Secure Synopsis compilation for February-2026

General Studies-3

Table of contents

Indian Economy and issues relating to planning, mobilization, of resources, growth, development and employment.

Q. Public investment can buy time, but not growth sustainability. Examine the role of government capital expenditure in driving growth and the limits of state-led investment as a long-term growth engine. Also discuss the conditions necessary for a durable private investment cycle. (15 M)

Introduction

Public capital expenditure has emerged as the principal macro-stabiliser in India's post-pandemic recovery, cushioning growth amid global uncertainty and weak private investment. However, growth sustainability ultimately depends on how quickly public investment can crowd in private capital rather than substitute for it.

Body

Role of government capital expenditure in driving growth

1. **Demand stimulus and counter-cyclical support:** Public capex directly injects demand during periods of private investment slowdown, stabilising the business cycle.
   Eg: Economic Survey 2023–24 highlights central government capex as a key counter-cyclical tool sustaining growth when global demand and exports weakened.
2. **Crowding-in of private investment through infrastructure:** High-quality infrastructure reduces logistics costs, improves productivity and raises expected private returns.
   Eg: National Infrastructure Pipeline (NIP) investments in roads and logistics corridors have lowered freight costs, cited by **NITI Aayog** as critical for manufacturing competitiveness.
3. **Balance-sheet repair and confidence building:** Sustained public investment signals policy commitment, improving business confidence and leveraging healthier corporate balance sheets.
   Eg: RBI Financial Stability Report 2024 notes improved corporate leverage and banking sector health alongside sustained public infrastructure spending.
4. **Employment and multiplier effects:** Capital spending has a higher output and employment multiplier compared to revenue expenditure.
   Eg: RBI research studies estimate infrastructure capex multipliers to be significantly above one, supporting both short-term growth and medium-term capacity.

5. **Strategic capability creation:** Public capex seeds future growth by building assets in transport, energy and digital infrastructure.
   Eg: PM Gati Shakti National Master Plan (2021) integrates infrastructure planning to unlock long-term productivity gains.

Limits of state-led investment as a long-term growth engine

1. **Fiscal constraints and debt sustainability:** Persistent reliance on public capex is constrained by fiscal deficit and debt considerations under **Article 292 of the Constitution**.
   Eg: FRBM framework emphasises fiscal discipline to maintain macroeconomic credibility and borrowing capacity.
2. **Risk of crowding out private investment:** Large government borrowing can keep long-term interest rates elevated, discouraging private capital formation.
   Eg: RBI Monetary Policy Reports caution that high sovereign bond supply can limit transmission of monetary easing.
3. **Diminishing marginal returns:** Once core infrastructure gaps narrow, incremental public investment yields lower growth dividends without complementary private activity.
   Eg: Economic Survey 2022–23 notes that infrastructure-led growth must eventually transition to productivity-driven private investment.
4. **Execution and governance limitations:** State capacity constraints can delay projects and reduce efficiency.
   Eg: CAG audit observations on infrastructure projects frequently highlight time and cost overruns.
5. **Limited innovation and risk-taking:** Governments are less suited than private firms to drive innovation, technology adoption and market discovery.
   Eg: OECD growth studies show innovation-led growth is predominantly private-sector driven.

Conditions necessary for a durable private investment cycle

1. **Macroeconomic stability and policy credibility:** Low inflation, predictable taxation and fiscal discipline reduce uncertainty for long-term investors.
   Eg: RBI's inflation-targeting framework (2016) has anchored expectations, supporting investment planning.
2. **Deep and efficient financial markets:** Availability of long-term finance at reasonable cost is critical for capital formation.
   Eg: Raghuram Rajan Committee on Financial Sector Reforms emphasised deep bond markets for infrastructure and industrial investment.
3. **Regulatory certainty and contract enforcement:** Stable rules and faster dispute resolution improve investor confidence.
   Eg: Insolvency and Bankruptcy Code, 2016, recognised by the **World Bank**, strengthened creditor confidence and capital recycling.
4. **Skilled workforce and productivity growth:** Private investment responds to availability of skilled labour and scalable talent pipelines.
   Eg: National Skill Development Corporation reforms align skilling with industry demand, as noted in **Economic Survey 2023–24**.
5. **Strong domestic demand and income growth:** Sustainable private investment requires expanding consumption driven by rising real wages and employment.

Eg: Periodic Labour Force Survey trends, cited in **Economic Survey**, link job-rich growth to investment revival.

Conclusion

Public investment can stabilise growth and build essential capacity, but it cannot substitute for private enterprise as the engine of long-term prosperity. A credible shift towards private-led, job-rich growth requires stable macroeconomics, deep finance, strong institutions and rising household incomes to convert today's public push into tomorrow's self-sustaining investment cycle.

Q. Monetary easing without adequate liquidity is like pressing the accelerator with the handbrake on. Analyse India's recent experience of rate cuts with tight liquidity. Suggest measures to strengthen monetary transmission. (15 M)

Introduction

Monetary easing transmits through the repo rate only when the banking system has sufficient liquidity to expand credit. If liquidity remains tight, rate cuts get offset by higher market borrowing costs, weakening transmission.

Body

Monetary easing without adequate liquidity is like pressing the accelerator with the handbrake on.

1. **Liquidity is the operating channel of monetary policy:** Repo cuts work only if system liquidity allows banks to borrow and lend at lower rates across the money market.
   Eg: RBI's Liquidity Management Framework (LAF) aims to keep **WACR** aligned with the policy repo rate.
2. **Tight liquidity hardens short-term rates:** Liquidity deficit pushes up overnight and short-term rates, diluting the impact of repo cuts.
   Eg: Persistent deficit increases dependence on **MSF** and repo windows, which are costlier than normal market funding.
3. **Banks protect margins by raising spreads:** When funding is tight, banks transmit rate cuts partially by widening spreads over the benchmark.
   Eg: In deficit phases, even with unchanged repo, banks often reprice **MCLR** upward due to higher marginal funding cost.
4. **Credit growth becomes quantity-constrained:** Easing becomes ineffective because banks face constraints in expanding loan books despite lower policy rates.
   Eg: Liquidity deficit reduces incremental lending to **MSMEs** and unsecured borrowers due to higher risk and funding cost.
5. **Expectations channel weakens:** If liquidity does not support easing, markets doubt durability of accommodative conditions, tightening financial conditions.
   Eg: Bond yields may remain elevated even after repo cuts if liquidity deficit persists.

India's recent experience of rate cuts with tight liquidity

1. **Easing cycle in 2025 with limited pass-through:** RBI reduced repo cumulatively in 2025, but transmission remained uneven due to liquidity constraints.
   Eg: The article notes repo cut to **5.25% in Dec 2025** and **125 bps cumulative cuts in 2025**.

2. **Liquidity stayed persistently tight for months:** System liquidity remained below comfortable levels, weakening the credit impulse.
   Eg: The article cites liquidity as % of **NDTL below 1% for five months**, and around **0.2% in January**.
3. **Government cash surplus drained liquidity:** High government balances parked with RBI reduced funds available with banks.
   Eg: The article explicitly flags **government cash surplus** as a key factor behind low system liquidity.
4. **Forex intervention created a liquidity drain:** RBI's forex operations to manage rupee volatility reduced rupee liquidity in the system.
   Eg: The article highlights continuing drain from **forex intervention**, tightening domestic liquidity.
5. **Shift in focus from rate cuts to liquidity tools:** With repo cuts nearing a pause, RBI's operational priority moved to liquidity infusion measures.
   Eg: The article points to possible **OMO calendar** and a **CRR cut** to inject durable liquidity.

Measures to strengthen monetary transmission

1. **Durable liquidity infusion through OMOs:** RBI should use bond purchases to inject stable liquidity when deficits persist.
   Eg: Announcement of an **OMO calendar** improves predictability and anchors money market expectations.
2. **CRR rationalisation for permanent liquidity:** A calibrated CRR cut can release lendable resources without waiting for market operations.
   Eg: The article itself flags a possible **CRR cut** to infuse durable liquidity.
3. **Better coordination on government cash management:** Aligning Centre's cash balances with RBI liquidity operations reduces unintended tightening.
   Eg: Improved timing of large transfers and cash build-ups reduces liquidity shocks in the banking system.
4. **Strengthen pass-through beyond repo-linked loans:** Improve transmission for MCLR-linked and deposit-driven segments through competition and transparency.
   Eg: External Benchmark Lending Rate (EBLR) has improved pass-through compared to legacy internal benchmarks.
5. **Liquidity forecasting and communication upgrades:** Clear liquidity guidance improves market alignment and reduces volatility in short-term rates.
   Eg: RBI's operating objective of keeping **WACR close to repo** requires accurate forecasting and timely intervention.

Conclusion

India's experience shows that repo cuts alone cannot deliver easier credit if liquidity remains structurally tight. Stronger transmission requires predictable durable liquidity, improved cash coordination, and deeper pass-through across lending benchmarks.

Q. Bring out the rationale for shifting fiscal policy focus from deficit targets to debt-to-GDP targeting. Evaluate the benefits and risks of such a framework for India. (15 M)

Introduction

Sound public finance is ultimately about one thing: **keeping the State solvent while keeping the economy growing**. In this context, shifting the fiscal anchor from annual deficit targets to **debt-to-GDP** aims to align fiscal policy with long-term sustainability rather than short-term accounting.

Body

Rationale for shifting from deficit targets to debt-to-GDP targeting

1. **Stock variable captures sustainability better than flow variable:** Fiscal deficit is an annual flow, but **debt is the accumulated burden**, making debt-to-GDP a more meaningful indicator of long-term fiscal health.
   Eg: FRBM Act, 2003 was originally deficit-focused, but post-Covid debt levels made debt sustainability a more realistic anchor.
2. **Allows counter-cyclical flexibility without losing credibility:** A debt anchor can permit temporary higher deficits during downturns while still committing to a medium-term debt path.
   Eg: During **Covid-19**, fiscal deficit widened sharply; a debt framework better accommodates such shocks than rigid annual deficit ceilings.
3. **Better alignment with global fiscal best practices:** Many countries increasingly use debt ratios as primary fiscal anchors, supported by medium-term fiscal frameworks.
   Eg: India's recent move to target **debt-to-GDP** reflects international macro-fiscal practice, especially after global post-pandemic debt expansion.
4. **Reduces incentive for creative accounting:** Strict deficit targets can encourage off-budget borrowings and shifting liabilities to PSUs, whereas a debt framework can capture these over time.
   Eg: The use of **extra-budgetary resources (EBR)** for financing public spending became prominent in the late 2010s, raising transparency concerns.
5. **Signals commitment to macro-stability for investors:** Debt targeting strengthens confidence by signalling that fiscal policy will not become structurally expansionary.
   Eg: Lower risk perception improves borrowing conditions and supports investment sentiment, especially when global rates are uncertain.

Benefits of a debt-to-GDP framework for India

1. **Improves fiscal credibility and stability:** A clear debt glide path strengthens confidence in macroeconomic management and reduces uncertainty for markets.
   Eg: A credible debt anchor supports stable government borrowing costs and reduces crowding-out risk for private investment.
2. **Creates space for growth-supporting public capex:** If debt remains on a stable path, fiscal policy can prioritise capital expenditure without being trapped by annual deficit optics.
   Eg: India's capex-led strategy in recent budgets relies on sustaining fiscal space while maintaining medium-term prudence.
3. **Encourages medium-term budgeting discipline:** Debt targeting naturally pushes governments toward **multi-year fiscal planning** instead of year-to-year deficit management.
   Eg: Medium-term fiscal frameworks reduce ad hoc spending spikes and improve expenditure quality.
4. **Captures long-term liabilities more realistically:** Debt frameworks can integrate contingent liabilities and off-budget borrowings into sustainability analysis.

Eg: PSU borrowings and guarantees become harder to ignore when debt sustainability becomes the central metric.

5. **Supports cooperative federalism in fiscal governance:** A debt anchor can enable more transparent fiscal coordination between Centre and States under a shared sustainability framework.
   Eg: Post-pandemic, both Centre and States faced elevated debt burdens, requiring coordinated consolidation rather than fragmented deficit rules.

Risks and limitations of debt-to-GDP targeting in India

1. **Debt ratio can fall due to inflation, not fiscal discipline:** High nominal GDP growth may reduce the ratio even when fiscal fundamentals are weak.
   Eg: If debt declines mainly due to inflation-driven GDP expansion, it may mask structural fiscal stress.
2. **Risk of weakening annual fiscal accountability:** A debt anchor may allow governments to postpone hard consolidation decisions by pushing adjustment into the future.
   Eg: Governments may keep running high deficits while claiming long-term debt convergence.
3. **State-level debt and contingent liabilities remain a challenge:** India's general government debt includes States, but coordination mechanisms are weaker than in unitary systems.
   Eg: Fiscal stress in some States can undermine overall debt sustainability even if the Centre stays on target.
4. **Interest-growth dynamics can turn adverse quickly:** Debt sustainability depends heavily on the gap between interest rates and growth; global tightening can worsen dynamics.
   Eg: If borrowing costs rise faster than growth, debt stabilisation becomes harder without spending cuts or higher taxes.
5. **Institutional weakness in fiscal transparency:** Without stronger disclosure norms, debt targeting can still coexist with hidden liabilities and off-budget financing.
   Eg: Persistent concerns around off-budget borrowings highlight the need for stronger fiscal transparency alongside new anchors.

Conclusion

Debt-to-GDP targeting is a more realistic fiscal compass for a post-pandemic economy, but it works only with transparent accounts and credible medium-term adjustment. For India, the real test is not choosing the anchor, but building institutions that ensure fiscal discipline without sacrificing growth.

Q. Climate-induced crop losses expose the limits of India's input-centric agricultural strategy. Assess the implications of large-scale weather-related damage. Suggest a risk-resilient reform package beyond insurance. (15 M)

Introduction

Climate shocks are now eroding farm output even when farmers apply fertilisers, HYV seeds and irrigation. With **13,12,157 hectares** of cropped area affected by hydro-meteorological disasters in **2024–25** (MoA&FW statement to Parliament, Feb 2026), the limits of India's input-centric agricultural strategy are clearly visible.

Body

How climate-induced crop losses expose limits of input-centric strategy

1. **Yield instability despite high inputs:** Weather extremes break the input–output relationship, making productivity uncertain.
   Eg: Unseasonal rainfall during harvest can destroy standing crops even after full input application, showing that inputs cannot ensure stability.
2. **Rising sunk costs and debt risk:** Input-heavy cultivation raises costs, so crop failure converts investment into distress.
   Eg: High spending on **seeds, fertilisers and pesticides** before a flood or drought often pushes smallholders into informal borrowing.
3. **Soil and water fragility worsens shock impact:** Intensive input use can degrade soil health and groundwater buffers needed for resilience.
   Eg: NITI Aayog Composite Water Management Index flagged severe groundwater stress, making drought years more damaging.
4. **Monoculture vulnerability:** Procurement-linked incentives lock farmers into climate-sensitive cropping patterns.
   Eg: Repeated **rice-wheat dominance** in irrigated belts increases systemic risk when heatwaves or floods hit.
5. **Input subsidies crowd out resilience investment:** Fiscal focus on fertiliser and power reduces resources for adaptation infrastructure.
   Eg: Limited public spending remains for **drainage, watershed works and micro-irrigation**, which directly reduce weather damage.

Implications of large-scale weather-related crop damage

1. **Food inflation and macroeconomic volatility:** Crop losses raise food prices and destabilise inflation management.
   Eg: RBI regularly highlights food inflation as a key driver of headline CPI volatility in India.
2. **Rural employment and wage distress:** Weather shocks reduce farm labour demand, increasing livelihood insecurity.
   Eg: After crop damage, demand for **MGNREGS** work rises, reflecting stress in rural labour markets.
3. **Fiscal stress on states:** Repeated disasters increase spending on relief, subsidies and compensation.
   Eg: Frequent reliance on **SDRF and NDRF** support shows how disasters create recurring fiscal pressure.
4. **Nutrition and dietary diversity shock:** Loss of pulses, vegetables and fodder worsens hidden hunger.
   Eg: NFHS-5 shows persistent malnutrition; climate shocks make nutritious foods less affordable for poor households.
5. **Rising inequality within agriculture:** Smallholders, rainfed farmers and tenants bear disproportionate losses due to weak buffers.
   Eg: Tenant farmers often remain excluded from formal relief because eligibility is tied to **land records**.

Risk-resilient reform package beyond insurance

1. **Climate-resilient cropping and diversification:** Incentivise shift towards millets, pulses, oilseeds and region-suited crops.
   Eg: Scaling **nutri-cereals and pulses** reduces dependence on water-intensive, climate-sensitive monocultures.
2. **Water security and demand-side management:** Expand micro-irrigation, watershed development and groundwater governance.
   Eg: PMKSY Per Drop More Crop improves water efficiency and stabilises yields under rainfall variability.
3. **Soil resilience and regenerative practices:** Improve soil organic carbon, balanced nutrients and moisture retention capacity.
   Eg: Soil Health Card Scheme supports rational input use and long-term soil restoration.
4. **Shock-proof rural infrastructure:** Build drainage, flood-safe storage, resilient rural roads and decentralised cold chains.
   Eg: Better **warehouse and cold storage access** reduces post-harvest losses after extreme rainfall.
5. **Early warning and advisory as a public service:** Strengthen IMD-based advisories with last-mile delivery.
   Eg: IMD's Gramin Krishi Mausam Sewa provides advisories; expanding delivery via FPOs improves adoption.
6. **Procurement reforms for climate-smart crops:** Use MSP and procurement to reward diversified, resilient cropping.
   Eg: Assured procurement for **millets and pulses** reduces the rice-wheat lock-in and improves resilience.
7. **Tenant inclusion and risk governance:** Ensure tenants and sharecroppers access credit, advisories and disaster relief.
   Eg: NITI Aayog Model Land Leasing Act (2016) provides a framework to formalise tenancy safely.
8. **Decentralised adaptation and Panchayat-led planning:** Strengthen local institutions for water budgeting and drought-proofing.
   Eg: Article 243G supports Panchayat planning for minor irrigation and natural resource management.

<u>Conclusion</u>

India must shift from an **input-maximisation** model to a **risk-resilience** model where water, soil, diversification and decentralised adaptation form the first line of defence. Insurance can compensate losses, but only structural reforms can prevent climate shocks.

Q. Resilience in agriculture is built more through decentralised production systems than through scale alone. Discuss. (15 M)

Introduction

Agricultural resilience is ultimately the capacity to absorb shocks and still sustain livelihoods, nutrition and ecological stability. India's lived reality shows that resilience often comes from diversification, decentralised risk-spreading and local institutions rather than scale alone.

Body

Why decentralised systems build stronger resilience than scale alone

1. **Risk diversification across crops, livestock and income streams:** Small and decentralised farms typically combine crops, dairy, poultry and wage work, reducing dependence on one commodity and one season.
   Eg: During **2023–24 El Niño-linked rainfall stress**, many mixed-farming households buffered losses through **dairy cash flows** and short-duration crops, unlike monoculture systems.
2. **Distributed production reduces systemic failure:** When production is spread across millions of units, climate shocks, pest attacks, or market failures do not collapse the entire supply chain at once.
   Eg: The **2020–22 global supply chain disruptions** showed that local milk procurement networks continued functioning even when long logistics chains faced breakdowns.
3. **Local ecological knowledge and low external input practices:** Decentralised farming is more likely to rely on traditional seed selection, local fodder systems, and adaptive practices suited to micro-climates.
   Eg: In many semi-arid belts, farmers use **millets + livestock integration** promoted under **National Food Security Mission (NFSM)**, lowering vulnerability to rainfall variability.
4. **Community institutions strengthen adaptive capacity:** Cooperatives, FPOs, SHGs and water user groups enable collective bargaining, storage, credit access and risk-sharing.
   Eg: Dairy cooperatives using transparent fat-testing and assured procurement (NDDB-led model) reduce price uncertainty for small producers.
5. **Resilience through decentralised nutrition security:** Diverse local food systems sustain household nutrition even when markets fluctuate, unlike scale-driven systems focused on commercial output.
   Eg: POSHAN Abhiyaan and local procurement efforts in several states have highlighted the value of **diet diversity** and locally available protein sources like milk and eggs.

Challenges and limitations of decentralised production systems

1. **Low productivity due to fragmented landholdings:** Small size limits mechanisation, irrigation efficiency and adoption of precision farming, keeping yields below potential.
   Eg: Agriculture Census 2015–16 shows dominance of **small and marginal holdings**, which constrains economies of scale in inputs and technology.
2. **Weak post-harvest and market infrastructure:** Decentralised production without decentralised storage, grading and cold chains leads to distress sales and wastage.
   Eg: FAO and NITI Aayog have repeatedly highlighted gaps in **cold chain capacity**, especially for perishables like milk, fruits and vegetables.
3. **Limited formal credit and insurance access:** Small producers face documentation barriers, delayed claims and inadequate risk cover, reducing resilience during shocks.
   Eg: Under **PMFBY**, issues of **delayed settlement and basis risk** have been flagged in multiple CAG observations and policy reviews.
4. **High transaction costs and weak bargaining power:** Individually, small farmers face price discrimination and information asymmetry in input and output markets.
   Eg: Many mandis still show weak price discovery despite reforms under **e-NAM**, due to uneven integration and grading capacity.
5. **Climate stress is outpacing local adaptation capacity:** Heat stress, new pests and rainfall extremes increasingly require scientific support beyond traditional coping.

Eg: IMD has reported rising frequency of **extreme rainfall events**, which overwhelm local drainage and soil protection measures.

<u>Way forward: Building "resilient scale" without destroying decentralisation</u>

1. **Scale through institutions, not through land consolidation:** Strengthen **FPOs, cooperatives and SHGs** to pool inputs, credit, storage and market access while keeping ownership decentralised.
   Eg: The **10,000 FPO scheme (2020)** enables aggregation for input purchase and output marketing without dispossessing small farmers.
2. **Invest in decentralised infrastructure and value chains:** Build village-level **milk chilling units, warehouses, primary processing and grading facilities** to reduce wastage and improve realisation.
   Eg: PM Gati Shakti and **PMKSY** can be aligned for last-mile agri-logistics and local processing clusters.
3. **Climate-resilient agriculture mission mode:** Expand climate services, heat action plans for livestock, and resilient seed systems using ICAR-KVK networks.
   Eg: ICAR climate resilient agriculture programmes and **KVKs** are critical for real-time advisories and varietal transition.
4. **Strengthen risk management with credible insurance + disaster support:** Reform PMFBY for faster settlement, use remote sensing carefully, and integrate with disaster relief.
   Eg: Digital crop loss assessment pilots can reduce delays, but must be backed by ground verification to avoid exclusion errors.
5. **Make resilience a constitutional governance priority:** Link agriculture resilience with **Directive Principles (Article 39(b) and 47)** to justify public investment in nutrition, livelihoods and equitable resource distribution.
   Eg: Article 47 supports state action to improve nutrition outcomes, strengthening the case for livestock, dairy and local food systems.

Conclusion

India should avoid a false binary between "small" and "scaled". The future lies in **scaling resilience through decentralised producers**, supported by modern institutions, climate-smart infrastructure and fair markets—so that productivity rises without creating systemic fragility.

Q. Discuss the economic significance of the orange economy for India. Analyse the structural constraints limiting its growth. Suggest a comprehensive policy framework to harness its potential. (15 M)

Introduction

India's growth story is entering a phase where value is increasingly created through ideas, content and digital platforms rather than only through factories and farms. The rise of the **orange economy**, centred on creative and cultural industries, offers a scalable pathway to leverage India's **demographic dividend and digital public infrastructure**.

Body

<u>Economic significance of the orange economy for India</u>

1. **Employment-intensive and youth-driven sector:** Creative industries such as media, design, gaming, music and digital content are labour-intensive and aligned with India's young population structure.
   Eg: The **National Skill Development Corporation (NSDC)** has identified **media and entertainment** as a high-growth sector under the Skill India framework, highlighting its job creation potential in the 2020s.
2. **High value-added and export potential:** Creative services generate significant value addition with low physical capital requirements, strengthening India's services exports.
   Eg: India's rise in **IT and digitally delivered services exports** as reflected in **RBI Balance of Payments data (2023–24)** demonstrates how intangible outputs can contribute strongly to foreign exchange earnings.
3. **Decentralisation of economic opportunity:** Digital platforms enable creators from Tier-2 and Tier-3 cities to access national and global markets, reducing metropolitan concentration.
   Eg: The spread of **BharatNet and UPI-based digital payments**, as reported by the **Ministry of Electronics and IT**, has expanded monetisation avenues for rural and semi-urban entrepreneurs.
4. **Integration with MSME ecosystem:** Creative entrepreneurs increasingly function as micro-brands, integrating with e-commerce and social commerce ecosystems.
   Eg: The **Government e-Marketplace (GeM)** has onboarded artisans and small creative producers, linking local creators to institutional buyers under formal procurement systems.
5. **Soft power and cultural diplomacy:** Creative industries enhance India's global cultural presence, complementing economic strategy with soft power.
   Eg: The global outreach of Indian cinema and digital streaming content, supported by policies under the **Ministry of Information and Broadcasting**, strengthens India's cultural exports.

<u>**Structural constraints limiting its growth**</u>

1. **Monetisation gap and informalisation:** A large number of creators remain outside formal financial and taxation systems, limiting income stability.
   Eg: The absence of tailored credit products for digital creators, as noted in discussions by **NITI Aayog on gig and platform economy (2022)**, reflects structural financing gaps.
2. **Credit and collateral limitations:** Financial institutions largely do not recognise **digital intellectual property** as collateral, constraining scale-up.
   Eg: The current credit appraisal frameworks under conventional banking norms prioritise tangible assets, as reflected in **RBI prudential guidelines**, limiting access for intangible-heavy ventures.
3. **Skilling architecture misalignment:** Traditional education and vocational systems are not fully aligned with digital creative entrepreneurship.
   Eg: While the **National Education Policy 2020** emphasises multidisciplinary and vocational integration, implementation in creative digital domains remains uneven across States.
4. **Platform dependence and algorithmic risks:** Creators are highly dependent on platform algorithms, creating income volatility and asymmetrical bargaining power.
   Eg: Global debates on platform regulation, including issues examined under India's **Information Technology Act, 2000 and Intermediary Rules**, highlight governance challenges.
5. **Digital divide and infrastructure gaps:** Uneven broadband access and digital literacy limit equitable participation in the creative economy.
   Eg: Despite progress under **Digital India**, rural internet penetration disparities, as reported in **TRAI performance indicators**, continue to constrain inclusive growth.

Comprehensive policy framework to harness its potential

1. **Dedicated creative economy mission:** Establish a coordinated national mission integrating skilling, finance and export promotion for creative industries.
   Eg: A model similar to the **India Semiconductor Mission (2021)** can be adapted to build structured support for high-growth creative clusters.
2. **Recognition of digital IP as financial capital:** Reform credit appraisal systems to accept monetisable digital assets and revenue streams.
   Eg: The success of the **Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE)** in collateral-free lending can inform similar frameworks for digital creators.
3. **Stackable and industry-linked skilling reforms:** Align skilling with digital markets through modular certifications in data analytics, IP management and content production.
   Eg: The **Skill India Mission (2015)** and **National Skill Qualification Framework (NSQF)** can incorporate specialised tracks for digital creative entrepreneurship.
4. **Tax and regulatory clarity for creators:** Simplify GST and income tax compliance for small digital entrepreneurs to reduce entry barriers.
   Eg: The rationalisation of compliance through the **GST Council** provides a template for sector-specific simplifications for emerging digital professions.
5. **Regional creative incubators and clusters:** Develop content incubators and innovation hubs in Tier-2 and Tier-3 cities linked to digital infrastructure.
   Eg: The experience of **Software Technology Parks of India (STPI)** in decentralising IT growth can guide cluster-based development for creative industries.

Conclusion

The orange economy can convert India's demographic advantage into a creative dividend if supported by finance, skilling and regulatory reform. By institutionalising support for digital creators, India can build a resilient, innovation-driven growth engine beyond traditional sectors.

Q. Analyse how integration of GST return data refines the estimation of Gross Value Added (GVA). Discuss its implications for sectoral productivity analysis. Evaluate associated data challenges. (15 M)

Introduction

Reliable national income measurement is foundational for macroeconomic stability and policy credibility. With the **Base Year 2022-23 revision (released on 26 February 2026)**, integration of **GST return data** into national accounts represents a structural shift toward transaction-based estimation of **Gross Value Added (GVA)**, particularly in the private corporate sector.

Body

Integration of GST data in refining estimation of GVA

1. **Transaction-based measurement of output:** GST outward supply data enables estimation of value addition based on actual reported turnover instead of relying primarily on survey-based proxies like ASI.

Eg: The **Ministry of Statistics and Programme Implementation (MoSPI)**, in the **Base Year 2022-23 GDP series**, linked **MCA corporate filings** with **GSTN registrations** using **PAN and CIN**, allowing output to be apportioned based on real transaction data rather than historical allocation ratios.

2. **Improved corporate sector coverage:** Cross-verification of MCA-listed companies with GST filings helps identify active versus inactive firms, reducing overestimation of corporate GVA.
   Eg: As per the revised methodology note of **MoSPI (2026)**, firms are categorised based on **GST filing status** such as active filers, nil return filers and non-filers, enabling more realistic adjustment of corporate value added.
3. **Enhanced state-wise allocation of value added:** Separate GST registrations in each state allow GVA to be distributed based on actual economic activity rather than proxy indicators.
   Eg: Earlier state allocation relied significantly on survey-based distribution from the **Annual Survey of Industries (ASI)**; the revised framework uses **GSTIN-level outward supply data**, strengthening state-level GVA estimation.
4. **Strengthening quarterly GVA estimation:** Monthly GST return data acts as a high-frequency indicator for sectors like trade and services, improving short-term GVA estimates.
   Eg: The **Sub-Committee on New Data Sources under MoSPI** recommended deeper use of GST data to strengthen **Quarterly National Accounts (QNA)** and improve advance GDP estimates.

<u>**Implications for sectoral productivity analysis**</u>

1. **Improved measurement of services productivity:** GST data captures transaction-level information in sectors like professional services, communication and trade, improving sectoral GVA precision.
   Eg: Classification under **SAC codes** in GST returns enables more granular mapping of service output, refining productivity assessment in fast-growing services segments.
2. **Clearer formal sector productivity trends:** Linking GST data with MCA filings strengthens the corporate sample, improving measurement of output per enterprise in the formal sector.
   Eg: Integration of **GSTN and MCA databases** allows more accurate estimation of value added within the private corporate sector in the revised GDP series.
3. **Granular manufacturing analysis through HSN codes:** Product-level data enhances understanding of output composition and sectoral shifts within manufacturing.
   Eg: The MoSPI Sub-Committee recommended use of **HSN-level data** to develop granular short-term indicators, supporting better productivity comparisons across manufacturing industries.
4. **Reduced distortion from proxy-based imputations:** Limiting reliance on paid-up capital or financial ratios improves the credibility of productivity estimates.
   Eg: Earlier imputations for non-filing firms used comparable firm ratios; cross-verification with **GST reporting data** reduces excessive extrapolation, leading to more realistic GVA estimates.

<u>**Associated data challenges**</u>

1. **Compliance-driven volatility:** GST returns are compliance instruments, and changes in compliance behaviour or tax policy can affect reported turnover independently of actual output.
   Eg: Variations in **GST filing patterns** during rate rationalisation or enforcement drives may temporarily influence outward supply data, requiring statistical smoothing in national accounts.
2. **Coverage differences across return types:** Variations in filing categories such as nil returns or delayed returns may create aggregation inconsistencies.

Eg: Firms filing **nil or late returns** can distort short-term sectoral aggregates, as acknowledged by the **MoSPI Sub-Committee on New Data Sources**.

3. **Data-matching complexities:** Accurate linkage between **PAN, CIN and GSTIN** identifiers is essential to prevent duplication or exclusion in corporate GVA estimation.
   Eg: The revised methodology relies on precise cross-referencing of **MCA and GSTN databases**, and mismatches can affect corporate output measurement accuracy.
4. **Limited coverage of informal activity:** GST data largely reflects registered entities, leaving segments of the informal economy outside its ambit.
   Eg: Enterprises below the GST registration threshold are not fully captured in return data, necessitating supplementary surveys for comprehensive GVA estimation.

Conclusion

The integration of GST return data strengthens the precision and granularity of GVA and sectoral productivity measurement in India's new GDP framework. Sustained statistical safeguards and transparent methodology will be essential to ensure that enhanced data integration translates into durable macroeconomic credibility.

Inclusive growth and issues arising from it.

Q. Employment protection laws should function as counter-cyclical stabilisers during periods of technological disruption. Discuss. (10 M)

Introduction

In a technology shock, job losses can spread faster than labour markets can adjust. Employment protection laws, if designed smartly, can act like **counter-cyclical stabilisers**—preventing panic retrenchment, preserving demand, and buying time for workers to transition.

Body

Employment protection as counter-cyclical stabilisers during technological disruption

1. **Demand stabilisation through job retention**: Preventing sudden layoffs protects household income and consumption, reducing the risk of a demand-led slowdown during automation shocks.
   Eg: During large shocks, job retention is widely recognised as protecting macro demand and preventing long unemployment spells (**ILO** policy frameworks on employment protection and job retention).
2. **Prevention of panic retrenchment and industrial unrest**: Job security provisions discourage opportunistic downsizing during uncertainty, maintaining industrial peace and reducing strike/lockout risks.
   Eg: The logic behind prior-permission provisions for large layoffs under **IDA/IRC** was to avoid sudden mass displacement and breakdown of industrial relations.
3. **Time for reskilling and labour market adjustment**: Employment protection creates a transition window, enabling workers to acquire new skills rather than being abruptly pushed into informal employment.
   Eg: The **Worker Re-Skilling Fund** under **IRC, 2020** requires employer contribution of **15 days' wages** per retrenched worker, acknowledging disruption-linked transitions.

4. **Fair distribution of adjustment costs**: Automation gains can become unequal if firms externalise disruption costs onto labour; protections help distribute transition burdens more fairly.
   Eg: The **OECD** and **ILO** have repeatedly flagged that technology transitions need worker protections to prevent inequality spikes.
5. **Welfare-state legitimacy and dignity of labour**: Employment protection aligns with India's welfare orientation by ensuring security and dignity in structural change.
   Eg: Article 41 (right to work/public assistance) and **Article 43** (living wage, decent conditions) provide the constitutional basis for protecting workers during shocks.

Challenges in using employment protection as counter-cyclical stabilisers

1. **Coverage gaps in a services-heavy workforce**: Many formal service workers and managerial categories fall outside classic "industrial worker" protections, limiting stabiliser impact.
   Eg: Large sections of the **IT and platform-enabled services workforce** remain outside the strongest retrenchment-permission framework under the IRC.
2. **Risk of discouraging formal job creation**: If protections are rigid or unpredictable, firms may avoid scaling up formal employment and prefer outsourcing or contract labour.
   Eg: Employers often respond to stricter thresholds by expanding through **contracting and third-party staffing**, reducing direct employment security.
3. **Weak enforcement capacity and delayed dispute resolution**: Stabiliser effects depend on quick enforcement, but labour administration and adjudication can be slow.
   Eg: Prolonged industrial dispute timelines reduce the deterrence value of protections, making layoffs a "fait accompli" before remedies arrive.
4. **Possibility of insider–outsider inequality**: Strong protection for a narrow group can increase inequality between protected formal workers and the vast informal workforce.
   Eg: India's labour market already has high informality, so protections may stabilise only a small "insider" segment.
5. **Moral hazard and productivity stagnation risk**: Over-protection can delay necessary restructuring and reduce incentives for firms and workers to adapt to new technology.
   Eg: Firms may postpone reorganisation, while workers may not receive timely upskilling if protections are not paired with **active labour market policies**.

Conclusion

In the AI era, the goal is not to freeze labour markets, but to prevent **shock-driven job collapse**. A balanced approach—**temporary safeguards, wider coverage, faster enforcement, and strong reskilling/social security**—can make technological disruption economically efficient and socially sustainable.

Q. "In water-scarce regions, the cost of water is paid more in labour-time than in money." Explain how this affects rural productivity. Suggest robust responses to address this challenge. (10 M)

Introduction

Water scarcity in rural India is not just a shortage of a resource, it is a daily drain on human effort and economic output. When water is fetched through long walks and repeated trips, the real price is paid in labour-time, health and lost productivity.

Body

In water-scarce regions, the cost of water is paid more in labour-time than in money

1. **Labour-time as the real cost:** In many water-scarce villages, households do not pay money for water, but pay through hours spent walking, waiting and carrying it.
   Eg: NSS Time Use Survey (2019) highlights heavy unpaid domestic work burdens on women, including water collection, reducing time for income activities.
2. **Invisible economic loss:** Water appears "free" but becomes expensive because the time spent fetching it reduces the household's productive capacity.
   Eg: Jal Jeevan Mission (2019) explicitly treats time saved from household tap water as a major welfare and productivity gain.

How it affects rural productivity

1. **Loss of labour for farming and wages:** Time spent fetching water reduces availability for agriculture operations, livestock care and rural wage work.
   Eg: In peak seasons, water-fetching burdens reduce participation in **MGNREGA**, lowering household cash flow and resilience.
2. **Lower agricultural output and crop choices:** Water scarcity pushes farmers towards low-value crops, single cropping and fallow land, reducing farm productivity.
   Eg: NITI Aayog Composite Water Management Index (2018) flagged water stress as a binding constraint on agricultural growth.
3. **Reduced livestock productivity:** Scarcity affects animal hydration, fodder planning and milk yields, weakening allied-sector incomes.
   Eg: In drought years, semi-arid regions see reduced milk yields and higher distress sales, often documented in state drought assessments.
4. **Health shocks and workday losses:** Dependence on unsafe surface water increases diarrhoeal diseases and reduces work capacity.
   Eg: NFHS-5 (2019–21) shows WASH-related illness and undernutrition links, weakening human capital and productivity.
5. **Gendered productivity penalty:** Women's time poverty limits their entry into paid work, skilling and non-farm livelihoods.
   Eg: World Bank and **ILO** studies repeatedly identify unpaid care burdens as a key barrier to women's workforce participation.
6. **Intergenerational productivity loss:** Children, especially girls, may lose schooling time due to water collection and illness.
   Eg: UNICEF WASH assessments highlight how water insecurity affects attendance and learning outcomes.

Robust responses to address the challenge

1. **Reliable household tap water delivery:** Focus on functional supply, not just coverage, by ensuring regularity and village-level operation and maintenance.
   Eg: Jal Jeevan Mission (2019) targets Functional Household Tap Connections and treats time saving as a core outcome.
2. **Source sustainability and groundwater recharge:** Strengthen water sources through watershed development, recharge and protection of common water bodies.
   Eg: Atal Bhujal Yojana (2019) promotes community-led groundwater management in stressed blocks.

3. **Safe water quality assurance:** Expand water testing, treatment and contamination control for fluoride, salinity and microbial risks.
   Eg: BIS IS 10500 standards define safe drinking water norms and guide quality monitoring.
4. **Demand management in agriculture:** Reduce pressure on drinking water by improving irrigation efficiency and promoting suitable cropping patterns.
   Eg: PMKSY Per Drop More Crop supports micro-irrigation to reduce water wastage.
5. **Decentralised local governance:** Empower Gram Panchayats and local committees for water planning, maintenance and grievance redressal.
   Eg: 73rd Constitutional Amendment (Part IX) provides the framework for decentralised service delivery through local bodies.
6. **Women-centred water governance:** Ensure women's leadership in village water committees since they bear the highest time burden.
   Eg: JJM implementation guidelines encourage community institutions like Pani Samitis with women's participation.
7. **Climate-resilient village water security plans:** Integrate drought preparedness, storage planning and climate variability into local water management.
   Eg: NDMA drought guidelines emphasise preparedness, local storage and demand-side measures.

Conclusion

Water scarcity reduces rural productivity by converting working hours into survival labour and by weakening health and livelihoods. Ensuring safe, reliable household water through sustainable sources and accountable local governance can transform water from a daily burden into a driver of rural growth.

Q. Trade policy uncertainty is a hidden cost that disproportionately burdens developing exporters. Examine its impact on investment and supply-chain decisions. (15 M)

Trade policy uncertainty acts like a "risk premium" on exports, raising costs even before any tariff is applied. For developing exporters, this unpredictability converts comparative advantage into fragile, reversible market access.

Body

Impact of trade policy uncertainty on developing exporters

1. **Risk premium on contracts and pricing:** Frequent tariff shifts force exporters to quote higher prices or shorter validity, reducing competitiveness.
   Eg: Indian rice exporters face renegotiation risk when **US applied tariffs and exemptions change**, making long-term price contracts harder to sustain.
2. **Higher cost of trade finance and insurance:** Uncertainty increases perceived default risk, raising **letters of credit costs** and shipment insurance for exporters.
   Eg: MSME exporters often face tighter credit when buyers fear sudden tariff hikes, increasing dependence on costly working capital.
3. **Compliance and documentation burden:** Differentiated tariffs increase rules-of-origin checks, classification disputes, and paperwork, raising fixed costs.
   Eg: Exporters must repeatedly adapt to **product-specific exemptions** and partner-specific rules, which hurts smaller firms more than large MNCs.
4. **Loss of credibility with buyers:** Importers prefer suppliers with stable access; uncertainty reduces trust and encourages switching even without price changes.

Eg: Buyers diversify away from a supplier if its market access becomes "politically risky", even when product quality is unchanged.

Impact on investment decisions

1. **Deferred capacity expansion:** Firms postpone new plants because expected export demand becomes unreliable.
   Eg: Electronics and machinery exporters hesitate to scale US-linked capacity when tariff rates can shift through **reciprocal measures**.
2. **Shift from efficiency to hedging investment:** Firms invest in redundancy (extra inventory, alternate sourcing) instead of productivity upgrades.
   Eg: Companies allocate funds to **multi-country sourcing** rather than **automation and upgrading**, lowering long-term competitiveness.
3. **Discouragement of FDI into export hubs:** Investors prefer predictable tariff regimes for export-oriented manufacturing.
   Eg: Export-platform FDI becomes cautious when market access depends on **bilateral exemptions**, not stable WTO-style predictability.
4. **Bias against MSMEs and late industrialisers:** Large firms can absorb shocks; small exporters exit due to volatility.
   Eg: MSMEs cannot maintain buffers for sudden tariff-driven order cancellations, leading to **export concentration** in fewer large firms.

Impact on supply-chain and GVC decisions

1. **Reconfiguration of supply chains away from the US market:** Firms reduce US dependence and redirect exports to alternative markets.
   Eg: Exporters increasingly explore **EU, West Asia and ASEAN** routes to reduce vulnerability to US policy swings.
2. **Friend-shoring and regionalisation pressures:** Firms choose suppliers based on political alignment, not cost efficiency.
   Eg: GVCs shift toward countries with **preferential access** or stable exemptions, disadvantaging neutral developing exporters.
3. **Inventory and logistics inefficiency:** Uncertainty forces higher inventory holding, increasing warehousing and logistics costs.
   Eg: Exporters build buffer stocks to manage sudden duty changes, raising costs in sectors like **textiles and agro-commodities**.

Way forward

1. **Diversify export markets and products:** Reduce single-market dependence through new product lines and destination mix.
   Eg: India's focus on **services exports**, and deeper penetration in **Africa and Latin America**, can reduce tariff vulnerability.
2. **Strengthen domestic competitiveness beyond tariffs:** Improve logistics, quality infrastructure, and standards compliance to compete even with tariff headwinds.
   Eg: PM Gati Shakti and **National Logistics Policy (2022)** aim to reduce logistics costs, improving resilience.

3. **Use trade remedies and legal strategy prudently:** Build capacity for WTO-consistent dispute response and safeguard measures.
   Eg: A stronger trade law ecosystem helps contest arbitrary restrictions while protecting domestic industry when needed.
4. **Create an exporter risk-management ecosystem:** Support hedging, export credit, and insurance to absorb volatility.
   Eg: Enhancing **ECGC** coverage and predictable credit support reduces the "uncertainty premium" for Indian exporters.

Conclusion

In the new tariff-differentiated world, competitiveness is shaped as much by policy stability as by production efficiency. India's best hedge is a mix of export diversification, logistics-led cost reduction, and strategic trade preparedness.

Q. Platform work has created a new form of informalisation under the cover of technology. What steps are needed to ensure decent work in the gig economy? (10 M)

Introduction

India's gig economy is expanding rapidly, but it is also reviving **informality in a digital form**—where work is mediated by apps but protections remain absent. This creates a workforce that is "visible to algorithms" but often **invisible to labour law**.

Body

Platform work as a new form of informalisation

1. **Task-based pay and unpaid waiting time:** Earnings are linked to completed deliveries/rides, while logged-in availability is unpaid, reducing real hourly wages.
   Eg: Platform delivery work often involves long idle hours waiting for orders, yet only "completed tasks" are compensated.
2. **Algorithmic control without employer liability:** Platforms control allocation, incentives, penalties and deactivations, but avoid responsibility by classifying workers as contractors.
   Eg: Sudden **account deactivation or reduced order allocation** based on ratings is reported across major ride-hailing and delivery platforms.
3. **Transfer of business risks to workers:** Costs like fuel, vehicle depreciation, insurance gaps and accident risks are borne by workers, unlike formal jobs.
   Eg: A delivery worker bears **fuel + maintenance + accident injury costs**, while the platform avoids payroll liabilities.
4. **Absence of stable employment benefits:** There is no assured minimum wage, paid leave, PF, gratuity, or income security, resembling informal sector vulnerabilities.
   Eg: Most gig workers lack **paid sick leave**, forcing continued work even during illness or injury.

Steps needed to ensure decent work in the gig economy

1. **Minimum wage and fair pay floor:** Ensure a legally enforceable wage floor linked to time worked, not only task completion.

Eg: A state-level initiative like **Rajasthan Platform Based Gig Workers (Registration and Welfare) Act, 2023** shows the direction towards enforceable protection.

2. **Social security operationalisation under the Code on Social Security, 2020:** Implement the proposed aggregator contribution and expand coverage for insurance and pensions.
   Eg: The **Code on Social Security, 2020** provides for gig/platform worker recognition and aggregator contributions to a social security fund.
3. **Algorithmic transparency and due process:** Mandate disclosure of pay logic, penalties, incentive slabs and deactivation rules with appeal mechanisms.
   Eg: The **EU Platform Work Directive (2024)** is a global best practice pushing transparency in algorithmic management.
4. **Formal grievance redressal and collective voice:** Establish platform-neutral grievance systems and allow worker unions/associations to negotiate.
   Eg: The **Indian Federation of App-based Transport Workers (IFAT)** has highlighted the need for institutional grievance forums for gig workers.
5. **Occupational safety and health coverage:** Extend OSH protections, accident compensation, and emergency support systems for platform workers.
   Eg: Road accident exposure for delivery riders requires coverage under **occupational safety norms**, similar to other hazardous work.
6. **Portable benefits and worker data rights:** Enable portability across platforms and ensure access to work-history, ratings and earnings data.
   Eg: A worker should be able to carry verified **work credentials and ratings** across platforms to prevent dependency on one app.

<u>Conclusion</u>

Gig work cannot be treated as informal labour simply repackaged through apps; it must be governed as a **new labour regime** with enforceable rights. Ensuring **minimum earnings, social security, algorithmic accountability and grievance mechanisms** is essential for India's vision of inclusive growth and decent work.

Government Budgeting.

Major crops-cropping patterns in various parts of the country, - different types of irrigation and irrigation systems storage, transport and marketing of agricultural produce and issues and related constraints; e-technology in the aid of farmers.

Q. Climate-induced crop losses expose the limits of India's input-centric agricultural strategy. Assess the implications of large-scale weather-related damage. Suggest a risk-resilient reform package beyond insurance. (15 M)

<u>Introduction</u>

Climate shocks are now eroding farm output even when farmers apply fertilisers, HYV seeds and irrigation. With **13,12,157 hectares** of cropped area affected by hydro-meteorological disasters in **2024–25** (MoA&FW

statement to Parliament, Feb 2026), the limits of India's input-centric agricultural strategy are clearly visible.

Body

How climate-induced crop losses expose limits of input-centric strategy

1. **Yield instability despite high inputs:** Weather extremes break the input–output relationship, making productivity uncertain.
   Eg: Unseasonal rainfall during harvest can destroy standing crops even after full input application, showing that inputs cannot ensure stability.
2. **Rising sunk costs and debt risk:** Input-heavy cultivation raises costs, so crop failure converts investment into distress.
   Eg: High spending on **seeds, fertilisers and pesticides** before a flood or drought often pushes smallholders into informal borrowing.
3. **Soil and water fragility worsens shock impact:** Intensive input use can degrade soil health and groundwater buffers needed for resilience.
   Eg: NITI Aayog Composite Water Management Index flagged severe groundwater stress, making drought years more damaging.
4. **Monoculture vulnerability:** Procurement-linked incentives lock farmers into climate-sensitive cropping patterns.
   Eg: Repeated **rice-wheat dominance** in irrigated belts increases systemic risk when heatwaves or floods hit.
5. **Input subsidies crowd out resilience investment:** Fiscal focus on fertiliser and power reduces resources for adaptation infrastructure.
   Eg: Limited public spending remains for **drainage, watershed works and micro-irrigation**, which directly reduce weather damage.

Implications of large-scale weather-related crop damage

1. **Food inflation and macroeconomic volatility:** Crop losses raise food prices and destabilise inflation management.
   Eg: RBI regularly highlights food inflation as a key driver of headline CPI volatility in India.
2. **Rural employment and wage distress:** Weather shocks reduce farm labour demand, increasing livelihood insecurity.
   Eg: After crop damage, demand for **MGNREGS** work rises, reflecting stress in rural labour markets.
3. **Fiscal stress on states:** Repeated disasters increase spending on relief, subsidies and compensation.
   Eg: Frequent reliance on **SDRF and NDRF** support shows how disasters create recurring fiscal pressure.
4. **Nutrition and dietary diversity shock:** Loss of pulses, vegetables and fodder worsens hidden hunger.
   Eg: NFHS-5 shows persistent malnutrition; climate shocks make nutritious foods less affordable for poor households.
5. **Rising inequality within agriculture:** Smallholders, rainfed farmers and tenants bear disproportionate losses due to weak buffers.
   Eg: Tenant farmers often remain excluded from formal relief because eligibility is tied to **land records**.

Risk-resilient reform package beyond insurance

1. **Climate-resilient cropping and diversification:** Incentivise shift towards millets, pulses, oilseeds and region-suited crops.
   Eg: Scaling **nutri-cereals and pulses** reduces dependence on water-intensive, climate-sensitive monocultures.
2. **Water security and demand-side management:** Expand micro-irrigation, watershed development and groundwater governance.
   Eg: PMKSY Per Drop More Crop improves water efficiency and stabilises yields under rainfall variability.
3. **Soil resilience and regenerative practices:** Improve soil organic carbon, balanced nutrients and moisture retention capacity.
   Eg: Soil Health Card Scheme supports rational input use and long-term soil restoration.
4. **Shock-proof rural infrastructure:** Build drainage, flood-safe storage, resilient rural roads and decentralised cold chains.
   Eg: Better **warehouse and cold storage access** reduces post-harvest losses after extreme rainfall.
5. **Early warning and advisory as a public service:** Strengthen IMD-based advisories with last-mile delivery.
   Eg: IMD's Gramin Krishi Mausam Sewa provides advisories; expanding delivery via FPOs improves adoption.
6. **Procurement reforms for climate-smart crops:** Use MSP and procurement to reward diversified, resilient cropping.
   Eg: Assured procurement for **millets and pulses** reduces the rice-wheat lock-in and improves resilience.
7. **Tenant inclusion and risk governance:** Ensure tenants and sharecroppers access credit, advisories and disaster relief.
   Eg: NITI Aayog Model Land Leasing Act (2016) provides a framework to formalise tenancy safely.
8. **Decentralised adaptation and Panchayat-led planning:** Strengthen local institutions for water budgeting and drought-proofing.
   Eg: Article 243G supports Panchayat planning for minor irrigation and natural resource management.

Conclusion

India must shift from an **input-maximisation** model to a **risk-resilience** model where water, soil, diversification and decentralised adaptation form the first line of defence. Insurance can compensate losses, but only structural reforms can prevent climate shocks.

Q. Identify key reasons for underperformance of major irrigation projects in India. Explain how these reasons weaken inclusive agricultural growth. (15 M)

Introduction

India's irrigation potential is not constrained only by water availability, but by **weak delivery systems and governance failures**. This is why many major projects create storage, yet fail to create **reliable, equitable and productivity-enhancing irrigation** on the ground.

Body

Key reasons for underperformance of major irrigation projects

1. **Delayed completion and cost overruns:** Long gestation leads to inflation of costs, design obsolescence and loss of credibility, while benefits arrive too late for farmers.
   Eg: CAG audits of irrigation projects repeatedly flag **time overruns and cost escalation**, reducing the cost-effectiveness of public irrigation spending.
2. **Weak command area development (CAD):** Canals exist, but field channels, drainage, and on-farm development remain incomplete, so water fails to reach farms efficiently.
   Eg: CAG performance audits have highlighted cases where **created irrigation potential was not utilised** due to incomplete distributaries and field channels.
3. **Poor operation and maintenance (O&M):** Silted canals, leakages, broken gates and weak maintenance reduce water delivery reliability even when storage is adequate.
   Eg: NITI Aayog's water management assessments point to chronic underfunding of **O&M**, leading to declining system performance over time.
4. **Inequitable distribution and tail-end deprivation:** Head-reach farmers capture water, while tail-end areas receive uncertain supply, producing spatial inequality within the same command.
   Eg: The **NCAER assessment for Central Water Commission** highlights uneven access in command areas, especially for **tail-end and small farmers**.
5. **Fragmented institutions and weak accountability:** Multiple agencies manage storage, canals and agriculture separately, leading to coordination failure and weak responsibility for outcomes.
   Eg: 2nd ARC recommended stronger **outcome-based accountability** and citizen-centric service delivery, relevant for irrigation governance.
6. **Over-extraction and canal–groundwater mismatch:** Canal irrigation often triggers groundwater pumping, causing waterlogging in some zones and depletion in others.
   Eg: CGWB reports show several canal command regions face a dual problem of **waterlogging** and **groundwater stress** due to unregulated pumping.
7. **Poor rehabilitation and social conflict:** Weak resettlement outcomes and livelihood disruption create resistance, litigation, and political contestation that delays benefits.
   Eg: The **Narmada Bachao Andolan** brought national focus on displacement and rehabilitation deficits in large dam projects.

How these reasons weaken inclusive agricultural growth

1. **Excludes small and marginal farmers from gains:** When water delivery is unreliable, smallholders cannot risk HYV seeds, fertilisers, or high-value crops, widening inequality.
   Eg: The **NCAER–CWC assessment** notes that benefits are often skewed against **tail-end and marginal households**, limiting inclusiveness.
2. **Reduces diversification and keeps farmers in low-value crops:** Uncertain irrigation forces farmers to remain dependent on coarse cereals or rainfed cropping instead of horticulture or pulses.
   Eg: NITI Aayog's Doubling Farmers' Income strategy emphasises irrigation reliability as a base for **crop diversification** and value addition.
3. **Weakens rural employment and allied sector growth:** When irrigation does not stabilise production, downstream activities like dairy, processing, storage and rural non-farm jobs remain limited.

Eg: Economic Survey discussions on structural transformation highlight that stable farm surplus is essential for rural non-farm expansion.

4. **Creates regional inequality and political economy distortions:** Uneven irrigation reinforces spatial disparity, enabling rent-seeking and capture by influential groups.
   Eg: CAG observations repeatedly point to governance gaps that allow **inequitable benefit distribution** and poor targeting of irrigation outcomes.
5. **Undermines climate resilience and increases vulnerability:** Poorly functioning irrigation systems fail during droughts and heat stress, increasing distress migration and indebtedness.
   Eg: IPCC AR6 highlights South Asia's rising climate risks, making **reliable irrigation** central for adaptation in agriculture.

<u>**Way forward**</u>

1. **Shift to outcome-based irrigation governance:** Move from "potential created" to measurable service delivery like assured supply days, tail-end coverage and reliability.
   Eg: Jal Jeevan Mission's outcome tracking model can be adapted for irrigation through transparent village-level service indicators.
2. **Strengthen command area development and last-mile delivery:** Prioritise field channels, lining, drainage and micro-irrigation integration so water reaches farms efficiently.
   Eg: PMKSY – Har Khet Ko Pani and CAD components can be converged with **micro-irrigation (Per Drop More Crop)** for end-to-end delivery.
3. **Ring-fence O&M funding with local accountability:** Create dedicated O&M budgets, social audit and third-party performance audits to prevent system decay after construction.
   Eg: CAG performance audits repeatedly stress that without O&M, created assets fail to deliver sustained benefits.
4. **Ensure equity through participatory water institutions:** Empower **Water User Associations (WUAs)** with legal authority, transparent warabandi scheduling and grievance redress for tail-end farmers.
   Eg: Mihir Shah Committee (2016) emphasised participatory irrigation management and basin-level governance for equitable water outcomes.

<u>**Conclusion**</u>

Major irrigation projects fail not because dams are inherently ineffective, but because **delivery, equity and maintenance are treated as secondary**. India's next irrigation reform must shift from "creating potential" to **guaranteeing outcomes**, especially for **tail-end and small farmers**.

Q. "Climate volatility is now a greater threat to food security than average rainfall decline." Discuss in the context of rabi crops. Suggest suitable measures to reduce rabi crop vulnerability. (10 M)

Introduction

India's food security challenge is no longer driven only by "how much rain falls", but by how unpredictably weather behaves across crop stages. Sudden February heat, terminal heat stress and irrigation shocks are now directly shrinking wheat output in key rabi belts.

Body

Why climate volatility is a greater threat than average rainfall decline wrt Rabi crops

1. **Stage-specific heat shocks:** Even with normal seasonal rainfall, short heat spikes during grain formation can sharply reduce yield and grain weight.
   Eg: Feb 2026 unseasonal heat in Sri Ganganagar–Hanumangarh hit wheat in the **milky stage**, risking grain shrinkage as reported by **KVK scientists**.
2. **Increased terminal heat stress:** Rabi crops face yield loss when temperatures rise early in late winter and March, forcing premature ripening.
   Eg: In **2022**, wheat yields in parts of north-west India reportedly fell sharply due to **early heat**, a trend highlighted in multiple **IMD and ICAR advisories**.
3. **Irrigation dependence amplifies volatility:** Rabi food security is highly tied to assured irrigation, so temperature spikes become disastrous when canals run short.
   Eg: The article notes canal supply in the **Gang Canal Project area** falling below requirement, leaving most channels closed during heat stress.
4. **Higher yield instability than slow rainfall decline:** Rainfall averages change gradually, but volatility creates sudden output shocks that destabilise markets and procurement.
   Eg: Wheat output shocks in heat years often trigger tighter market supply and stronger inflation pressures, flagged repeatedly in **RBI inflation reports**.

Suitable measures to reduce rabi crop vulnerability

1. **Climate-resilient agronomy package:** Promote heat-tolerant varieties, early sowing, mulching and micro-irrigation scheduling during sensitive stages.
   Eg: ICAR and state agriculture advisories recommend sowing-window optimisation and protective irrigation during grain formation to reduce heat damage.
2. **Irrigation reliability and water governance:** Prioritise canal modernisation, rotational supply transparency and command-area efficiency to avoid “no-water” shocks.
   Eg: PMKSY (More crop per drop) supports efficiency measures, crucial for canal-dependent rabi regions.
3. **Climate services and early warning:** Strengthen IMD–KVK last-mile alerts and crop-stage based advisories for heat, frost and irrigation scheduling.
   Eg: IMD’s Agromet Advisory Services can be expanded for block-level heat-risk warnings during wheat’s milky stage.
4. **Risk financing and safety nets:** Improve crop insurance claim timeliness and link compensation to scientifically assessed heat stress losses.
   Eg: PMFBY needs better weather-station density and quicker loss assessment for heat-induced yield shrinkage.

Conclusion

Rabi food security is increasingly threatened by sudden weather swings that hit crops at their most sensitive stages. India must shift from rainfall-centric planning to **volatility-ready agriculture**, combining resilient seeds, reliable irrigation and real-time climate services

Q. "Agrifood systems are both victims and drivers of biodiversity loss." Analyse this paradox. Suggest policy recalibrations required to align agrifood systems with biodiversity targets. (15 M)

Introduction

Food systems today stand at the intersection of ecological stability and developmental imperatives. The recent deliberations under the **Convention on Biological Diversity (CBD)** before **COP17 (2026, Yerevan)** reaffirm that agrifood systems are central to achieving the **Kunming–Montreal Global Biodiversity Framework (2022)** targets.

Body

<u>Agrifood systems as drivers of biodiversity loss</u>

1. **Land-use change and habitat conversion:** Expansion of agriculture remains the single largest driver of terrestrial biodiversity loss, fragmenting forests, wetlands and grasslands.
   Eg: As per **IPBES Global Assessment Report (2019)**, agriculture accounts for nearly **75% of terrestrial environmental change**, with deforestation in tropical regions driven largely by commercial cropping and livestock expansion.
2. **Intensive input use and soil degradation:** Excessive use of chemical fertilisers and pesticides reduces soil biota, pollinator diversity and contaminates freshwater ecosystems.
   Eg: The **FAO State of the World's Soil Biodiversity (2020)** reports declining soil microbial diversity due to monocropping and agrochemical dependence, affecting long-term productivity.
3. **Overfishing and aquaculture pressures:** Unsustainable fishing and poorly regulated aquaculture disrupt marine food webs and genetic diversity.
   Eg: The **FAO State of World Fisheries and Aquaculture (2022)** indicates over one-third of global fish stocks are overfished, undermining marine biodiversity.
4. **Monoculture and genetic erosion:** Industrial agriculture promotes uniform crop varieties, narrowing genetic diversity and increasing vulnerability to climate and pest shocks.
   Eg: The **Second Report on the State of the World's Plant Genetic Resources (FAO, 2010)** documented significant genetic erosion in traditional crop varieties replaced by hybrids.
5. **Invasive species and pest proliferation:** Globalised agrifood trade facilitates invasive alien species that outcompete native biodiversity.
   Eg: The **IPBES Invasive Alien Species Assessment (2023)** identifies agricultural trade as a key pathway for invasive species affecting agro-ecosystems.

<u>Agrifood systems as victims of biodiversity loss</u>

1. **Pollinator decline and yield instability:** Loss of pollinators directly threatens food production and nutritional diversity.
   Eg: The **IPBES Pollinator Assessment (2016)** estimated that over **75% of global food crops** depend partly on pollination, making biodiversity essential for food security.
2. **Soil biodiversity loss and productivity decline:** Reduced soil fauna and microorganisms impair nutrient cycling and crop resilience.

Eg: The **FAO (2020)** notes that degraded soils reduce yields and increase input dependency, creating a negative ecological spiral.

3. **Fisheries collapse and livelihood vulnerability:** Biodiversity loss in oceans undermines small-scale fisheries and coastal economies.
   Eg: The **FAO (2022)** highlights that millions of small-scale fishers face income risks due to stock depletion.
4. **Pest outbreaks and ecosystem imbalance:** Simplified agro-ecosystems become more prone to pest outbreaks in absence of natural predators.
   Eg: CBD Secretariat reports (2023) observe rising pest pressures in monoculture systems due to declining ecosystem services.
5. **Climate-biodiversity feedback loops:** Biodiversity loss weakens ecosystem resilience to climate shocks, directly affecting food systems.
   Eg: The **IPCC Sixth Assessment Report (2022)** recognises biodiversity as critical for climate adaptation in agriculture.

<u>Policy recalibrations to align agrifood systems with biodiversity targets</u>

1. **Mainstreaming biodiversity into agricultural policy:** Align subsidies and incentives with ecosystem restoration and sustainable practices under **CBD Target 14 (2022)**.
   Eg: India's promotion of **Natural Farming under Paramparagat Krishi Vikas Yojana** seeks to reduce chemical inputs and restore soil biodiversity, aligned with the **National Biodiversity Action Plan (updated draft 2023)**.
2. **Reforming harmful subsidies:** Gradually repurpose environmentally harmful agricultural subsidies consistent with **CBD Target 18 (2022)**.
   Eg: The **OECD Agricultural Policy Monitoring Report (2023)** notes that global farm support often incentivises input-intensive practices, necessitating redirection toward sustainability.
3. **Strengthening constitutional environmental mandate:** Integrate biodiversity-sensitive agrifood planning under **Article 48A** and **Article 51A(g)** of the Constitution of India.
   Eg: The **Supreme Court in T.N. Godavarman Thirumulpad vs Union of India (1996 onwards)** reinforced ecological protection as a governance priority influencing land-use decisions.
4. **Promoting agroecology and diversified farming:** Encourage crop diversification, mixed farming and landscape-level planning to restore ecosystem services.
   Eg: The **FAO Agroecology Guidelines (2018)** advocate diversified systems to enhance resilience and biodiversity outcomes.
5. **Strengthening monitoring and reporting:** Improve National Biodiversity Strategies and Action Plans reporting mechanisms to ensure measurable agrifood targets under the **Kunming–Montreal Global Biodiversity Framework (2022)**.
   Eg: Limited submission of national reports ahead of **COP17 (2026)** highlights implementation gaps in global biodiversity governance.

Conclusion

Sustainable agrifood systems are the hinge on which biodiversity conservation and food security balance. Recalibrating policies toward ecological stewardship will determine whether food systems become instruments of restoration rather than drivers of degradation.

Issues related to direct and indirect farm subsidies and minimum support prices; Public Distribution System-objectives, functioning, limitations, revamping; issues of buffer stocks and food security; Technology missions; economics of animal-rearing.

Q. "Parliamentary privilege is not absolute and operates within the discipline of procedural rules." Explain the constitutional foundations of parliamentary privilege. Bring out how rules of procedure regulate and constrain its exercise in legislative functioning. (10 M)

Introduction

Parliamentary privilege exists to secure the independence and dignity of the legislature, not to place it above constitutional discipline. In a constitutional democracy governed by the rule of law, privilege functions within clearly defined procedural and institutional boundaries.

Body

Constitutional foundations of parliamentary privilege

1. **Article 105 as the primary source: Article 105(1) and 105(2)** confer freedom of speech in Parliament and immunity from judicial proceedings for speeches and votes, ensuring uninhibited legislative deliberation.
   Eg: Supreme Court in Raja Ram Pal vs Speaker (2007) affirmed that privileges exist to protect institutional functioning, not individual immunity.
2. **Inherited privileges under Article 105(3):** Privileges are derived from those of the **House of Commons** until defined by law, embedding parliamentary convention into constitutional practice.
   Eg: Constituent Assembly Debates (1949) clarified that privileges were retained to safeguard legislative authority, not to create legislative supremacy.
3. **Collective rather than individual character:** Privileges primarily vest in the House as an institution, reinforcing collective legislative dignity over personal discretion.
   Eg: Keshav Singh case (1965) held that legislative privilege cannot override constitutional supremacy or fundamental rights.
4. **Link with separation of powers:** Privilege protects legislative autonomy against executive or judicial encroachment, maintaining institutional balance.
   Eg: Raja Ram Pal judgment recognised limited judicial review to prevent constitutional transgression while respecting legislative autonomy.
5. **Subordination to constitutional morality:** Parliamentary privilege operates within the broader framework of **constitutional supremacy**, not parliamentary absolutism.
   Eg: Supreme Court jurisprudence consistently holds that no constitutional authority is above the Constitution itself.

Role of procedural rules in regulating and constraining privilege

1. **Article 118 and rule-making power: Article 118** empowers each House to frame rules regulating conduct of business, placing procedural discipline over privilege.
   Eg: Rules of Procedure of Lok Sabha and Rajya Sabha govern admissibility of speeches, references, and documents.

2. **Authority of the Presiding Officer:** The **Speaker/Chairman** enforces procedural rules, acting as the first institutional check on misuse of privilege.
   Eg: Speaker's rulings under Rules of Procedure routinely restrict references not connected with listed business.
3. **Restrictions on admissible material:** Procedural rules bar references to documents not formally before the House, ensuring deliberative discipline.
   Eg: Lok Sabha Rule 349 limits quotations from external material unrelated to parliamentary business.
4. **Disciplinary mechanisms within the House:** Rules provide for naming, suspension, and expunction, preventing privilege from shielding disorderly conduct.
   Eg: Rule-based suspensions of members have been upheld as internal matters essential for orderly functioning.
5. **Codification demands and reform debates:** Institutional bodies emphasise clearer procedural regulation to prevent arbitrariness.
   Eg: National Commission to Review the Working of the Constitution (2002) recommended defining privileges by law to enhance clarity and accountability.

<u>Conclusion</u>

Parliamentary privilege is a functional safeguard, not a constitutional exemption. Its legitimacy lies in disciplined exercise through procedural rules that preserve both legislative freedom and constitutional order in a democratic polity.

Q. Analyse the economic rationale behind fertiliser subsidies in India. Analyse how the present subsidy architecture influences farmer input behaviour and cropping choices. Propose reforms to improve efficiency without compromising affordability. (15 M)

Introduction

Fertiliser subsidies were designed to make modern inputs affordable and raise foodgrain output after the Green Revolution. However, over time, they have also become a powerful driver of distorted nutrient use, cropping concentration and rising fiscal stress.

<u>Body</u>

<u>Economic rationale behind fertiliser subsidies in India</u>

1. **Food security and productivity stabilisation:** Subsidies reduce input costs and support stable yields, especially for cereals.
   Eg: Economic Survey has repeatedly linked input affordability with India's ability to sustain high output of **rice and wheat** under MSP-led procurement.
2. **Protecting small and marginal farmers:** They face low risk-bearing capacity and high price sensitivity for essential inputs.
   Eg: NSS Situation Assessment surveys consistently show small farmers have weak net incomes, making input price shocks highly damaging.
3. **Containing food inflation:** Fertiliser cost increases transmit quickly into food prices through higher cultivation costs.

Eg: During global fertiliser price spikes after **Russia-Ukraine conflict (2022)**, India absorbed shocks largely through higher subsidies.

4. **Correcting market failures in agriculture:** Thin input markets and imperfect credit make farmers under-invest in productivity.
   Eg: Regions with weak private input supply chains show higher dependence on subsidised urea through cooperative channels.
5. **Strategic necessity due to import dependence:** India is highly dependent on imports for phosphatic and potassic fertilisers.
   Eg: India imports almost all **MOP** and significant quantities of **phosphoric acid and rock phosphate**, making subsidy crucial for stability.

How present subsidy architecture influences farmer behaviour and cropping choices

1. **Urea overuse due to severe price distortion:** Fixed low MRP makes nitrogen artificially cheap relative to P and K.
   Eg: The urea MRP has remained frozen since **2012**, encouraging excessive nitrogen application in cereals.
2. **Nutrient imbalance and declining soil health:** Farmers optimise for immediate yield, not long-term soil fertility.
   Eg: Soil Health Card Scheme data and ICAR studies have highlighted widespread **micro-nutrient deficiencies** like zinc and boron.
3. **Cropping concentration towards water-intensive cereals:** Subsidised urea supports high-input rice-wheat systems.
   Eg: Punjab–Haryana rice-wheat belt shows high fertiliser intensity linked with **groundwater depletion** flagged by **NITI Aayog (Composite Water Management Index)**.
4. **Lower adoption of speciality fertilisers and precision nutrition:** Non-subsidised nutrients remain costly and less promoted.
   Eg: Fertigation-grade nutrients for horticulture face limited uptake despite expansion of **micro-irrigation under PMKSY**.
5. **Leakages, diversion and black marketing incentives:** Large price gaps create incentives for diversion to non-farm uses.
   Eg: Reports of **industrial diversion of urea** and periodic shortages in peak seasons are repeatedly flagged in policy discussions.
6. **Regional inequality in access and use:** States with better procurement, cooperatives and logistics get more stable supply.
   Eg: Fertiliser availability differences across States are often noted in **RBI State finances** and agriculture ministry distribution reviews.

Reforms to improve efficiency without compromising affordability

1. **Gradual urea price rationalisation with farmer protection:** Correct price distortion while compensating vulnerable farmers.
   Eg: The **Economic Survey** has supported rationalising subsidies to reduce distortions while protecting small farmers.
2. **Shift to nutrient-neutral support under NBS expansion:** Extend true nutrient-based subsidy principles to urea.

Eg: Nutrient Based Subsidy (NBS, 2010) covers P&K, but excluding urea has kept the distortion intact.

3. **Strengthen fertiliser DBT and reduce diversion:** Improve tracking from manufacturer to retailer to farmer.
   Eg: DBT in fertilisers (2016) improved transparency, but diversion persists due to low urea price differentials.
4. **Promote balanced fertilisation using SHC and extension:** Link subsidies to soil-based recommendations and behaviour change.
   Eg: Soil Health Card advisories can be integrated with local extension and KVK demonstrations for NPK balance.
5. **Incentivise nano and alternative nutrient efficiency products cautiously:** Use evidence-based scaling, not blanket promotion.
   Eg: Nano urea rollout by **IFFCO** has been promoted, but scaling should remain linked to independent agronomic evaluation.
6. **Support speciality nutrients for high-value crops:** Encourage precision fertilisers for horticulture without blanket subsidy.
   Eg: Expanding horticulture and micro-irrigation requires **water-soluble fertilisers** for fertigation, especially in fruits and vegetables.
7. **Improve domestic production and import resilience:** Reduce external vulnerability in P and K supply chains.
   Eg: Policy focus on long-term contracts and overseas resource partnerships aligns with concerns raised after the **2022 global shock**.

Conclusion

Fertiliser subsidies remain vital for food security and farmer welfare, but the current architecture encourages inefficiency and ecological stress. India needs a calibrated shift towards nutrient-neutral, soil-based and farmer-protective reforms that sustain affordability while improving productivity and sustainability.

Q. Evaluate the effectiveness of MSP in mitigating agrarian distress. Assess whether its benefits are equitably distributed across regions and farm sizes. Propose corrective measures to enhance inclusivity and efficiency. (15 M)

Introduction

Agrarian distress in India reflects income volatility, rising input costs and market uncertainties despite sustained growth in foodgrain output. The **Minimum Support Price (MSP)** mechanism, rooted in price assurance, remains central to the State's commitment under **Article 39(b)** to ensure equitable distribution of resources and livelihood security.

Body

<u>**Role of MSP in mitigating agrarian distress**</u>

1. **Price assurance against market volatility:** MSP acts as a floor price that protects farmers from distress sales during bumper production or price crashes.
   Eg: The **Commission for Agricultural Costs and Prices (CACP)** recommends MSP for 23 crops

annually, and procurement of **wheat and paddy** by **Food Corporation of India (FCI)** has stabilised prices during surplus years, as reflected in **Economic Survey 2022-23** data on procurement operations.

2. **Income stabilisation through cost-plus formula:** The policy of fixing MSP at least 1.5 times the **all-India weighted average cost of production (A2+FL)** has improved predictability of returns.
   Eg: As per **Union Budget 2018-19 announcement**, MSPs have been fixed at 1.5 times cost, with crops like **pulses and oilseeds** witnessing enhanced MSP hikes to incentivise production diversification.
3. **Signal for crop diversification:** Higher MSPs for pulses and oilseeds aim to reduce cereal-centric bias and import dependence.
   Eg: MSP increases for **tur and moong** in recent years were aligned with the **National Food Security Mission**, encouraging acreage expansion in rainfed regions.
4. **Psychological and institutional confidence:** Assured price announcements before sowing season provide planning security to farmers.
   Eg: MSPs are announced ahead of sowing seasons based on **CACP recommendations**, strengthening forward planning and input investment decisions.

Equity of MSP distribution across regions and farm sizes

1. **Regional concentration of procurement:** MSP benefits are heavily concentrated in a few states due to strong procurement infrastructure.
   Eg: According to **FCI procurement data**, states like **Punjab and Haryana** account for a disproportionately high share of wheat and paddy procurement, while eastern states receive limited coverage.
2. **Crop bias towards cereals:** Operational procurement is largely restricted to wheat and paddy, marginalising farmers growing other MSP-notified crops.
   Eg: Despite MSP announcements for 23 crops, effective procurement remains limited mainly to cereals, as noted in **CACP reports**, leading to uneven realisation of benefits.
3. **Large farmer advantage:** Farmers with marketable surplus benefit more compared to small and marginal farmers who consume a large share of output.
   Eg: Agricultural Census 2015-16 shows over **86% holdings are small and marginal**, limiting their capacity to participate meaningfully in MSP procurement operations.
4. **Limited outreach in non-traditional states:** Infrastructure gaps and delayed procurement operations weaken access.
   Eg: Variations in procurement centres and storage capacity across states have been highlighted in **NITI Aayog discussion papers** on agricultural reforms.

Corrective measures to enhance inclusivity and efficiency

1. **Decentralised procurement expansion:** Strengthening procurement in eastern and rainfed states can correct regional skewness.
   Eg: The **Decentralised Procurement Scheme (DCP)** allows states to undertake procurement on behalf of the Centre, enabling wider coverage when effectively implemented.
2. **Diversified crop procurement:** Expanding effective procurement beyond cereals to pulses, oilseeds and fibre crops can improve equity.

Eg: Enhanced procurement of **pulses through agencies like NAFED** during price crashes has demonstrated potential for broader MSP realisation.

3. **Integration with direct income support:** Complementing MSP with income transfers can reduce dependence on procurement-heavy models.
   Eg: PM-KISAN, launched in **2019**, provides direct income support to small farmers, supplementing price-based interventions.
4. **Transparent cost calculation reforms:** Improving methodology of cost estimation can enhance credibility and fairness.
   Eg: The debate around **A2+FL versus C2 cost formula**, discussed in the context of the **Swaminathan Commission (National Commission on Farmers, 2006)**, underscores need for clarity in cost benchmarks.
5. **Market reforms and infrastructure development:** Strengthening storage, logistics and digital platforms can improve efficiency.
   Eg: Initiatives like **e-NAM (launched 2016)** aim to integrate agricultural markets and enhance price discovery beyond MSP-dependent channels.

Conclusion

MSP remains a critical stabiliser in India's agrarian economy but suffers from structural inequities and operational concentration. A calibrated blend of decentralised procurement, diversified crop coverage and complementary income support can transform MSP into a more inclusive and sustainable instrument of farm welfare.

Food processing and related industries in India- scope' and significance, location, upstream and downstream requirements, supply chain management.

Land reforms in India.

Effects of liberalization on the economy, changes in industrial policy and their effects on industrial growth.

Q. "India's next manufacturing leap will be defined more by what it produces than by how much it produces". Analyse the strategic significance of technology-intensive manufacturing. Discuss the structural and capability-related challenges involved in such a transition. (15 M)

Introduction

Modern manufacturing competitiveness is increasingly shaped by **technological depth, strategic relevance and value-chain positioning**, rather than sheer production volumes. In a fragmented global economy, manufacturing strength today reflects **capability intensity more than capacity expansion**.

Body

Manufacturing value over manufacturing volume

1. **Value capture dominance:** High-technology manufacturing enables retention of profits through design ownership, intellectual property and system integration rather than low-margin assembly.
   Eg: In **electronics manufacturing**, design, components and system architecture capture most value, while final assembly contributes marginally.
2. **Strategic leverage in global systems:** Countries producing complex and non-substitutable goods gain leverage in trade negotiations and crisis situations.
   Eg: India's role as a supplier of **generic medicines and vaccines** made it an indispensable node in global health supply chains.
3. **Resilience against supply-chain shocks:** Technology-intensive products are harder to substitute quickly, providing insulation against external disruptions.
   Eg: The **global semiconductor shortage** disrupted automobile production worldwide, highlighting the strategic weight of advanced manufacturing.
4. **Quality of growth outcomes:** Value-driven manufacturing supports higher productivity, formal employment and durable income growth.
   Eg: Pharmaceuticals and electronics show higher productivity levels compared to low-technology manufacturing segments.

Strategic significance of technology-intensive manufacturing

1. **Higher productivity and skill premiums:** Technology-intensive sectors generate superior labour productivity and higher-skilled employment.
   Eg: Advanced roles in **electronics design and precision engineering** command higher wage and skill premiums.
2. **Export sophistication and competitiveness:** High-technology goods improve export quality and reduce vulnerability to commodity price volatility.
   Eg: Rising exports of **electronics and specialised pharmaceuticals** reflect improved manufacturing sophistication.
3. **Innovation spillover effects:** Advanced manufacturing stimulates upstream suppliers, tooling industries and engineering services.
   Eg: Growth of **automobile and electronics clusters** has strengthened domestic component ecosystems.
4. **Strategic and security relevance:** Technology-intensive manufacturing underpins defence preparedness and critical infrastructure resilience.
   Eg: Dependence on imported **semiconductors and electronics** has implications for defence and communication systems.

Structural and capability-related challenges

1. **Limited indigenous R&D depth:** Manufacturing firms rely heavily on imported technologies rather than in-house innovation.
   Eg: Many firms focus on **process adaptation instead of original product development**.
2. **Fragmented firm structure:** Dominance of small and sub-scale enterprises limits capital deepening and technology absorption.
   Eg: A large share of manufacturing units remain **low-capital and low-productivity**.
3. **Skill–technology mismatch:** Workforce capabilities lag behind the requirements of advanced manufacturing systems.
   Eg: Shortages persist in **electronics design, precision machining and advanced materials handling**.
4. **Import dependence for critical inputs:** Incomplete domestic supply chains restrict value addition and strategic autonomy.

Eg: Continued reliance on imported **electronic components and active pharmaceutical ingredients** constrains upgrading.

Way forward

1. **Capability-driven industrial deepening:** Manufacturing must progress from assembly orientation to mastery over design, engineering and systems integration.
   Eg: Firms internalising **product design and advanced process control** retain higher long-term value.
2. **Strengthening firm-level technological learning:** Continuous experimentation and incremental innovation enable gradual movement up the value chain.
   Eg: Indian firms upgrading from **basic components to complex sub-systems** illustrate this learning pathway.
3. **Building integrated industrial ecosystems:** Dense and interconnected ecosystems support scale economies, supplier upgrading and faster diffusion of technology.
   Eg: Deep **automobile and electronics ecosystems** show stronger productivity gains than isolated units.
4. **Aligning skills with advanced manufacturing needs:** Human capital must match the requirements of automation, precision manufacturing and digital production.
   Eg: Rising demand for skills in **electronics design, robotics and advanced machining** reflects this shift.

Conclusion

India's manufacturing future will be determined by **technological depth, strategic indispensability and ecosystem maturity**, not output alone. Overcoming capability and structural constraints is central to transforming India into a **globally relevant manufacturing power**.

Q. Examine the structural reasons behind India's dominance in generics manufacturing. Discuss the constraints in transitioning to innovation-driven pharma growth. (10 M)

Introduction

India's pharmaceutical industry is central to global public health and industrial capability. Its dominance in generics reflects structural policy design, but moving from scale to science-led innovation remains a complex challenge.

Body

Structural reasons behind India's dominance in generics manufacturing

1. **Process patent regime under Patents Act, 1970:** The shift to process patents enabled reverse engineering of drugs and fostered domestic capabilities in affordable generics production.
   Eg: The **Patents Act, 1970** replaced product patents with **process patents**, which allowed firms like **Cipla and Ranbaxy** to manufacture low-cost versions of essential medicines, contributing to India supplying nearly **20 per cent of global generics by volume (IBEF, 2023)**.
2. **Strong manufacturing ecosystem and USFDA compliance:** India developed large-scale manufacturing clusters with high regulatory standards, especially USFDA-approved facilities.
   Eg: India has the **largest number of USFDA-approved plants outside the US (CDSCO/IBEF data)**, enabling exports to regulated markets and strengthening global credibility.

3. **Cost competitiveness and skilled human capital:** A robust base of chemistry graduates and lower production costs ensured global price advantage in off-patent drugs.
   Eg: The presence of clusters in **Hyderabad and Ahmedabad**, combined with engineering and pharmacy institutes, created economies of scale in **Active Pharmaceutical Ingredients (APIs)** and formulations.
4. **Policy support for generics exports:** Export promotion measures and global regulatory integration supported expansion into 200+ countries.
   Eg: The **Pharmaceuticals Export Promotion Council of India (Pharmexcil)** has facilitated market access, contributing to pharma exports crossing **USD 25 billion in 2022–23 (Ministry of Commerce)**.
5. **Public health orientation and global demand:** Global demand for affordable HIV and TB drugs strengthened India's generics leadership.
   Eg: Indian firms supplied affordable **antiretrovirals** that significantly reduced global HIV treatment costs, acknowledged in **WHO reports on access to medicines**.

<u>Constraints in transitioning to innovation-driven pharma growth</u>

1. **Weak R&D intensity and science ecosystem:** India's gross expenditure on R&D remains around **0.7 per cent of GDP (DST data)**, limiting breakthrough drug discovery capacity.
   Eg: Compared to advanced economies investing over **2–3 per cent of GDP in R&D (World Bank data)**, India's limited research funding constrains biologics and novel molecule development.
2. **Risk capital and long gestation cycles:** Innovation requires patient capital and risk tolerance, which remains underdeveloped in India's pharma ecosystem.
   Eg: Venture funding in deep-science biotech remains modest compared to the US, affecting transition from generics to **new chemical entities (NCEs)**.
3. **Dependence on imported APIs, especially from China:** High reliance on imported intermediates creates vulnerability and limits value addition.
   Eg: Government launched the **Production Linked Incentive scheme for APIs (2020)** to reduce dependence on Chinese imports in key bulk drugs.
4. **Regulatory complexity and ease of doing business:** Lengthy approvals and compliance burdens affect innovation timelines.
   Eg: The government's push for **trust-based decriminalisation in Budget 2023–24** aims to reduce regulatory friction and improve the innovation climate.
5. **Limited university-industry collaboration:** Innovation ecosystems require strong linkages between academia and industry, which remain fragmented.
   Eg: Reports of the **Economic Survey 2022–23** emphasised strengthening research universities and industry partnerships to build a knowledge-driven economy.

Conclusion

India's generics success was built on smart policy and manufacturing depth, but innovation leadership demands deeper science investment and ecosystem reform. The shift from pharmacy of volume to pharmacy of value will define India's economic and technological sovereignty in the coming decades.

Infrastructure: Energy, Ports, Roads, Airports, Railways etc.

Q. Hydrogen adoption is constrained as much by safety infrastructure as by production capacity. Evaluate the safety risks in hydrogen value chains. Discuss why sensing and leak detection technologies are critical for scaling hydrogen. (10 M)

Introduction

Hydrogen can decarbonise hard-to-abate sectors, but it also introduces a **high-consequence industrial risk** because it is highly flammable and difficult to detect without specialised systems. Therefore, scaling hydrogen is as much a **safety engineering challenge** as it is an energy transition challenge.

Body

Safety risks across the hydrogen value chain

1. **High flammability and wide ignition range:** Hydrogen forms explosive mixtures with air and can ignite easily, making even small leaks dangerous.
   Eg: Hydrogen safety standards globally treat it as a high-risk gas because ignition can occur from low-energy sources like static discharge.
2. **Leak-prone due to small molecular size:** Hydrogen molecules can escape through tiny imperfections, seals, and joints, increasing the probability of unnoticed leakage.
   Eg: In pipeline and storage systems, micro-leaks can occur at valves and welds, requiring continuous monitoring.
3. **Invisible flame and detection difficulty:** Hydrogen burns with a near-invisible flame, making it hard to identify fires quickly in industrial environments.
   Eg: Safety protocols in hydrogen handling emphasise detection systems because visual identification is unreliable.
4. **Embrittlement of metals and material degradation:** Hydrogen can weaken certain metals over time, raising risks of cracking and structural failure in storage and transport infrastructure.
   Eg: High-pressure hydrogen cylinders and pipelines require specialised alloys and periodic integrity testing.
5. **High-pressure storage and cascading failure risk:** Hydrogen is often stored at high pressure, so failures can cause rapid releases and escalation into explosions.
   Eg: Refuelling stations and industrial storage sites require multi-layered safety systems similar to other high-pressure hazardous gases.

Why sensing and leak detection are critical for scaling hydrogen

1. **First line of defence for prevention:** Early detection stops leaks before they reach ignition thresholds, reducing accident probability.
   Eg: Modern hydrogen safety designs treat sensors as essential for automatic shutdown and isolation systems.
2. **Enables safe operation in humid and industrial conditions:** Real-world hydrogen environments often include moisture (fuel cells, industrial processes), where conventional sensors may fail.
   Eg: Recent sensor innovations focus on maintaining sensitivity in humid air, improving reliability for fuel-cell ecosystems.
3. **Supports public acceptance and regulatory clearance:** Safety assurance determines whether hydrogen infrastructure gains social legitimacy and regulatory approvals.

Eg: Hydrogen refuelling stations require strict compliance with safety norms, where leak detection is a core requirement.

4. **Reduces insurance, investment and project risk:** Reliable detection lowers perceived risk, improving bankability of hydrogen projects and supply chains.
   Eg: Industrial-scale hydrogen deployment needs credible safety monitoring to attract private investment.
5. **Strengthens emergency response and disaster management:** Sensors enable alarms, evacuation, and rapid containment, preventing escalation into large-scale disasters.
   Eg: Automated detection-linked shutdown systems are standard in hazardous industrial plants and will be equally vital for hydrogen.

Conclusion

Hydrogen's scalability will be decided not only by production cost but by the credibility of its safety ecosystem. Robust sensing, detection and standards can turn hydrogen from a high-risk fuel into a dependable pillar of India's clean energy transition.

Q. Transport contributes significantly to India's final energy demand and emissions. Analyse why decarbonising transport is structurally harder than decarbonising electricity. Suggest a sectoral sequencing strategy up to 2035. (15 M)

Introduction

India's transport system is where **growth, oil dependence, urban air pollution and climate risk** collide. Unlike electricity—where emissions can be cut at the generator—transport emissions are embedded in **millions of vehicles, fuels and travel choices**.

Body

Transport contributes significantly to India's final energy demand and emissions

1. **Oil-dominated energy profile: Transport runs primarily on imported petroleum**, making it a major contributor to final energy use and external vulnerability.
   Eg: India's crude import dependence remains very high; transport is the largest consumer of **diesel and petrol**, linking mobility directly with the **current account deficit** (Source: **PPAC**, **MoPNG**).
2. **Urbanisation-driven demand surge: Rising incomes and city expansion increase vehicle-km travelled**, raising emissions even if efficiency improves.
   Eg: Rapid growth of **urban travel demand** and motorisation in Indian cities is repeatedly flagged in **NITI Aayog's Net Zero pathways** as a lock-in risk.
3. **Freight intensity of the economy: Logistics demand expands with manufacturing, e-commerce and construction**, raising heavy-duty emissions.
   Eg: Growth in **e-commerce trucking and express logistics** has increased freight movement, while **road remains the dominant freight mode** (Source: **NITI Aayog**, **MoRTH**).

Why decarbonising transport is structurally harder than decarbonising electricity

1. **Asset lock-in and slow fleet turnover: Vehicles remain on roads for 10–20 years**, so policy changes take long to reflect in emissions.

Eg: A large stock of **legacy ICE vehicles** (two-wheelers, trucks, buses) continues operating despite new EV sales (Source: **NITI Aayog** transport decarbonisation report, 2026).

2. **Hard-to-abate segments: Heavy trucks, aviation and shipping have limited near-term substitutes**, unlike power where renewables can directly replace coal generation.
   Eg: Long-haul trucking needs high energy density; **SAF** and **green hydrogen** are still costly and supply-constrained for aviation/shipping.
3. **Infrastructure dependence: Transport decarbonisation needs parallel networks**—charging, hydrogen, CBG, blending, depots—while electricity decarbonisation is mainly grid + generation.
   Eg: Scaling EVs requires **fast-charging corridors**, while hydrogen needs **production–storage–dispensing** ecosystems (Source: **NITI Aayog**, **MNRE**).
4. **Behavioural and modal challenge: Emissions depend on travel behaviour and mode choice**, not only technology.
   Eg: Even with cleaner cars, a shift away from **bus/metro** to private vehicles can raise congestion and emissions; hence NITI stresses **modal shift**.
5. **Federal and multi-agency governance: Urban transport involves multiple authorities**, causing fragmented planning and weak accountability.
   Eg: Metro, bus services, road design, parking, land-use are split across **ULBs, State Transport Departments, Development Authorities** leading to inconsistent outcomes.
6. **Affordability and political economy: Transport fuels and vehicle prices are politically sensitive**, making carbon pricing and rapid transitions harder.
   Eg: Any sharp transition that raises costs affects **farm logistics, MSMEs, and informal workers**, creating resistance unless compensated.
7. **Grid-emissions coupling: EV decarbonisation depends on power-sector cleanliness**, while electricity decarbonisation does not depend on transport.
   Eg: If coal-heavy marginal power supplies charging, emissions reduction is smaller—hence EV gains depend on **renewables + storage** expansion (Source: **CEA**, **NITI Aayog**).
8. **Local air pollution vs climate trade-offs: Some fuels reduce PM but not CO_2**, complicating policy choices.
   Eg: CNG improves urban air quality but is not net-zero; policy must balance **PM reduction** with **long-term decarbonisation**.

<u>**Sectoral sequencing strategy up to 2035**</u>

1. **2026–2030: Electrify two-/three-wheelers first (highest impact, fastest adoption)** because they dominate urban trips and are cost-competitive earlier.
   Eg: State EV policies and **FAME-type incentives** have already shown faster adoption in **e-2W and e-3W**; scale with **battery swapping and charging**.
2. **2026–2032: Public transport electrification (buses + depots) as the backbone of modal shift** to cut both emissions and congestion.
   Eg: PM e-Bus Sewa supports deployment of e-buses; pairing with **bus priority lanes** maximises emission reduction per rupee.
3. **2026–2035: Freight efficiency first, then fuel transition for trucks**—reduce tonne-km and empty runs before expensive fuel substitution.
   Eg: PM Gati Shakti + National Logistics Policy (2022) enable multimodal planning; integrate with **rail–road modal shift**, warehousing hubs and digitised freight.

4. **2027–2035: Accelerate rail-based freight and RRTS/metro expansion in dense corridors** to lock-in low-carbon mobility.
   Eg: Expansion of **RRTS** and metro systems with **last-mile integration** aligns with NITI's modal rebalancing strategy.
5. **2028–2035: Scale CBG and ethanol FFVs for transitional decarbonisation where electrification is slower** (rural, long-distance, specific fleets).
   Eg: SATAT promotes **Compressed Bio-Gas (CBG)**; ethanol blending roadmap supports FFV ecosystem, reducing oil dependence (Source: **MoPNG**).
6. **2030–2035: Begin hydrogen adoption in niche heavy-duty and industrial freight corridors** where total cost can become viable with green hydrogen scale-up.
   Eg: National Green Hydrogen Mission (2023) can enable early hydrogen trucking pilots in **mining, ports, and dedicated freight routes**.
7. **2030–2035: Aviation and shipping—focus on efficiency + pilots for sustainable fuels** rather than premature mandates.
   Eg: Start with **operational efficiency, green ports, shore power**, and limited **SAF trials** while building domestic supply chains.
8. **Cross-cutting till 2035: Align electricity decarbonisation with transport electrification** to avoid emissions shifting.
   Eg: Green Open Access rules, RE procurement for charging depots, and grid upgrades recommended by **CEA planning** can ensure EVs run on cleaner power.

<u>Conclusion</u>

Electricity can be decarbonised at the **source**, but transport must be decarbonised across **technology, infrastructure and behaviour** simultaneously. A sequenced strategy—**EVs for light mobility, buses + rail for modal shift, and efficiency-first freight**—is the most realistic pathway to 2035 without economic disruption.

Q. Analyse the structural challenges facing India's civil aviation sector. Suggest reforms to ensure safe and sustainable growth. (10 M)

<u>Introduction</u>

India's civil aviation has expanded at a scale where **operational reliability and safety governance** are now as important as passenger growth. As India emerges as the **world's 3rd largest domestic aviation market**, the sector's next phase must be built on **resilience, manpower depth and strong regulation**.

<u>Body</u>

<u>Structural challenges facing India's civil aviation sector</u>

1. **Pilot and crew shortage:** Rapid fleet expansion has outpaced pilot availability, pushing airlines into overstretched scheduling and fatigue risks.
   Eg: Parliamentary disclosures estimated a need of **~7,000 pilots (2024–26)**, while DGCA issued only **~5,700 CPLs (2020–24)**, creating a persistent manpower gap.
2. **Fatigue and compliance stress under FDTL:** Tight schedules and low spare crew make compliance with **Flight Duty Time Limitation (FDTL)** operationally difficult.
   Eg: The tightening of **FDTL Phase-2** triggered large-scale cancellations and delays, exposing schedules that were legally non-viable without crew buffers.

3. **Regulatory capacity deficit in DGCA:** Oversight capacity has not scaled with fleet size, weakening inspections, audits and enforcement credibility.
   Eg: Reports show **DGCA technical vacancies remain high**, forcing reliance on post-facto notices instead of preventive safety surveillance.
4. **Duopoly-driven systemic risk:** High market concentration reduces redundancy, so disruption in one airline becomes a nationwide connectivity shock.
   Eg: DGCA market shares (2024–25) show **IndiGo ~63–65%** and **Air India group ~27–28%**, meaning failures lead to **capacity contraction**, not passenger redistribution.
5. **Airport and ATC bottlenecks:** Slot scarcity, runway congestion and airspace constraints create cascading delays and poor passenger experience.
   Eg: Delhi and Mumbai face persistent **slot saturation**, where minor disruptions spill over into nationwide network instability.
6. **ATF price volatility and forex exposure:** Airlines face structural cost instability due to **ATF linkage to global crude** and **dollar-denominated leasing**.
   Eg: Airline failures such as **Jet Airways (2019)** and **Go First (2023)** show how fuel and lease stress can quickly convert into insolvency.
7. **Weak regional aviation viability:** Thin routes, low frequency, and infrastructure gaps make regional airlines fragile despite policy intent.
   Eg: Despite **UDAN** expanding connectivity, several carriers failed (e.g., **TruJet 2022**), indicating ecosystem weaknesses beyond subsidies.

<u>**Reforms to ensure safe and sustainable growth**</u>

1. **Aviation human capital mission:** Expand flying schools, simulators and type-rating pipelines to reduce pilot supply inelasticity.
   Eg: A national capacity push aligned with **DGCA licensing + simulator infrastructure** can reduce dependence on costly foreign pilots.
2. **Safety-first regulation with DGCA strengthening:** Fill vacancies, modernise surveillance tools, and institutionalise risk-based inspections.
   Eg: Using **ICAO's safety oversight approach** through systematic audits can shift India from reactive notices to preventive regulation.
3. **Resilience buffers in airline operations:** Mandate minimum spare crew/fleet buffers and enforce schedule realism during peak seasons.
   Eg: Global airlines maintain spare capacity to absorb shocks; India can adapt this via DGCA norms linked to fleet size and utilisation.
4. **ATF and financial risk management reforms:** Reduce cost volatility through taxation rationalisation and hedging enablement.
   Eg: Policy options like bringing **ATF under GST** (debated) and permitting structured **fuel hedging** can stabilise airline finances.
5. **Airport capacity and airspace modernisation:** Expand runways/terminals, improve slot coordination and upgrade ATC for efficiency.
   Eg: Faster execution of capacity plans under **National Civil Aviation Policy (2016)** and greenfield airports like **Noida** can reduce delay cascades.

<u>**Conclusion**</u>

India's aviation growth must shift from **high utilisation** to **high reliability**. A stronger DGCA, deeper manpower pipelines, resilient airline operations and modern airport capacity can make Indian aviation both **safe and sustainably affordable**.

Investment models.

Science and Technology- developments and their applications and effects in everyday life.

Q. "India's AI ambition will be constrained less by talent and more by compute, energy and institutional capacity". Discuss. (15 M)

Introduction

India has a strong base of engineers, startups and digital public infrastructure, but AI leadership is no longer determined only by talent. The binding constraints are increasingly the "hard foundations" of AI power: **compute access, energy reliability and institutional capability**.

Body

Constraints from compute

1. **GPU access bottleneck:** Training and deploying frontier models requires large-scale **GPU clusters**, and India remains heavily dependent on imports for high-end accelerators.
   Eg: IndiaAI Mission (2024) explicitly focuses on building national compute capacity, reflecting that compute scarcity is a systemic constraint.
2. **High cost of compute for startups and academia:** Limited domestic compute raises costs, making experimentation, scaling and research less competitive compared to global peers.
   Eg: Indian AI startups often rely on **foreign cloud compute**, increasing operating costs and exposure to pricing and access shocks.
3. **Supply chain and geopolitics risk:** AI hardware is embedded in global strategic competition, where export controls and supply restrictions can directly affect India's AI momentum.
   Eg: The global discourse on **chip export controls** shows how compute availability can be shaped by geopolitics, not market forces alone.
4. **Weak domestic AI hardware ecosystem:** India's semiconductor push is growing, but the ecosystem for **AI accelerators, high-end GPUs, and advanced packaging** remains limited.
   Eg: Semicon India programme signals intent, but domestic AI-grade compute hardware remains a long-gestation gap.

Constraints from energy

1. **Rising power demand from data centres:** AI inference and training are energy-intensive, making **power availability and grid stability** key determinants of AI scale.
   Eg: India's policy push for **data centre expansion** reflects that AI competitiveness now depends on power infrastructure.
2. **Clean energy trade-off:** AI growth can raise emissions unless paired with renewables, storage and efficiency, creating a new climate–growth policy trade-off.
   Eg: India's net-zero pathway requires that data centre growth aligns with **renewable integration and storage**.

3. **Local infrastructure stress:** Concentrated data centres can strain local **power distribution, cooling systems and water availability**, creating sustainability and social licensing challenges.
   Eg: Data centre clusters often face concerns around **water-intensive cooling** and local electricity load stress.
4. **Energy security and strategic autonomy:** If AI depends on imported fuels or unstable power, the ecosystem becomes vulnerable, limiting long-term AI sovereignty.
   Eg: The growing global discussion on linking AI expansion with **firm low-carbon power** shows why energy becomes a competitiveness lever.

Constraints from institutional capacity

1. **Fragmented AI governance:** AI touches multiple ministries and sectors, but coordination is weak, leading to inconsistent standards across health, finance, policing and education.
   Eg: The need for cross-sector AI rules is visible in debates on **AI use in public service delivery**.
2. **Limited regulatory capability for frontier tech:** Institutions often lack specialised capacity to audit models for **bias, safety, privacy and accountability**.
   Eg: The global move towards **AI assurance and model audits** highlights a capability gap in many developing states.
3. **Weak public sector procurement and deployment readiness:** Government adoption is slowed by rigid procurement, low technical capacity, and lack of outcome-based evaluation.
   Eg: DPI success (like UPI) shows state capacity matters, but AI needs stronger **evaluation and oversight frameworks**.
4. **Skewed innovation ecosystem:** India has talent, but insufficient long-term funding for deep research, labs, and academia–industry pipelines needed for foundational models.
   Eg: Global AI leadership is driven by strong **university-lab ecosystems**, which India is still scaling.

Way forward

1. **Build national compute as public digital infrastructure:** Scale shared GPU capacity with transparent access for startups, academia and strategic sectors through mission-mode governance.
   Eg: IndiaAI Mission can be strengthened by prioritising **open, affordable compute access** for domestic innovators.
2. **Create an AI-energy strategy:** Link data centre growth with renewables, grid upgrades, storage and efficiency standards to avoid an AI-driven energy shock.
   Eg: A sustainability pathway can be built through **green data centre norms** and renewable purchase obligations.
3. **Institutionalise AI assurance and accountability:** Build model evaluation capacity, sectoral guidelines and audit mechanisms for high-risk AI deployments in governance.
   Eg: Standards-based approaches used globally for **AI risk classification** can be adapted for India's context.
4. **Strengthen deep-tech R&D and public research capacity:** Expand long-horizon funding, national labs, and academia–startup pipelines for indigenous models and critical AI components.
   Eg: India's experience with mission-mode tech programmes shows that **public R&D ecosystems** are crucial for strategic autonomy.

Conclusion

India's AI future will be decided not by talent alone but by its ability to build **compute sovereignty, energy readiness and institutional competence**. The winners will be those who treat AI as **national infrastructure**, not merely a market product.

Achievements of Indians in science & technology; indigenization of technology and developing new technology.

Q. What are solar flares and coronal mass ejections (CMEs)? Explain how they can cause radio blackouts on Earth. (10 M)

Introduction

In the digital age, the Sun can behave like a "natural disruptor" of critical infrastructure. Events like **solar flares** and **coronal mass ejections (CMEs)** disturb Earth's ionosphere and magnetosphere, leading to radio blackouts and navigation errors.

Body

What are solar flares?

1. **Radiation burst (Core nature):** A solar flare is a sudden release of **electromagnetic radiation** (mainly **X-rays and extreme ultraviolet**) from the Sun's atmosphere due to magnetic reconnection.
   Eg: NOAA Space Weather Scale categorises major flares as **M-class and X-class**, which are linked to radio blackout warnings.
2. **Immediate arrival (Speed of impact):** Flare radiation travels at the **speed of light**, so its effects reach Earth in about **8 minutes**.
   Eg: Such sudden disruptions are known as **Sudden Ionospheric Disturbances (SIDs)** in space-weather monitoring.
3. **Short duration but intense:** Solar flare impacts generally last from **minutes to a few hours**, depending on strength.
   Eg: Brief but severe communication loss has been reported globally during strong flare windows affecting HF bands.

What are coronal mass ejections (CMEs)?

1. **Plasma + magnetic cloud (Core nature):** A CME is a large-scale eruption of **charged plasma** carrying embedded magnetic fields from the Sun's corona into space, sometimes Earth-directed.
   Eg: The **Carrington Event (1859)** is the classic example of an extreme CME-driven geomagnetic storm.
2. **Delayed arrival (Forecast window):** CMEs typically take about **15 hours to 3 days** to reach Earth depending on their speed.
   Eg: This time lag enables agencies like **NOAA** and national space agencies to issue storm alerts in advance.

3. **Wider and longer impact:** CMEs can trigger geomagnetic storms lasting **hours to days**, affecting multiple systems.
   Eg: The **1989 Quebec blackout** is widely associated with a CME-driven geomagnetic storm.

How solar flares and CMEs cause radio blackouts on Earth

1. **Solar flare → D-layer absorption (Primary blackout mechanism):** X-ray/EUV radiation sharply increases ionisation in the **D-region (60–90 km)**, causing **HF radio waves** to be absorbed rather than reflected.
   Eg: Aviation and maritime HF communication becomes unreliable during strong flare events, especially over oceans.
2. **Solar flare → Day-side disruption (Spatial pattern):** Flare-driven blackouts mainly affect the **sunlit side** of Earth because ionisation rises where solar radiation is present.
   Eg: Daytime radio blackouts are commonly reported during intense flare alerts.
3. **CME → Geomagnetic storm → Ionospheric instability:** Earth-directed CMEs compress Earth's magnetosphere and create geomagnetic storms, causing rapid ionospheric density changes that disrupt radio propagation.
   Eg: GNSS/GPS errors and HF disruptions increase during geomagnetic storms due to ionospheric irregularities.
4. **CME → Scintillation and satellite link disruption:** CME-driven storms produce ionospheric turbulence, leading to **signal scintillation** (rapid fluctuations in amplitude/phase), degrading satellite communication and navigation signals.
   Eg: During high solar activity, agencies like **ISRO (ISTRAC)** monitor satellites closely for communication instability and stress on systems.

Conclusion

Solar flares cause **immediate HF radio blackouts** through D-layer over-ionisation, while CMEs cause **delayed but wider geomagnetic disruptions** affecting radio, satellites, and navigation. With **Aditya-L1**, India is strengthening its ability to anticipate and manage such space-weather risks.

Q. Discuss why the Open Network for Digital Commerce (ONDC) was conceptualised in India's retail ecosystem. Evaluate its performance and constraints so far. Suggest reforms to improve its effectiveness as a competitive alternative. (15 M)

Introduction

India's digital retail has expanded rapidly, but market power has become concentrated in a few platforms, limiting fair access for small sellers. The **Open Network for Digital Commerce (ONDC)** was conceptualised to build an open, interoperable e-commerce ecosystem in line with India's Digital Public Infrastructure approach.

Body

Why the Open Network for Digital Commerce (ONDC) was conceptualised

1. **Reducing platform concentration:** ONDC was designed to prevent e-commerce from becoming a closed ecosystem dominated by a few marketplaces by enabling interoperability.

Eg: A buyer app can discover sellers across the ONDC network instead of being limited to a single platform's captive listings.

2. **Expanding MSME and kirana inclusion:** It aimed to bring small sellers online without high commissions, heavy advertising spend, or exclusive platform dependence.
   Eg: A local kirana can list products through an ONDC seller app without paying for costly visibility tools.
3. **Unbundling the commerce value chain:** ONDC conceptualised e-commerce as modular where discovery, payments, logistics and fulfilment can be offered by different providers.
   Eg: A seller can use one app for listing and another logistics partner for delivery, similar to how UPI separated banking from payment apps.
4. **Improving price discovery and competition:** By allowing multiple buyer apps to access the same seller base, ONDC aimed to strengthen competition and reduce entry barriers.
   Eg: The same seller can be discovered by users on different buyer apps, reducing dependence on one dominant intermediary.
5. **Supporting formalisation and compliance-friendly growth:** By onboarding informal retail into digital rails, ONDC can improve traceability and formal economic participation.
   Eg: Integration with GST-linked supply chains can support formal MSME scaling, consistent with the formalisation push noted in the **Economic Survey**.

<u>Performance and constraints so far</u>

1. **Limited consumer-scale adoption:** ONDC has expanded across categories but has not yet become a default choice for mass consumers.
   Eg: Unlike UPI's rapid adoption, ONDC still lacks a widely recognised everyday consumer use-case.
2. **Fragmented user experience:** Multi-app journeys can create friction in order tracking, cancellations, refunds and grievance handling.
   Eg: When buyer app, seller app and logistics provider are different entities, accountability for delays becomes unclear.
3. **Logistics and reverse logistics gaps:** Delivery reliability and returns handling remain uneven, hurting trust and repeat usage.
   Eg: Small sellers struggle to match the delivery and return experience of quick-commerce firms.
4. **Capital and pricing disadvantage:** Many ONDC sellers cannot match the pricing and discounting capacity of large capital-backed retail players.
   Eg: Quick-commerce firms can subsidise delivery and offer aggressive pricing through dark-store inventory.
5. **Trust and quality assurance constraints:** Open discovery does not automatically ensure product authenticity, ratings integrity, and consumer confidence.
   Eg: Consumers often rely on platform-level guarantees, which ONDC is still developing.
6. **Low seller capability readiness:** Many MSMEs lack skills for cataloguing, inventory syncing, packaging standards and customer support.
   Eg: A small manufacturer may onboard but struggle with returns management and service-level compliance.

<u>Reforms to improve ONDC as a competitive alternative</u>

1. **Network-level consumer protection:** Establish clear single-window accountability for refunds, returns and grievance redress across the ONDC ecosystem.
   Eg: A network dispute-resolution layer aligned with the **Consumer Protection Act, 2019** can build trust.
2. **Strengthening logistics capacity:** Build standard service-level agreements and incentivise reliable last-mile and reverse logistics partners.

Eg: Partnerships with India Post and private logistics with performance-linked incentives can improve delivery outcomes.

3. **Seller capability and credit support:** Combine onboarding with training, packaging support and working-capital access for small sellers.
   Eg: Linking ONDC sellers with **SIDBI** and digital MSME credit systems can improve competitiveness.
4. **Trust layers and verification:** Introduce stronger seller verification, quality badges and interoperable ratings to reduce information asymmetry.
   Eg: Using **Udyam registration** and **GSTIN-based verification** can improve credibility without excluding micro sellers.
5. **Anchor demand through public procurement:** Use institutional demand to create predictable early scale and stable order flows.
   Eg: Selective integration with **GeM** for MSME-heavy categories can provide initial momentum.

<u>Conclusion</u>

ONDC is a strategic attempt to make India's e-commerce ecosystem more open, competitive and inclusive, but it still faces gaps in trust, logistics and user experience. With stronger consumer protection, logistics reliability and MSME capability support, ONDC can evolve into a credible competitive alternative in digital retail.

Awareness in the fields of IT, Space, Computers, robotics, Nano-technology, bio-technology and issues relating to intellectual property rights.

Q. AI can either amplify women's empowerment or automate discrimination. Examine this statement. Illustrate with domains where women are most vulnerable. (10 M)

Introduction

AI is no longer a neutral tool; it is increasingly a decision-maker in hiring, credit, policing, welfare and health. If its design and data ignore women's lived realities, AI can scale empowerment for millions or industrialise discrimination at unprecedented speed.

Body

<u>How AI can amplify women's empowerment</u>

1. **Financial inclusion and credit access:** AI-driven alternative credit scoring can bring first-time women borrowers into formal finance by recognising cash-flow patterns beyond collateral.
   Eg: Digital lending and account aggregation under India Stack can expand women's access to micro-credit, but only when models avoid penalising informal work histories.
2. **Health access and early diagnosis:** AI-enabled screening and telemedicine can reduce barriers of distance, stigma and shortage of specialists for women's health needs.
   Eg: AI-based support tools in **telemedicine platforms under Ayushman Bharat Digital Mission (ABDM)** can improve outreach for reproductive and maternal health services.
3. **Safety and mobility solutions:** AI can improve women's safety through faster distress response, hotspot mapping and safer public transport planning.
   Eg: Women safety apps and **112 Emergency Response Support System** can be strengthened through AI-based routing and risk analytics with privacy safeguards.

How AI can automate discrimination

1. **Biased hiring and workplace screening:** AI recruitment tools trained on male-dominated historical data can downgrade women's profiles, reinforcing occupational segregation.
   Eg: Global evidence has shown automated hiring systems can replicate past bias; this risk is higher when **women are underrepresented in AI research (UN Women)**.
2. **Algorithmic exclusion in welfare delivery:** AI-based eligibility filters can wrongly exclude women due to documentation gaps, mobility constraints and household-level data capture.
   Eg: Women often face higher risk of exclusion in digitised welfare due to **ID, banking and device gaps**, making algorithmic errors more harmful.
3. **Surveillance, privacy harms and online abuse:** AI can scale gendered harms through deepfakes, doxxing, stalking and profiling, threatening dignity and freedom.
   Eg: The rise of **AI-generated deepfake harassment** has become a major safety threat for women, demanding stronger platform accountability.

Domains where women are most vulnerable

1. **Labour markets and informal work:** Women are concentrated in sectors prone to AI-driven disruption, while lacking reskilling access and social security coverage.
   Eg: UN Women–LinkedIn analysis notes a large share of women in Asia-Pacific are in job categories classified as **"augmented or disrupted"** by AI.
2. **Credit, insurance and consumer profiling:** AI can silently encode gender stereotypes, leading to discriminatory interest rates, credit limits and product targeting.
   Eg: Algorithmic decision systems can penalise women due to career breaks, part-time work or unpaid care roles, despite strong repayment behaviour.
3. **Public services and policing:** AI tools used in surveillance, predictive policing or citizen scoring can disproportionately target women, especially from marginalised communities.
   Eg: Without transparency, AI in law enforcement can violate **Article 14** and **Article 21** protections by enabling arbitrary profiling.

Conclusion
AI can be a force multiplier for women's empowerment only when built with representation, transparency and accountability. India must ensure gender-responsive AI through rights-based governance so that technology expands dignity, not discrimination.

Q. Discuss the major technological and operational challenges in maintaining large Low Earth Orbit (LEO) satellite constellations. Analyse how mega-constellations affect orbital safety and space sustainability. (10 M)

Introduction
Mega-constellations in **Low Earth Orbit (LEO)** have turned satellites into mass-produced network infrastructure rather than isolated space assets. However, scaling from hundreds to thousands introduces complex engineering, operations and sustainability risks for the orbital environment.

Body

Technological and operational challenges in maintaining large LEO constellations

1. **Collision avoidance and space traffic management:** Thousands of fast-moving satellites require continuous tracking, manoeuvre planning and coordination to avoid close approaches.
   Eg: ESA has repeatedly flagged the rising number of conjunction alerts due to dense LEO deployments, increasing operational burden for all space actors.
2. **Limited satellite lifespan and reliability degradation:** LEO satellites face radiation, thermal cycling and component fatigue, leading to failures within a few years.
   Eg: NASA's Orbital Debris Program Office highlights that higher satellite numbers increase the probability of failures that can become debris sources.
3. **Frequent replenishment and launch logistics:** Short lifespans create a permanent replacement cycle requiring high launch cadence, supply chain stability and rapid production.
   Eg: SpaceX Starlink relies on repeated launches to maintain constellation density, illustrating the "continuous replenishment" model.
4. **Spectrum coordination and interference management:** Constellations must coordinate frequencies to prevent harmful interference with other satellites and ground networks.
   Eg: The **International Telecommunication Union (ITU)** framework exists, but overlapping filings and congestion have increased disputes in satellite broadband.
5. **Ground segment complexity and network handover:** Maintaining uninterrupted service needs dense gateway stations, phased-array terminals, and seamless satellite-to-satellite handovers.
   Eg: LEO broadband requires frequent handovers due to high orbital speed, unlike GEO systems where satellites appear stationary.

<u>How mega-constellations affect orbital safety and space sustainability</u>

1. **Orbital congestion and higher collision probability:** Dense constellations increase the risk of cascading collisions, making LEO a high-risk operational environment.
   Eg: The **Kessler Syndrome** risk is widely discussed in space safety literature and is referenced in global space sustainability debates.
2. **Debris creation from failures and fragmentation events:** Non-responsive satellites, break-ups and collisions add long-lived debris that threatens all operators.
   Eg: NASA regularly reports growth in trackable debris, and large constellations multiply the number of potential debris-generating events.
3. **Strain on global tracking infrastructure:** Monitoring millions of objects (including smaller debris) demands advanced sensors and international data-sharing.
   Eg: The **US Space Surveillance Network** provides tracking support, but global reliance raises concerns about data dependence and transparency.
4. **De-orbit compliance and end-of-life disposal risks:** Even with de-orbit plans, failures can leave satellites uncontrolled, increasing debris persistence.
   Eg: The **UN COPUOS Long-term Sustainability (LTS) Guidelines (2019)** emphasise responsible end-of-life disposal and debris mitigation.
5. **Astronomy and night-sky pollution:** Reflective satellites affect optical astronomy and can interfere with radio astronomy observations.
   Eg: The **International Astronomical Union (IAU)** has raised concerns about satellite streaks affecting survey telescopes and long-exposure imaging.

Conclusion

Large LEO constellations represent the future of global connectivity, but also the future of **orbital risk** if not governed responsibly. The next phase must be defined by **space traffic rules, enforceable debris norms and sustainable constellation design**, not just launch speed.

Q. Explain how concentration of the core AI stack (compute, data and foundational models) shapes the global AI economy. Discuss how the MANAV framework can reduce exclusion and ensure wider access to AI benefits. (10 M)

Introduction
AI is fast becoming the "general-purpose infrastructure" of the 21st century, similar to electricity and the internet. However, its economic power is increasingly shaped by the concentration of the **core AI stack**, raising risks of unequal access and asymmetric gains.

Body

How concentration of the core AI stack shapes the global AI economy

1. **Compute concentration and entry barriers:** Control over high-end chips, cloud clusters and AI supercomputing creates a winner-take-all market and limits new entrants.
   Eg: US export controls on advanced AI chips (2022 onwards) have shown how compute access can become a geopolitical and market gatekeeper.
2. **Data enclosure and competitive advantage:** Firms with access to large, high-quality and proprietary datasets build better models and lock-in users through network effects.
   Eg: Big platforms leverage **user-generated data** at scale, creating a reinforcing cycle where better data produces better AI and attracts more users.
3. **Foundational model dominance and dependency:** A few firms controlling frontier foundational models shape global standards, pricing and downstream innovation pathways.
   Eg: The global AI ecosystem is increasingly built around a small number of **frontier foundation models**, creating dependency for startups and states.
4. **Standards and ecosystem lock-in:** Dominant players set de facto technical standards, APIs and safety benchmarks, shaping the global AI value chain.
   Eg: Developers worldwide often build applications around proprietary model APIs, creating **switching costs** and long-term lock-in.
5. **Unequal value capture and digital colonial patterns:** Countries that generate data may still lose value if compute and models are owned elsewhere, limiting domestic innovation capture.
   Eg: Several developing economies risk becoming **data suppliers** while IP, profits and high-skill jobs remain concentrated in model-owning jurisdictions.

How MANAV can reduce exclusion and ensure wider access to AI benefits

1. **Accessible and inclusive technology as public capacity:** Promoting affordable, multilingual and DPI-linked AI can expand adoption beyond elite users and firms.
   Eg: India's DPI model like **UPI and DigiLocker** demonstrates scalable inclusion, offering a pathway for AI delivery as a public utility layer.
2. **Accountable governance for trust and adoption:** Building auditability, transparency and liability frameworks reduces harm and increases user confidence in AI systems.
   Eg: The **DPDP Act, 2023** provides a legal base for responsible data use, enabling safer AI deployment without uncontrolled extraction.
3. **National sovereignty to prevent exploitative extraction:** Ensuring "who controls data and compute" reduces one-way dependence and strengthens domestic AI capability.
   Eg: IndiaAI Mission (2024) includes building domestic compute capacity, reducing reliance on external compute monopolies.

4. **Moral and ethical systems to prevent exclusionary outcomes:** Ethical guardrails can reduce bias, discrimination and harmful deployment in welfare, credit and jobs.
   Eg: Global experience shows AI systems can amplify bias in **hiring and credit scoring**, making ethics essential for inclusive AI benefits.
5. **Valid and legitimate systems for dispute resolution:** Clear redress mechanisms and institutional legitimacy reduce fear of AI harms and widen responsible adoption.
   Eg: A strong grievance-redress framework aligned with **consumer protection principles** can improve trust in AI-enabled services.

Conclusion
Concentration of the core AI stack risks turning AI into a closed club of power and profits. **MANAV** offers a practical pathway to expand access, reduce exclusion, and ensure AI serves as a broad-based development multiplier.

Q. Explain the concept of Physical AI and world models. Evaluate their impact on manufacturing, healthcare and urban infrastructure. Propose a strategic roadmap for India to secure technological and economic advantage in this transition. (15 M)

Introduction
Artificial intelligence is entering a new phase where cognition is embedded into machines that sense, reason and act in the real world. The rise of **Physical AI and world models** signals a shift from software-centric intelligence to infrastructure-level transformation of production systems and public services.

Body

Concept of Physical AI and world models

1. **Embodied intelligence beyond digital AI:** Physical AI refers to AI systems integrated with robots and cyber-physical systems that combine perception, decision-making and motor execution in real-world environments.
   Eg: The rapid growth of industrial robots globally, as recorded in the **International Federation of Robotics World Robotics Report (2023)**, reflects increasing deployment of AI-driven embodied systems in manufacturing.
2. **World models as predictive simulation engines:** World models are physics-aware AI systems capable of simulating real-world environments, enabling virtual testing, optimisation and decision-making before physical deployment.
   Eg: The use of **digital twins in advanced manufacturing ecosystems**, documented by the **World Economic Forum**, demonstrates how simulation reduces design costs and operational risks.
3. **Vision-Language-Action integration:** Physical AI operates through multimodal learning, integrating camera vision, sensor inputs, contextual reasoning and motor control for adaptive behaviour.
   Eg: Autonomous warehouse robots combine **LiDAR mapping, computer vision and reinforcement learning** to navigate dynamic logistics environments, a standard industry practice.
4. **Edge AI and real-time inference capability:** Unlike cloud-based AI, Physical AI systems rely on low-latency edge computing for immediate decision-making in dynamic physical spaces.
   Eg: AI-enabled inspection robots in manufacturing units use **edge processors for defect detection** without relying on remote cloud servers.

5. **Data-feedback learning loops:** Physical AI systems continuously improve through real-world interaction, creating feedback-driven training datasets for model refinement.
   Eg: Robotics R&D under the **National Mission on Interdisciplinary Cyber-Physical Systems (2018)** encourages iterative testing environments where machines learn from deployment data.

Impact on manufacturing, healthcare and urban infrastructure

1. **Smart manufacturing and flexible production:** Physical AI enables predictive maintenance, adaptive assembly lines and mass customisation, enhancing productivity and reducing downtime.
   Eg: Indian automotive clusters in **Tamil Nadu and Maharashtra** have adopted Industry 4.0 practices integrating robotics and IoT, as reflected in reports of the **Ministry of Heavy Industries**.
2. **Supply chain resilience and re-shoring:** World models allow virtual supply chain simulations, improving resilience against disruptions and geopolitical shocks.
   Eg: Post-pandemic industrial recovery strategies globally have relied on **digital twin simulations** to optimise logistics networks.
3. **Precision healthcare and robotic surgery:** AI-enabled robotic systems enhance diagnostic accuracy, surgical precision and elderly assistance in ageing societies.
   Eg: Deployment of robotic-assisted surgical systems in leading Indian hospitals demonstrates integration of AI-driven precision tools in healthcare delivery.
4. **Public health monitoring and tele-robotics:** Physical AI supports remote diagnostics, automated laboratory systems and infectious disease monitoring.
   Eg: AI-enabled diagnostic platforms during health emergencies have improved early detection capabilities, as documented in **NITI Aayog AI healthcare strategy papers (2018)**.
5. **Smart urban infrastructure management:** AI-driven robotics enhance traffic optimisation, waste segregation and infrastructure maintenance.
   Eg: Under the **Smart Cities Mission (2015)**, several cities have deployed AI-based surveillance and predictive maintenance systems as per **Ministry of Housing and Urban Affairs reports**.
6. **Energy-efficient urban systems:** World models simulate energy flows and building performance, optimising sustainability planning.
   Eg: Smart grid integration and energy modelling initiatives align with India's commitments under the **National Smart Grid Mission (2015)**.

Strategic roadmap for India

1. **Component-level indigenisation:** Reducing reliance on imported sensors, actuators and processors is essential for technological sovereignty.
   Eg: The **Production Linked Incentive Scheme for Electronics Manufacturing (2020)** demonstrates targeted industrial support for high-tech component ecosystems.
2. **Sovereign robotics data infrastructure:** Establish distributed robotics testbeds across IITs, IIITs and research institutions to generate indigenous multimodal datasets.
   Eg: Technology Innovation Hubs under the **National Mission on Interdisciplinary Cyber-Physical Systems (2018)** provide foundational research infrastructure.
3. **Standards and certification ecosystem:** Strengthen domestic robotics testing and certification through the **Bureau of Indian Standards (BIS)** to ensure safety and global competitiveness.
   Eg: BIS's expanding role in emerging technology standardisation reflects India's regulatory preparedness framework.

4. **Human capital pipeline development:** Integrate robotics education from school to higher technical institutions to build long-term innovation capacity.
   Eg: Atal Tinkering Labs (launched 2016 by NITI Aayog) provide early exposure to robotics and AI tools.
5. **Strategic public procurement and demand aggregation:** Pool procurement demand across Railways, Defence and PSUs to create stable markets for domestic robotics manufacturers.
   Eg: The demand aggregation model of **Energy Efficiency Services Limited (EESL)** in LED adoption illustrates how coordinated procurement can transform industrial sectors.
6. **Dedicated robotics manufacturing clusters:** Establish specialised Robotics Parks with prototyping, testing and certification facilities to reduce entry barriers.
   Eg: Industrial cluster models in electronics manufacturing have accelerated production capacity under central industrial policy frameworks.

Conclusion

Physical AI and world models are redefining the boundary between digital intelligence and physical infrastructure. India's strategic advantage will depend on sovereign data ecosystems, deep manufacturing capabilities and coordinated policy architecture that converts engineering talent into global technological leadership.

Conservation, environmental pollution and degradation, environmental impact assessment.

Q. What makes steel a hard-to-abate sector in climate mitigation efforts? Discuss the pathways available for decarbonising steel production in India. (10 M)

Introduction

Steel is foundational to India's infrastructure, manufacturing and energy transition, yet it remains one of the most emissions-intensive industries globally. Its decarbonisation is critical for achieving India's climate commitments without compromising developmental priorities.

Body

Structural reasons why steel is a hard-to-abate sector

1. **Coal-based blast furnace dominance**: India's steelmaking is structurally locked into the blast furnace–basic oxygen furnace route, which relies on coking coal as both fuel and reducing agent, making emissions intrinsic to production.
   Eg: BF-BOF route accounts for ~70% of India's steel output, emitting around **2.3 tCO_2 per tonne of steel** (Source: **National Steel Policy 2017, Ministry of Steel**).
2. **Process emissions beyond energy use**: Unlike power or transport, steel emits CO_2 through chemical reduction of iron ore, meaning electrification alone cannot eliminate emissions.
   Eg: Process emissions form nearly half of steel sector emissions globally, as highlighted in **IEA Iron and Steel Technology Roadmap 2023**.
3. **Capital-intensive and long asset lifecycles**: Steel plants operate on 30–40 year lifecycles, making premature retirement economically unviable and leading to carbon lock-in.

Eg: New blast furnace investments planned under capacity expansion up to 2030 risk locking emissions till mid-century (Source: **Ministry of Steel capacity projections**).

4. **Dependence on imported coking coal**: Limited domestic availability of coking coal constrains fuel switching and increases vulnerability to global supply and price shocks.
   Eg: India imports over 85% of its coking coal, mainly from Australia, as per **Ministry of Coal 2024 data**.
5. **Limited scrap availability and informality**: Secondary steelmaking is constrained by low scrap generation and an unorganised recycling ecosystem.
   Eg: Scrap-based steel contributes only ~30% of production, compared to over 60% in advanced economies (Source: **Steel Scrap Recycling Policy, 2019**).

<u>Pathways available for decarbonisation of steel in India</u>

1. **Hydrogen-based direct reduced iron**: Green hydrogen can replace coal as a reducing agent, enabling near-zero emission steel when paired with renewable electricity.
   Eg: National Green Hydrogen Mission 2023 targets 5 MTPA hydrogen production, with steel identified as a priority end-use sector (Source: **MNRE**).
2. **Expansion of scrap-based electric arc furnaces**: Increasing secondary steelmaking reduces emissions by avoiding iron ore reduction altogether.
   Eg: Steel Scrap Recycling Policy 2019 aims to formalise scrap markets and raise recycling efficiency to global benchmarks.
3. **Renewable energy integration in steel plants**: Shifting auxiliary and captive power demand to renewables lowers indirect emissions significantly.
   Eg: Tata Steel and JSW Steel have signed large-scale renewable power purchase agreements, cutting Scope-2 emissions (Source: **Company sustainability disclosures 2023–24**).
4. **Carbon capture, utilisation and storage**: CCUS can abate emissions from existing blast furnaces where immediate transition is not feasible.
   Eg: Greening Steel Roadmap 2023 identifies CCUS as a transition solution for legacy assets (Source: **Ministry of Steel**).
5. **Market-based instruments and carbon pricing**: Emission constraints create economic incentives for low-carbon production pathways.
   Eg: Carbon Credit Trading Scheme notified in 2023 places emission intensity targets on steel units, encouraging cleaner technologies (Source: **MoP & Bureau of Energy Efficiency**).

<u>Conclusion</u>

Decarbonising steel requires aligning industrial strategy with climate policy rather than treating emissions as an externality. A phased shift combining technology, markets and regulation can transform steel from a climate liability into a pillar of sustainable growth.

Q. Carrying capacity is central to sustainable development in biodiversity hotspots. Explain the concept of ecological carrying capacity. Assess its relevance for tourism planning in fragile forest landscapes. (10 M)

<u>Introduction</u>

India's biodiversity hotspots face rising human pressure from tourism even as climate change intensifies ecological stress. Sustainable development in such regions requires respecting ecological limits beyond which ecosystems lose their regenerative capacity.

<u>Body</u>

<u>Concept of ecological carrying capacity</u>

1. **Ecological threshold of ecosystems:** Ecological carrying capacity refers to the **maximum level of human activity an ecosystem can absorb without irreversible degradation** of biodiversity, soil, water and ecological processes.
   Eg: Supreme Court in Vellore Citizens' Welfare Forum vs Union of India (1996) recognised **sustainable development and precautionary principle** as integral to environmental governance under **Articles 48A and 51A(g)**.
2. **Dynamic and site-specific nature:** Carrying capacity is **not static**; it varies with ecosystem type, seasonal resilience, climate stress and human interventions, requiring periodic scientific reassessment.
   Eg: Kasturirangan Committee (2013) on Western Ghats stressed **region-specific ecological thresholds** instead of uniform development norms.
3. **Integration of biophysical limits:** It incorporates limits related to **water availability, waste assimilation, habitat tolerance and species disturbance**, not merely visitor numbers.
   Eg: National Environment Policy, 2006 highlights ecosystem limits as central to sustainable resource use.
4. **Preventive environmental management tool:** Carrying capacity functions as a **preventive planning instrument**, avoiding environmental damage rather than relying on post-damage mitigation.
   Eg: Supreme Court in MC Mehta vs Union of India (Oleum Gas Leak case, 1987) reinforced the need for preventive environmental safeguards.
5. **Linked to intergenerational equity:** Respecting carrying capacity ensures that present development does not compromise the ecological rights of future generations.
   Eg: Supreme Court in State of Himachal Pradesh vs Ganesh Wood Products (1995) emphasised conservation over short-term economic gains.

<u>Relevance for tourism planning in fragile forest landscapes</u>

1. **Protection of biodiversity and habitats:** Fragile forest ecosystems have low tolerance for disturbance; carrying capacity prevents habitat fragmentation and wildlife stress caused by excessive tourism.
   Eg: MoEFCC Eco-Sensitive Zone Guidelines (revised 2022) mandate regulation of tourism intensity around protected areas.
2. **Preservation of ecosystem services:** Forests provide flood moderation, carbon sequestration and climate resilience; exceeding carrying capacity weakens these life-support systems.
   Eg: Sundarbans mangroves, recognised as a **UNESCO World Heritage Site**, act as natural cyclone buffers, making low-impact tourism essential.
3. **Avoidance of infrastructure-led degradation:** Tourism infrastructure such as roads, resorts and jetties often exceeds ecological tolerance if not capacity-linked.
   Eg: National Tiger Conservation Authority guidelines restrict tourism infrastructure inside core forest areas to prevent ecological disturbance.
4. **Community livelihood sustainability:** Capacity-based tourism prevents boom-and-bust cycles that harm forest-dependent communities by ensuring stable, long-term income generation.
   Eg: Joint Forest Management framework promotes community participation aligned with conservation objectives.
5. **Climate resilience and disaster risk reduction:** Fragile forests are climate-sensitive; limiting tourism pressure enhances ecosystem resilience against floods, cyclones and heat stress.

Eg: IPCC Sixth Assessment Report (2022) identifies ecosystem integrity as central to climate adaptation in vulnerable regions.

Conclusion

Ecological carrying capacity provides the scientific foundation for balancing conservation and development in fragile forest landscapes. Embedding it into tourism planning ensures biodiversity protection, climate resilience and sustainable livelihoods, aligning development with long-term ecological security.

Q. Invasive aquatic weeds are often symptoms of ecological collapse, not its root cause. Identify the structural drivers behind invasive proliferation in Indian wetlands. (10 M)

Introduction

Invasive weeds such as **water hyacinth** usually flourish when wetlands lose their natural self-regulation. Their spread is often a visible outcome of **stagnation, nutrient overload and ecosystem stress**, not the original trigger.

Body

Invasive aquatic weeds are symptoms of ecological collapse, not root cause

1. **Eutrophication signal:** Dense weed mats typically indicate **high nutrient loading (nitrogen, phosphorus)** from sewage and runoff, showing the wetland is already ecologically imbalanced.
   Eg: Water hyacinth proliferation is commonly seen in lakes receiving **untreated domestic wastewater**, alongside foul odour and algal blooms.
2. **Hydrological stagnation marker:** Invasive weeds expand when wetlands lose **seasonal flushing and flow variability**, allowing persistent surface mats to form.
   Eg: Floodplain wetlands affected by **embankments and blocked channels** often turn stagnant, enabling continuous weed spread.
3. **Biodiversity collapse indicator:** When native plants and fish decline, invasives dominate because they tolerate **low oxygen and polluted waters**.
   Eg: Wetlands with heavy weed mats often show **low dissolved oxygen**, with visible decline in indigenous fish catch.

Structural drivers behind invasive proliferation in Indian wetlands

1. **Untreated sewage inflows:** Weak sanitation and inadequate treatment lead to continuous **organic waste and nutrient enrichment**, accelerating invasive growth.
   Eg: CPCB assessments have repeatedly flagged nutrient pollution in waterbodies receiving **untreated or partially treated sewage**.
2. **Agricultural runoff intensification:** Fertiliser-heavy catchments drive **nutrient enrichment** and weaken native plant resilience, creating conditions for invasives.
   Eg: Wetlands adjoining **paddy-growing belts** often show post-monsoon weed surges due to fertiliser runoff.
3. **River–wetland disconnection:** Embankments, channel modification and encroachments break natural connectivity, reducing **flushing, oxygenation and sediment movement**.

Eg: Cut-off floodplain wetlands frequently shift from dynamic systems to **stagnant ponds**, where weeds dominate.

4. **Siltation and depth loss:** Catchment erosion and sediment deposition convert wetlands into **shallow, warmer, nutrient-rich waters**, ideal for invasive spread.
   Eg: Many beels and oxbow lakes show shrinkage with **shallowness**, followed by weed choking and fish decline.
5. **Governance fragmentation and weak enforcement:** Multiple agencies, unclear wetland boundaries, and weak monitoring enable **waste dumping and encroachment**, worsening weed conditions.
   Eg: Under the **Wetlands (Conservation and Management) Rules, 2017**, States must notify wetlands and prepare management plans, but delays leave many wetlands unmanaged.

Way forward

1. **Nutrient source control first:** Prioritise **sewage interception, STP performance and catchment nutrient management**, since removal without source control leads to regrowth.
   Eg: Restoration experience under **National Lake Conservation Plan (NLCP)** shows lasting improvement requires **sewage diversion**.
2. **Restore hydrological connectivity:** Reopen feeder channels, protect floodplain corridors and maintain **seasonal inflow-outflow** to enable natural flushing.
   Eg: Wetland revival is more durable when linked to **basin-level flow restoration** rather than isolated desilting.
3. **Integrated weed management:** Combine selective mechanical removal with **native macrophyte recovery** and controlled biological measures where suitable.
   Eg: Community-led removal plus **native plant reintroduction** improves habitat stability and reduces reinvasion.
4. **Governance and monitoring strengthening:** Notify wetlands, enforce buffer zones, use **remote sensing** for annual monitoring and integrate wetlands into district planning.
   Eg: The **Ramsar "wise use" approach** supports combining conservation with regulated livelihoods like fisheries and eco-restoration.

Conclusion

Invasive weeds are best treated as **warning signals** of deeper wetland stress. Sustainable control requires repairing **hydrology, nutrient inflows and governance**, not cosmetic weed clearing.

Q. Discuss how extreme heat can alter India's employment structure through job losses, distress migration and informalisation. Analyse the risks for human capital. Propose a strategy for climate-resilient livelihoods. (15 M)

Introduction

Extreme heat is no longer only a climate hazard; it is becoming a structural constraint on India's labour-intensive growth model. In a workforce dominated by informality and outdoor work, heat stress can silently reshape jobs, migration and human capital.

Body

How extreme heat can alter India's employment structure

1. **Heat-driven job losses in outdoor sectors:** Rising heat stress reduces safe working hours and labour demand in agriculture, construction, logistics and sanitation.
   Eg: Lancet Countdown flags large-scale heat-related labour-hour losses in India, especially in agriculture and construction, directly translating into wage and job loss.
2. **Distress migration and mobility intensification:** Heat reduces farm viability and increases rural income volatility, accelerating distress migration to cities.
   Eg: Repeated pre-monsoon heat waves in north and central India have increased short-term seasonal migration towards construction and informal services.
3. **Deepening informalisation and casualisation:** Employers respond to heat disruptions by shifting towards flexible, low-liability work arrangements rather than formal jobs.
   Eg: Many worksites adopt task-based hiring during peak summer months, increasing dependence on daily wage work without paid rest.
4. **Occupational shift to low-productivity services:** Reduced physical work capacity pushes workers into petty trade, vending and gig-type delivery work.
   Eg: In major cities, heat stress reinforces reliance on street vending and platform delivery where earnings remain unstable and exposure continues.
5. **Accelerated exit from agriculture by youth:** Heat-linked yield volatility and uncertainty weaken agriculture's attractiveness, changing the long-term employment mix.
   Eg: Heat stress in wheat-growing regions has strengthened the trend of rural youth moving away from farming into urban informal jobs.

<u>Risks for human capital</u>

1. **Chronic health burden and reduced work capacity:** Heat exposure increases dehydration, heat illness and kidney stress, lowering long-term productivity.
   Eg: Studies link chronic occupational heat exposure with higher risk of kidney stress among outdoor workers in high-heat regions.
2. **Learning losses through heat-related school disruption:** Heat waves trigger closures and reduce classroom learning quality, weakening future workforce productivity.
   Eg: Several states have altered school timings or closed schools during extreme heat episodes, disrupting foundational learning.
3. **Nutrition and productivity trap for poor households:** Heat-driven income shocks reduce food security and healthcare spending, worsening long-term human capital.
   Eg: For daily wage families, even a few days of lost work can reduce spending on nutrition and medical care, reinforcing vulnerability.
4. **Gendered depletion of human capital:** Women face higher exposure through unpaid care work, cooking, water collection and informal labour, increasing health risks.
   Eg: In heat-stressed rural areas, water scarcity raises women's workload, increasing fatigue and heat illness risk.
5. **Intergenerational skill erosion via migration:** Heat-linked mobility disrupts schooling and weakens stable skill accumulation, reinforcing informality.
   Eg: Migrant construction households often face education discontinuity, limiting children's future access to formal-sector jobs.

<u>Strategy for climate-resilient livelihoods</u>

1. **Enforce heat-safe work standards:** Mandate shaded rest, hydration, rescheduling and heat advisories across sectors with clear compliance checks.
   Eg: City-level protocols under **Heat Action Plans** (such as Ahmedabad) show mortality reduction when early warnings link to worker advisories.
2. **Climate-resilient skilling and job transitions:** Expand skilling for heat-resilient sectors such as green jobs, repair services, care economy and climate adaptation work.
   Eg: Align skilling under **PMKVY** with solar installation, energy efficiency, water management and cooling technologies.
3. **Heat-sensitive housing and labour colonies:** Scale cool roofs, ventilation standards, shaded corridors and drinking water points for informal settlements.
   Eg: Cool roof initiatives in Indian cities demonstrate low-cost temperature reduction for vulnerable housing.
4. **Portable social protection for informal workers:** Strengthen portability of food security, health cover and worker welfare benefits for migrants and casual labour.
   Eg: One Nation One Ration Card supports migrant food security during climate-driven mobility.
5. **Strengthen heat-health systems:** Improve surveillance, train frontline health workers, and integrate heat illness protocols into district health systems.
   Eg: Heat preparedness can be mainstreamed through district systems under the **National Health Mission**.

Conclusion

If untreated, extreme heat can push India into a low-productivity, high-informality employment trap and weaken human capital formation. Climate-resilient livelihoods require enforceable labour protections, portable safety nets and heat-smart investments in skills, housing and public health.

Q. Discuss the ecological and strategic significance of coral reefs for India's blue economy. Analyse how mass bleaching can affect fisheries, tourism, and coastal infrastructure. Suggest adaptation measures. (15 M)

Introduction

Coral reefs are among the most productive ecosystems on Earth and act as "natural capital" for India's island and coastal economy. In the era of climate shocks, reef resilience is directly linked to the sustainability of India's **blue economy**, coastal security and livelihoods.

Body

<u>Ecological and strategic significance of coral reefs for India's blue economy</u>

1. **Marine biodiversity foundation:** Coral reefs provide habitat, nursery and feeding grounds for a large share of marine species, sustaining ecosystem productivity.
   Eg: Gulf of Mannar Biosphere Reserve supports rich reef-linked biodiversity and associated artisanal fishing communities, making conservation a livelihood issue.
2. **Fisheries and food security:** Reef ecosystems support reef fish diversity and sustain coastal fisheries, especially for small-scale fishers.
   Eg: Lakshadweep tuna fishery depends on healthy reef-associated food webs and lagoon ecology that support baitfish availability.
3. **Tourism and local income generation:** Reefs support high-value marine tourism like diving, snorkelling and eco-tourism, creating local jobs and revenue.

Eg: **Andaman and Nicobar Islands** have reef-based dive tourism where reef degradation directly reduces tourist value and local service incomes.

4. **Coastal protection as natural infrastructure:** Reef frameworks dissipate wave energy, reduce erosion and act as first-line defence for islands and low-lying coasts.
   Eg: Lakshadweep atolls are naturally protected by reef barriers; reef weakening increases vulnerability to storm surges and shoreline retreat.
5. **Carbon and nutrient cycling services:** Coral reefs regulate local biogeochemical cycles, support productivity and maintain water quality in lagoons.
   Eg: In reef-lagoon systems, healthy coral cover stabilises ecological balance, whereas degraded reefs often shift to algal dominance, harming fish diversity.
6. **Strategic maritime relevance for island territories:** Reefs stabilise islands that host India's maritime presence, aiding long-term habitability and infrastructure.
   Eg: Lakshadweep's island stability supports India's strategic footprint in the **Arabian Sea**, linking ecology with maritime security.

<u>How mass bleaching affects fisheries, tourism and coastal infrastructure</u>

1. **Fisheries decline through habitat loss:** Bleaching reduces live coral cover, degrading breeding grounds and lowering reef fish biomass and diversity.
   Eg: Post-bleaching phases often show reduced reef fish abundance, forcing fishers to travel farther, raising fuel costs and livelihood stress.
2. **Food-web disruption and baitfish collapse:** Bleaching can destabilise lagoon ecosystems and reduce baitfish, indirectly affecting larger fisheries.
   Eg: Pole-and-line tuna fisheries are vulnerable when **baitfish availability** falls due to reef-lagoon degradation.
3. **Tourism value erosion and reputation loss:** Dead or algae-covered reefs reduce dive quality, lowering tourist footfall and harming local enterprises.
   Eg: Reef tourism destinations globally have seen demand fall after severe bleaching, and similar risks apply to **Andaman–Lakshadweep** circuits.
4. **Higher coastal infrastructure damage risk:** Reef weakening reduces wave buffering, increasing damage to ports, jetties, sea walls and coastal roads.
   Eg: In atoll environments, reef decline can increase dependence on hard engineering, raising costs and causing further ecological harm.
5. **Sediment instability and beach loss:** Coral rubble and reef-derived sediments maintain beaches; bleaching reduces reef growth and long-term sediment supply.
   Eg: For **coral atolls**, reduced sediment formation can accelerate beach narrowing, affecting settlements and tourism beaches.
6. **Economic shock to blue economy sectors:** Bleaching impacts multiple linked sectors simultaneously, increasing systemic risk for island economies.
   Eg: A single bleaching episode can affect **fisheries income + tourism earnings + infrastructure repair costs**, creating a compound shock.

<u>Adaptation measures to protect reefs and sustain the blue economy</u>

1. **Marine heatwave early warning systems:** Strengthen real-time monitoring of sea surface temperature and bleaching alerts for rapid response.
   Eg: Using **IMD-INCOIS ocean services** for heat stress advisories can help regulate tourism pressure and improve reef management readiness.
2. **No-take zones and adaptive marine protected areas:** Expand well-enforced MPAs with dynamic zoning based on reef health and spawning cycles.
   Eg: Gulf of Mannar shows how conservation zones can be designed around ecological sensitivity and livelihood dependence.

3. **Reducing local stressors to build resilience:** Control sewage discharge, sedimentation, destructive fishing and anchor damage to improve coral recovery chances.
   Eg: Strict regulation of **anchoring and reef-walking** in tourism sites prevents physical breakage, improving post-bleaching recovery.
4. **Climate-resilient reef restoration:** Use science-led restoration, including coral gardening and transplantation only where ecological conditions support survival.
   Eg: ICAR-CMFRI and marine research institutions have piloted reef restoration methods, which can be scaled cautiously with monitoring.
5. **Sustainable tourism codes and carrying capacity:** Implement visitor caps, reef-safe practices, diver certification norms and eco-fee mechanisms.
   Eg: Island systems worldwide use **tourism carrying capacity frameworks**; similar models can protect reefs in Lakshadweep and Andamans.
6. **Community-based reef stewardship:** Empower local fishers and dive operators through co-management, incentives and compliance-linked benefits.
   Eg: Co-management models in small islands improve surveillance, reduce illegal extraction, and align livelihoods with conservation outcomes.
7. **Mainstreaming reefs into coastal infrastructure planning:** Treat reefs as "natural infrastructure" and integrate them into coastal regulation and disaster planning.
   Eg: Aligning reef protection with **NDMA coastal hazard planning** can reduce reliance on costly sea walls and improve long-term resilience.
8. **Institutionalising long-term ecological monitoring:** Create permanent reef observatories and standardized national coral health indicators.
   Eg: The discovery of a healthy reef patch in **Lakshadweep (Kalpeni)** can serve as a reference site for resilience research and policy design.

Conclusion

Coral reefs are not a niche biodiversity concern but a core pillar of India's blue economy and coastal security. Building reef resilience through science-based monitoring, local stress reduction and community-led governance is essential to protect livelihoods and sustain India's maritime future.

Q. "Climate change is increasingly blurring the distinction between invasive species and climate-resilient species. "Evaluate the long-term ecological consequences of this shift for biodiversity conservation. (10 M)

Introduction

Accelerating climate change is restructuring ecological niches faster than evolutionary adaptation. In this churn, species once labelled invasive are increasingly viewed through the lens of climate resilience, complicating biodiversity governance and conservation ethics.

Body

<u>**Climate change is blurring the distinction between invasive and climate-resilient species**</u>

1. **Range shifts driven by warming:** Rising temperatures and altered precipitation patterns enable species to expand poleward and upward, challenging static "native–alien" classifications.
   Eg: The **IPCC Sixth Assessment Report (2021–23)** documents widespread **poleward and elevational shifts** of terrestrial and marine species due to warming, indicating that distributional changes are increasingly climate-driven rather than solely human-mediated.

2. **Functional resilience under extreme stress:** Some non-native species survive drought, salinity and degraded soils better than native flora, making them appear adaptive assets under climate stress.
   Eg: In **semi-arid regions of India**, hardy woody species such as **Prosopis juliflora (Neltuma juliflora)** persist under **recurrent drought and salinity**, conditions intensifying with climate variability as reflected in the **India State of Forest Report 2021 (FSI)**.
3. **Human-assisted adaptation and restoration dilemmas:** Climate adaptation programmes sometimes prioritise fast-growing or stress-tolerant species, complicating ecological purity norms.
   Eg: Under India's **Land Degradation Neutrality target (UNCCD commitment for 2030)**, debates persist on whether severely degraded lands should prioritise **strict native restoration** or tolerate hardy non-natives for rapid soil stabilisation.
4. **Dynamic ecosystems and shifting baselines:** Climate-induced biome transitions challenge the feasibility of restoring historical species compositions.
   Eg: The **IPBES Global Assessment Report 2019** highlights that over **1 million species face extinction risks**, partly because climate change is pushing ecosystems beyond historical ecological thresholds.

Long-term ecological consequences for biodiversity conservation

1. **Biodiversity homogenisation and erosion of endemism:** Resilient generalist species may outcompete specialised natives, leading to ecological simplification.
   Eg: The **IPBES 2019 Report** identifies **invasive alien species** as a major direct driver of biodiversity loss globally, contributing to increasing ecological homogenisation.
2. **Disruption of ecosystem functions and trophic networks:** Dominant climate-resilient species can alter nutrient cycles, hydrology and fire regimes, affecting entire food webs.
   Eg: The **Millennium Ecosystem Assessment (2005)** documents how invasive plants modify **soil nutrients and fire frequency**, producing cascading ecosystem-level impacts.
3. **Policy and legal ambiguity in conservation governance:** Static regulatory frameworks may struggle to classify species under shifting climatic baselines.
   Eg: India's **Biological Diversity Act, 2002** aims to conserve native biological resources, but climate-driven range shifts create challenges in defining and regulating "alien" species.
4. **Carbon–biodiversity trade-offs:** Species resilient to climate stress may enhance carbon sinks but undermine native diversity.
   Eg: India's updated **Nationally Determined Contribution (2022)** targets enhanced carbon sinks; however, poorly designed monoculture plantations risk reducing **species diversity despite higher biomass accumulation**.

Conclusion

Climate change is transforming invasion biology into a complex governance dilemma rather than a binary ecological issue. Biodiversity conservation must shift towards adaptive, evidence-based management that safeguards ecological integrity amid climatic uncertainty.

Q. Explain the mechanisms through which oceans absorb and store atmospheric carbon dioxide. Discuss why regional disparities in data collection complicate climate modelling. (10 M)

Introduction

Oceans operate as the Earth's most significant active carbon sink, buffering the pace of global warming by absorbing nearly one-fourth of anthropogenic carbon dioxide emissions. Yet, uneven scientific understanding and regional data gaps introduce serious uncertainties in climate modelling and long-term mitigation planning.

Body

<u>Mechanisms through which oceans absorb and store atmospheric carbon dioxide</u>

1. **Solubility pump and physical dissolution:** Atmospheric carbon dioxide dissolves in surface waters depending on temperature, salinity and pressure gradients, forming carbonic acid and bicarbonate ions, with colder waters absorbing more carbon. This physical process drives large-scale uptake especially in high-latitude regions.
   Eg: According to **IPCC AR6 (2021)**, the **Southern Ocean** contributes a disproportionately high share of global ocean carbon uptake due to its **cold surface waters and deep-water formation**, strengthening physical absorption.
2. **Biological pump and planktonic fixation:** Phytoplankton absorb carbon dioxide through photosynthesis and convert it into organic matter, which sinks to deeper layers when organisms die, enabling long-term sequestration. Microbial activity regulates decomposition and storage depth.
   Eg: The **IOC-UNESCO Integrated Ocean Carbon Research Report (2026)** notes that **warming-induced shifts in plankton distribution** may reduce biological pump efficiency, directly influencing long-term carbon storage.
3. **Carbonate pump and shell formation:** Marine organisms such as corals and molluscs form calcium carbonate shells, temporarily locking carbon in solid form which may eventually accumulate in marine sediments.
   Eg: As highlighted in **IPCC AR6**, increasing **ocean acidification** is weakening calcification in coral reef systems, thereby affecting carbonate cycling and carbon storage dynamics.
4. **Deep ocean sequestration through thermohaline circulation:** Surface-absorbed carbon is transported to deeper layers via global overturning circulation, where it can remain stored for centuries.
   Eg: Observations under the **Global Ocean Observing System (GOOS)** show that deep-water formation zones in the **North Atlantic and Southern Ocean** act as major long-term carbon reservoirs.

<u>Regional disparities in data collection and their impact on climate modelling</u>

1. **Limited long-term observational datasets:** Many ocean regions, particularly the deep ocean and polar areas, lack continuous multi-decadal carbon measurements, weakening model calibration.
   Eg: The **IOC-UNESCO (2026)** report identifies significant observational gaps in the **Southern**

Hemisphere and polar oceans, leading to 10–20 percent variation in global carbon absorption estimates.

2. **Underrepresentation of coastal and polar processes:** Coastal zones and polar regions exhibit complex air–sea carbon exchange, yet remain insufficiently monitored, increasing regional modelling uncertainty.
   Eg: According to **IPCC AR6**, polar regions show higher variability in carbon flux projections due to limited in-situ measurements and rapidly changing sea-ice dynamics.
3. **Technological and capacity asymmetries among nations:** Developing countries often lack advanced monitoring infrastructure such as autonomous floats and satellite-linked sensors, leading to uneven data quality.
   Eg: The **Global Ocean Observing System** highlights disparities in deployment of **biogeochemical Argo floats**, with concentration in developed regions and sparse coverage in parts of the Indian Ocean.
4. **Incomplete integration of biological processes in models:** Complex plankton–microbe interactions and ecosystem shifts are not fully integrated into Earth system models, reducing predictive accuracy.
   Eg: The **IOC-UNESCO (2026)** report stresses the need to integrate **biological experiments and transdisciplinary research** into carbon cycle models to reduce structural uncertainty.

Conclusion

Strengthening ocean carbon science through comprehensive monitoring and equitable data sharing is indispensable for credible climate modelling. A scientifically robust understanding of ocean processes will determine the realism of global carbon budgets and the success of future mitigation pathways

Q. Discuss the concept of hybrid monitoring networks in air pollution management. Assess their potential advantages and operational challenges in India. (10 M)

Introduction

India's air pollution crisis reflects not only emission intensity but also uneven measurement capacity. In a constitutional framework anchored in **Article 48A** and the expanded interpretation of **Article 21 (Right to Life)**, credible and inclusive monitoring becomes central to lawful and equitable environmental governance.

Body

<u>Concept of hybrid monitoring networks</u>

1. **Integration of regulatory and non-regulatory technologies:** A hybrid network combines **Continuous Ambient Air Quality Monitoring Stations (CAAQMS)** with **validated low-cost sensors and satellite datasets**, ensuring regulatory accuracy alongside spatial expansion.
   Eg: The **Central Pollution Control Board (CPCB)** operates CAAQMS under the **National Air Quality Monitoring Programme (1984–85)**, while cities such as **Delhi** have supplemented these with calibrated sensor networks to widen neighbourhood-level monitoring.
2. **Multi-layered data architecture:** It creates a tiered framework where reference-grade monitors anchor compliance assessment and sensor grids provide hyper-local exposure mapping.
   Eg: Under the **National Clean Air Programme (NCAP), 2019**, cities have expanded monitoring near traffic corridors and industrial clusters to support targeted mitigation.

3. **Satellite-ground data fusion:** Hybrid systems integrate satellite-based aerosol data with ground observations to improve regional pollution modelling and fill spatial gaps.
   Eg: ISRO's aerosol optical depth datasets are used in conjunction with ground monitors to strengthen regional pollution assessment.
4. **Dynamic and exposure-based siting strategy:** Hybrid networks enable flexible placement and relocation of sensors based on evolving land use and emission hotspots rather than static administrative locations.
   Eg: The **CSE State of India's Environment 2026** recommends exposure-based siting near **schools and hospitals**, reflecting the need for dynamic monitoring in expanding peri-urban areas.

<u>Potential advantages in India</u>

1. **Enhanced spatial equity:** Hybrid models extend monitoring beyond metropolitan clusters to underserved peri-urban and industrial regions.
   Eg: The **State of India's Environment 2026 (CSE)** reports that over **60% of districts lack continuous monitoring**, underscoring the importance of inclusive expansion.
2. **Cost-effective scalability:** Low-cost sensors reduce capital expenditure, enabling faster expansion compared to exclusive reliance on CAAQMS.
   Eg: Expansion supported by **NCAP funding** allows tier-II and tier-III cities to broaden coverage without the high infrastructure cost of full regulatory stations.
3. **Improved exposure-based governance:** Greater spatial granularity supports targeted public health advisories and preventive action.
   Eg: In **M.C. Mehta v. Union of India**, the **Supreme Court** emphasised the State's duty to safeguard health from pollution, which presupposes reliable exposure data.
4. **Strengthening evidence-based policymaking:** Richer datasets enhance modelling for source apportionment, emission inventories and clean air action planning.
   Eg: Cities under **NCAP** are required to prepare action plans based on baseline pollution data, and expanded monitoring improves scientific credibility of such plans.

<u>Operational challenges in India</u>

1. **Data standardisation and calibration issues:** Sensor reliability can be affected by humidity, dust and maintenance gaps, raising concerns over regulatory acceptance.
   Eg: CPCB mandates calibration protocols to ensure readings meet standards under the **Air (Prevention and Control of Pollution) Act, 1981**.
2. **Fragmented data governance:** Air quality data are published by multiple agencies without full interoperability or a unified national platform.
   Eg: Separate dashboards maintained by **CPCB, SPCBs and urban local bodies** limit seamless integration for performance assessment under **NCAP**.
3. **Institutional capacity deficits:** State Pollution Control Boards often face manpower and technical shortages affecting maintenance and validation.
   Eg: Parliamentary Standing Committee reports on environment have highlighted capacity constraints in **SPCBs**, impacting enforcement of pollution control norms.
4. **Financial sustainability and maintenance burden:** Continuous calibration, data management and periodic replacement of sensors require sustained funding and technical expertise.

Eg: Many smaller municipalities depend heavily on **central assistance under NCAP**, raising concerns about long-term operational viability once project funding cycles end.

Conclusion

A well-designed hybrid monitoring framework can reconcile scientific rigour with spatial inclusivity in India's air governance. Its success, however, hinges on institutional strengthening, calibration discipline and an integrated national data ecosystem that converts monitoring into measurable public health protection.

Disaster and disaster management.

Linkages between development and spread of extremism.

Role of external state and non-state actors in creating challenges to internal security.

Challenges to internal security through communication networks, role of media and social networking sites in internal security challenges, basics of cyber security; money-laundering and its prevention.

Security challenges and their management in border areas - linkages of organized crime with terrorism.

Q. Examine the significance of PRAHAAR as India's first comprehensive anti-terror policy. What structural gaps in earlier counter-terror mechanisms does it seek to address? (10 M)

Introduction

India's counter-terror framework has evolved through legislation like the **Unlawful Activities (Prevention) Act, 1967 (amended 2019)** and institutions such as the **National Investigation Agency (NIA), 2008**, yet lacked a unified doctrine. The release of **PRAHAAR in February 2026 by the Ministry of Home Affairs** marks a shift toward an integrated and forward-looking counter-terror architecture.

Body

<u>Significance of PRAHAAR</u>

1. **Unified national counter-terror doctrine:** PRAHAAR provides India's first comprehensive strategic framework, aligning prevention, intelligence, investigation and prosecution under one policy vision, strengthening coherence in internal security governance under **Article 355 of the Constitution**.
   Eg: The policy was officially uploaded by the **MHA in February 2026**, formalising a national doctrine beyond fragmented operational guidelines.
2. **Expansion beyond cross-border terrorism:** While acknowledging sponsored terrorism, PRAHAAR recognises cyber-attacks by **criminal hackers and nation-states**, broadening the threat

spectrum to hybrid warfare.
Eg: The policy explicitly identifies threats to **power, railways, aviation, ports, defence, space and atomic energy sectors**, reflecting a critical infrastructure security approach.

3. **Integration of cyber and digital dimensions:** PRAHAAR addresses use of **encryption, dark web, crypto wallets and drones**, signalling adaptation to technology-enabled terrorism.
   Eg: The emphasis on misuse of **drones in Punjab and Jammu and Kashmir** reflects operational realities observed in recent security briefings.
4. **Graded de-radicalisation strategy:** The policy adopts a calibrated response to radicalised youth, combining surveillance, counselling and legal action depending on severity.
   Eg: Engagement of **community leaders, moderate preachers and NGOs** demonstrates a multi-stakeholder preventive model rather than solely punitive action.
5. **Focus on prosecution and legal robustness:** PRAHAAR stresses involvement of legal experts from FIR registration to prosecution, addressing conviction-rate concerns under counter-terror laws.
   Eg: This complements reforms under the **Criminal Law (Amendment) Act, 2019** strengthening NIA jurisdiction in terror cases.

<u>Structural gaps in earlier counter-terror mechanisms addressed</u>

1. **Absence of an integrated national strategy:** Earlier mechanisms were institution-centric without a declared overarching policy doctrine.
   Eg: While the **NIA Act, 2008** created an investigative agency, it did not provide a comprehensive national counter-terror strategy framework.
2. **Limited attention to critical infrastructure security:** Earlier focus was primarily on physical attacks, with insufficient strategic emphasis on sectoral resilience.
   Eg: PRAHAAR's explicit reference to protecting **economic sectors** marks institutional recognition of economic security as national security.
3. **Inadequate cyber-terror preparedness:** Previous counter-terror frameworks did not sufficiently address encrypted communication and anonymous financing.
   Eg: The policy's mention of **crypto wallets and dark web operations** reflects response to evolving terror financing patterns.
4. **Weak inter-agency coordination and prosecution focus:** Investigations often faced evidentiary and procedural challenges, affecting conviction outcomes.
   Eg: The **Second Administrative Reforms Commission (2008 Report on Public Order)** had earlier recommended integrated intelligence and prosecution coordination, a gap PRAHAAR attempts to bridge.
5. **Limited preventive and community engagement approach:** Earlier counter-terror strategy emphasised reactive security operations over structured de-radicalisation.
   Eg: PRAHAAR's prison de-radicalisation measures respond to concerns about radical networks within correctional institutions.

Conclusion

PRAHAAR signifies India's transition from a reactive security model to a comprehensive and anticipatory counter-terror doctrine. Its success will depend on federal coordination, technological capacity-building and sustained legal robustness in an evolving threat landscape.

Various Security forces and agencies and their mandate.

Q. Explain the role of the Chief of Defence Staff in promoting jointness among the armed forces. Analyse why jointness is critical for modern warfare. (10 M)

Introduction

India's security environment has evolved towards multi-domain, technology-intensive and time-compressed conflicts, exposing the limitations of service-specific military planning. The creation of the **Chief of Defence Staff (CDS) in 2019** reflects a systemic effort to institutionalise jointness as the core principle of India's higher defence management.

Body

Role of the Chief of Defence Staff in promoting jointness

1. **Single-point military advice to political leadership:** The CDS acts as the principal military adviser to the Government, integrating perspectives of the Army, Navy and Air Force to overcome fragmented service-based inputs.
   Eg: Eg: The establishment of the **Department of Military Affairs (DMA) in 2020** under the CDS streamlined inter-service coordination in defence planning and prioritisation (Source: **Government of India notification, 2020**).
2. **Institutional integration through DMA:** By heading the DMA, the CDS oversees joint policy areas such as training, procurement prioritisation and staffing, fostering structural jointness beyond coordination.
   Eg: Eg: DMA's role in harmonising **tri-service training and staffing norms** reflects implementation of recommendations of the **Naresh Chandra Task Force (2012)**.
3. **Advancing theatre command concept:** The CDS is mandated to facilitate the transition towards integrated theatre commands to enable unified operational control.
   Eg: Eg: Ongoing deliberations on **theatreisation of commands** aim to replace service-specific commands with geographically integrated ones (Source: **Ministry of Defence annual reports**).
4. **Optimisation of resources and logistics:** Joint planning under the CDS reduces duplication of assets, logistics and support structures across services.
   Eg: Eg: Implementation of **joint logistics nodes** follows the spirit of the **Shekatkar Committee (2016)** recommendations on force optimisation.
5. **Capability-based force development:** The CDS promotes a shift from platform-centric acquisitions to joint capability development aligned with long-term threats.
   Eg: Eg: Integration of cyber, space and special operations planning under unified doctrines supports capability-based planning (Source: **Integrated Defence Staff publications**).

Why jointness is critical for modern warfare

1. **Multi-domain nature of contemporary conflicts:** Modern warfare spans land, sea, air, cyber and space, demanding coordinated responses rather than isolated service actions.

Eg: Eg: The **Russia–Ukraine conflict** demonstrated the decisive impact of integrated cyber, air and ground operations on battlefield outcomes.

2. **Speed and complexity of decision-making:** Fragmented command structures delay responses in high-tempo conflicts where simultaneity is crucial.
   Eg: Eg: Joint command structures enable faster operational decisions during **short-duration, high-intensity conflicts**.
3. **Efficient utilisation of scarce defence resources:** Jointness maximises combat power within fiscal constraints by avoiding redundancy.
   Eg: Eg: Integrated procurement planning under the CDS supports optimal allocation within India's constrained defence budget (Source: **Standing Committee on Defence reports**).
4. **Enhanced deterrence and war-fighting credibility:** Unified military posture strengthens deterrence by signalling coordinated national resolve.
   Eg: Eg: Integrated planning enhances credibility against **two-front threat scenarios** frequently highlighted in official defence assessments.
5. **Alignment with global best practices:** Advanced militaries emphasise joint commands to manage complex security environments.
   Eg: Eg: The **United States Goldwater–Nichols Act (1986)** is often cited in Indian defence reforms discourse as a benchmark for jointness (Source: **Kargil Review Committee Report, 1999**).

Conclusion

The CDS is the institutional fulcrum of India's transition from service-centric operations to integrated war-fighting. Deepening jointness is indispensable for credible deterrence and effective response in future multi-domain conflicts.