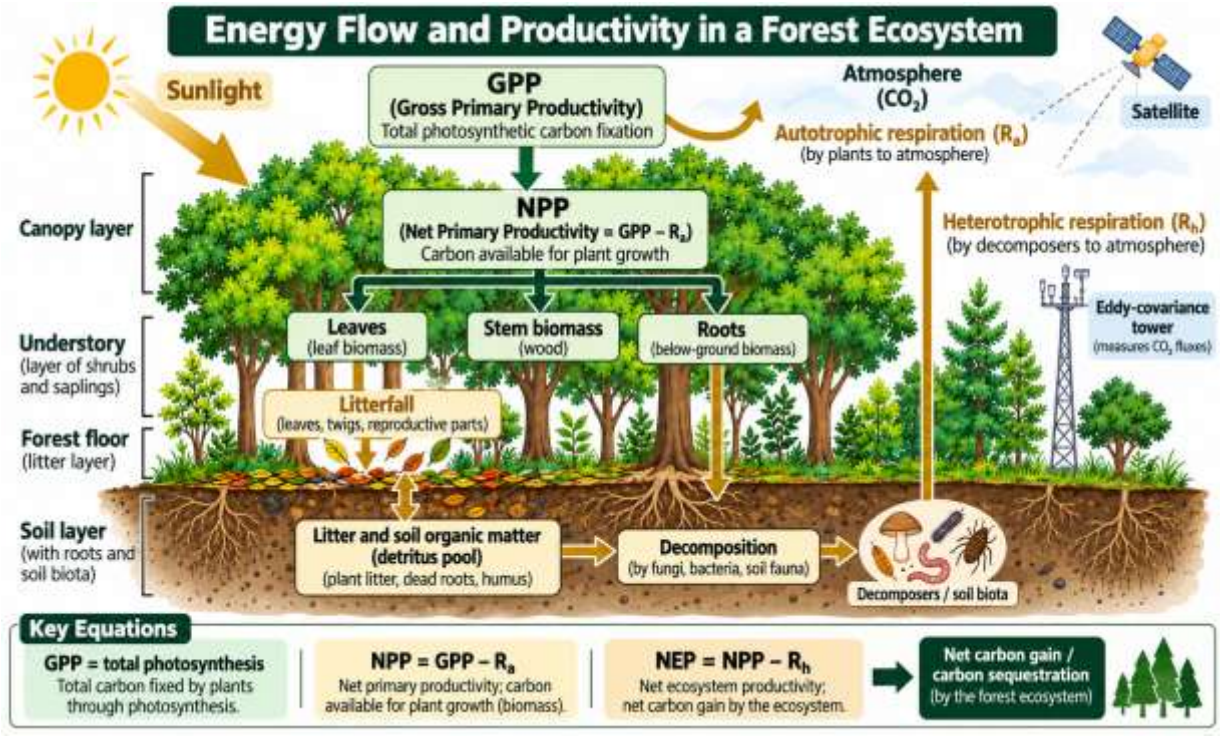
- ***PAR/solar radiation***, ***temperature***, ***moisture*** (precipitation, soil moisture, transpiration), ***mineral***

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nutrients, and ***biotic/human interference***; e.g. swamps and marshes (~2500 g m^{-2} yr^{-1}) > temperate forest (~1250) > cultivated land (~650) > tundra (~140).

C. Methods of Measurement

Method	Principle	Remarks
Harvest method	Periodic clipping/felling and ***dry weighing*** of biomass	Accurate, destructive; grasslands, plantations
Allometric equations	Biomass from **DBH**, ***height***, ***wood density***	Standard for forests
Litterfall and increment method	NPP = biomass increment + litterfall + losses	Long-term plots
Gas-exchange / CO2 method	Chamber or ***Eddy covariance*** flux towers	Measures GPP, NEP directly
O2 (light-dark bottle) method	O2 change in light vs dark	Aquatic systems
Chlorophyll method	Chlorophyll per area vs photosynthetic rate	Indirect
Remote sensing	**NDVI**, **LAI**, satellite NPP models (MODIS)	Landscape and national scale



Thus, measuring **GPP, NPP *and* NEP** through combined field and ***remote-sensing methods*** underpins ***yield regulation and carbon accounting***.

8 (b) : What are environmentally sound forest harvesting practices? Why are they important for sustainable forestry?. **[15 M]**

Approach

Understanding the Question !!

Here, the examiner wants the concept and ***components of environmentally sound harvesting*** *(Reduced Impact Logging) across* ***pre-harvest, harvest and post-harvest*** *stages, and its* ***ecological, economic and social importance****.*

❶ **Introduction** : *Define logging and RIL.*

❷ **Main Body** : ❖ *Concept* ❖ *Pre-harvest practices* ❖ *Harvest practices* ❖ *Post-harvest practices* ❖ *Importance*

❸ **Conclusion** : *Sound harvesting reconciles production with conservation.*

Environmentally sound harvesting – mainly ***Reduced Impact Logging (RIL)*** – is the ***intensively planned and carefully controlled*** execution of felling, extraction and transport to ***minimise damage to residual stand, soil and water***. In conventional logging ***45–55% of wood*** becomes useless.

A. *Pre-harvest Practices*

1. ***Forest organization*:** operational plan, compartments and ***working plan*** prescriptions.
2. *Pre-harvest inventory* and *mapping of crop trees*, terrain and streams.
3. *Planning of roads, skid trails, landings* to minimize soil disturbance; ***stream buffers***.
4. ***Vine cutting*** where vines link crowns; fixing *felling direction* per tree; marking *seed trees and potential crop trees*; pre-constructing trails.

B. *Harvesting Practices*

1. ***Directional felling*** to protect residual trees and ease skidding.
2. ***Low stumps*** and ***optimal bucking*** to maximise recovery.
3. ***Winching*** logs to planned trails; machines stay on trails.
4. ***Yarding systems*** that suspend logs above ground on steep slopes; ***seasonal restrictions*** in monsoon.
5. ***Animal logging*** (elephants, bullocks) in sensitive Indian terrain.

C. *Post-harvest Practices*

- ***Restoring drainage***, closing skid trails, ***erosion control***.
- ***Post-harvest assessment*** to give feedback to managers and crews on RIL compliance; ***regeneration*** (natural/artificial).

D. *Importance for Sustainable Forestry*

Dimension	***Benefit***
Ecological	Less *soil compaction and erosion*, protects *water quality*, *biodiversity* and ***regeneration***
Climate	Lower ***carbon emissions*** from damage; supports **REDD+**
Economic	Fewer ***lost logs*** (felled but not extracted), higher recovery and revenue, ***lower harvesting cost*** through better planning
Silvicultural	Healthy ***residual stand*** ensures ***sustained yield***
Social & market	Worker ***safety***, ***FSC/PEFC certification*** and export access

E. *Constraints*

- Poor ***philosophical acceptance*** (logging hidden away, poorly supervised), belief that RIL is costlier, lack of ***skilled personnel***, and ***aerial systems*** being uneconomic in developing countries – solved by ***training*** and ***certification incentives***.

Thus, environmentally sound harvesting turns logging from a ***destructive operation*** into a ***silvicultural tool*** for ***sustainable forest management***.

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8 (c) : How do cooperatives and the private sector shape forest economics and enhance the socio-economic well-being of forest-dependent communities through sustainable resource management, value addition and livelihood generation? **[10 M]**

Approach

Understanding the Question !!

Here, the examiner wants the ***roles of cooperatives and the private sector*** *in* ***forest economics****, specifically in* ***sustainable resource management, value addition and livelihoods****, with* ***Indian examples*** *and limitations.*

❶ ***Introduction*** **:** *Forest-dependent communities and MFP dependence.*

❷ ***Main Body*** **:** ❖ *Role of cooperatives* ❖ *Role of private sector* ❖ *Socio-economic impacts* ❖ *Concerns*

❸ ***Conclusion*** **:** *Partnerships must be equitable and ecologically safe.*

MFP provides 20–40% of the annual income of forest-dwelling tribals, but it is ***perishable***, with *no holding* ***capacity***, poor infrastructure, little value addition and *exploitation by middlemen*. Cooperatives and private enterprises link these producers to markets.

A. Role of Cooperatives

1. ***Collective bargaining*****:** *tendu leaf cooperatives* of *MP MFP Federation*; *TRIFED* and *LAMPS* eliminate middlemen.
2. ***Value addition*****: PM Van Dhan Yojana** – SHGs of up to *20 MFP gatherers*, a *Van Dhan Vikas Kendra per 15 SHGs (300 beneficiaries)* – processing honey, lac, *Madhuca indica* products; **TRIFED** gives market access via *tribal melas, retail outlets and e-commerce*.
3. ***Sustainable harvest*****:** improved *collection methods, sustainable extraction through JFM committees* and CFR.
4. ***Benefit sharing*****:** bonus/profit distribution to collectors; ***women empowerment***.

B. Role of Private Sector

1. ***Agroforestry partnerships*****:** *ITC Bhadrachalam, WIMCO* – clonal *Eucalyptus, Populus* with ***buy-back*** assure farm income.
2. ***Technology and processing*****:** efficient processing reduces *wastage*, builds *supply chains* and *monetises tribal knowledge* (crafts, cuisine, organic foods).
3. ***Markets and brands*****:** e-commerce, GI products, ***certification*** (FSC).
4. ***Finance and CSR*****: PPP** and CSR funds for Van Dhan; **CSR–NGO–*Panchayat*** tie-ups for education, health, water, off-grid power; alternate livelihoods (***Kadaknath poultry***, ecotourism).

C. Socio-economic Outcomes

- ***Higher income and employment***, poverty alleviation, reduced distress migration.
- Better health, education, ***ecological and food security***; less pressure on forests, ***soil–water conservation*** and nutrient recycling.

D. Concerns

- Private ***profit motive*** may cause *over-exploitation* and tribal exploitation; cooperatives suffer *politicization, low working capital*. Need *FRA-based rights*, fair pricing (**MSP *for* MFP**) and monitoring.

Thus, a *cooperative–private–state partnership* can make forest economics *inclusive, value-adding and sustainable*.