6. Agricultural Engineering - Geography

1. Why in News

1. Indian agriculture increasingly shaped by climate variability and rising input costs
2. Agricultural engineering emerging as crucial driver of efficiency, sustainability, and resilience
3. Growing recognition of need for technological interventions in farming sector
4. Government pushing mechanization through various schemes and policies
5. Climate challenges require engineering solutions for adaptation and mitigation
6. Post-harvest losses highlighting need for engineering interventions

2. Context and Background

1. Indian agriculture faces multiple challenges - fragmented landholdings, water scarcity, soil degradation
2. Climate change bringing erratic rainfall, heat stress, and extreme weather events
3. Rising input costs squeezing farmer margins and profitability
4. Traditional farming methods proving insufficient for productivity needs
5. Growing population requiring increased food production with limited resources
6. Need for sustainable and climate-resilient agricultural practices
7. Agricultural engineering offers solutions through technology and innovation

3. What is Agricultural Engineering?

Definition and Scope

1. Agricultural engineering involves application of engineering principles to agriculture
2. Integrates scientific knowledge and technological innovations
3. Aims to improve agricultural productivity and sustainability
4. Focuses on systems, tools, and infrastructure enabling farming
5. Distinct from agronomy which deals with crop science and biology
6. Bridges gap between engineering and agriculture

Distinction from Agronomy

1. Agronomy - Deals with crop science, plant biology, soil-plant relationships
2. Agricultural Engineering - Focuses on systems, tools, machinery, and infrastructure
3. Agronomy studies what to grow and how crops respond
4. Engineering determines how to grow efficiently using technology
5. Complementary disciplines working toward agricultural development

Four Broad Domains

Farm Mechanization -

1. Tractors, harvesters, planters, seed drills
2. Power tillers, combine harvesters
3. Implements for land preparation and cultivation
4. Automation in farming operations

Soil and Water Conservation -

5. Irrigation systems and water management
6. Drainage and erosion control structures
7. Soil conservation techniques
8. Watershed management engineering

Post-Harvest Engineering -

9. Storage structures and cold chains
10. Processing equipment and facilities
11. Packaging and preservation technologies

12. Quality control systems

Precision/Digital Agriculture -

13. Drones, sensors, GPS-based systems
14. Satellite imagery and remote sensing
15. Data analytics and decision support systems
16. Internet of Things (IoT) in agriculture

4. Role of Agricultural Engineering in Modernizing Indian Agriculture

Enhancing Farm Productivity

1. Use of tractors improves land preparation efficiency
2. Seed drills and planters ensure uniform sowing and optimal plant density
3. Harvesters reduce grain losses and harvest time
4. Laser land levellers improve water distribution and crop uniformity
5. **Impact (NITI Aayog data) -**
    1. Farm mechanization boosts productivity by 12-15%
    2. Reduces cultivation costs by 20%
    3. Cuts sowing labor requirements by 60-70%
6. Enables timely farm operations critical for crop success
7. Reduces drudgery and physical labor burden

Water Resource Management

Drip irrigation systems -

1. Deliver water directly to plant roots
2. Save 30-70% water compared to flood irrigation
3. Improve water use efficiency significantly

Sprinkler systems -

4. Suitable for various crops and terrain
5. Reduce water wastage through evaporation control
6. Enable irrigation in undulating land

Fertigation -

7. Combines irrigation with fertilizer application
8. Ensures precise nutrient delivery
9. Reduces fertilizer wastage and cost

Smart irrigation technologies -

10. Moisture sensors monitor soil water content
11. Automated systems prevent overuse
12. Improve crop health through optimal watering
13. Enable remote monitoring and control

Strengthening Soil Management

Bunding and terracing -

1. Prevent soil erosion on slopes
2. Retain water and nutrients
3. Create micro catchments for moisture conservation

Drainage systems -

4. Remove excess water preventing waterlogging
5. Maintain optimal soil aeration
6. Enable cultivation in low-lying areas

Erosion control structures -

7. Check dams, gabions, vegetative barriers
8. Preserve topsoil and fertility

9. Prevent land degradation

Conservation tillage -

10. Minimum tillage and no-till systems
11. Preserve soil structure and organic matter
12. Reduce fuel consumption and emissions

Reducing Post-Harvest Losses

1. India loses agricultural produce worth over ₹1.5 lakh crore annually
2. Losses due to inefficiencies in -
    1. Storage infrastructure (inadequate warehousing)
    2. Transportation (poor roads, lack of refrigerated transport)
    3. Processing facilities (limited capacity)
    4. Supply chain management (weak linkages)

Engineering solutions -

Cold chain infrastructure -

1. Can cut post-harvest wastage by up to 75%
2. Extends shelf life of perishables
3. Maintains quality during transportation

Modern storage structures -

4. Silos, scientific warehouses
5. Controlled atmosphere storage
6. Protection from pests and moisture

Processing equipment -

7. Cleaning, grading, sorting machines
8. Value addition technologies
9. Packaging solutions

Promoting Precision and Smart Agriculture

Drone technology -

1. Crop health monitoring through multispectral imaging
2. Precise pesticide and fertilizer spraying
3. Damage assessment and yield estimation
4. Reduces chemical usage and environmental impact

GPS-based machinery -

5. Auto-steering tractors for precise field operations
6. Variable rate application of inputs
7. Reduces overlap and gaps in coverage
8. Improves operational efficiency

Sensors and IoT devices -

9. Soil moisture, temperature, nutrient sensors
10. Weather stations for microclimate monitoring
11. Pest and disease early warning systems
12. Real-time data for decision-making

Satellite imagery -

13. Crop acreage estimation
14. Vegetation health assessment (NDVI)
15. Water stress detection
16. Yield forecasting

Impact (ICAR, Economic Survey 2024-25) -

17. Precision technologies improve fertilizer efficiency by 12-15%

18. Reduce pesticide use by ~20%
19. Optimize resource use and reduce costs
20. Minimize environmental pollution

Climate Resilience

Adaptation technologies -

1. Precision irrigation adapts to water scarcity
2. Weather-indexed sensors provide early warnings
3. Drone-based monitoring detects stress early
4. Helps farmers respond to erratic rainfall and heat stress

Conservation agriculture equipment -

5. Zero-till drills - Enable sowing without plowing
6. Happy Seeders - Plant crops in standing stubble
7. Benefits (triple environmental dividend) -
    1. Reduces soil erosion and degradation
    2. Retains soil moisture improving drought resilience
    3. Curbs stubble burning reducing air pollution

Biotechnology integration -

8. Climate-resilient crop varieties tolerate stress
9. Genome editing develops improved cultivars
10. Biocontrol solutions reduce chemical dependence
11. Complements precision agriculture
12. Enhances productivity, sustainability, and resilience

Challenges in Adoption of Agricultural Engineering

High Capital Costs

1. Advanced machinery involves high initial investments
2. Smart technologies (drones, sensors) expensive for individual farmers
3. Small and marginal farmers cannot afford mechanization
4. Financial barriers -
    1. Limited access to institutional credit
    2. Bank loans require collateral many farmers lack
    3. Inadequate subsidy coverage
    4. Subsidies don't reach all beneficiaries
    5. High interest rates on agricultural loans

Status of Farm Mechanization

1. India's farm mechanization level - approximately 40-45% (as of recent data)

Overall mechanization stands at 47% (2024)

2. Far behind developed and developing countries -
    1. United States - 95%
    2. Brazil - 75%
    3. China - 57%

Uneven across operations -

    4. Seed-bed preparation - 70% (highest mechanization)
    5. Harvesting and threshing - 34% (lagging significantly)
    6. Gaps in transplanting, weeding, spraying

Regional disparity -

    7. Concentrated in Punjab, Haryana (Green Revolution states)
    8. Low mechanization in Eastern and Northeastern states
    9. Reflects uneven agricultural development across India

Low Technical Awareness

1. Farmers often lack technical knowledge to operate modern equipment
2. Maintenance skills inadequate leading to equipment breakdowns
3. Difficulty understanding precision agriculture technologies
4. Language barriers in equipment manuals and interfaces

Weak agricultural extension system -

1. Insufficient extension personnel
2. Poor farmer-to-extension worker ratio
3. Limited training programs
4. Weak dissemination of best practices and innovations
5. Gap between research and farm-level adoption

Fragmented Landholdings

1. About 84% of holdings below 1 hectare
2. Makes individual machinery ownership economically unviable
3. High per-unit cost for small farms

Custom Hiring Centre (CHC) model -

1. Rental-based access only realistic option
2. Allows shared use of expensive equipment
3. However, CHC network still inadequate

Lack of land consolidation -

4. Prevents efficient use of high-capacity machinery
5. Machinery cannot achieve economies of scale
6. Precision technologies less effective on tiny plots
7. Increases operational complexity and costs

Infrastructural and Institutional Gaps

Inadequate rural infrastructure -

1. Insufficient storage facilities and warehouses
2. Limited cold chain network
3. Poor rural road connectivity
4. Unreliable electricity supply affecting operations
5. Weak communication networks for digital agriculture

Market linkages -

6. Weak connections between farmers and markets
7. Fragmented supply chains
8. Multiple intermediaries reducing farmer share
9. Limited price information and transparency

Supply chain inefficiencies -

10. Poor coordination among stakeholders
11. Transportation bottlenecks
12. Lack of quality control systems
13. Limited value addition opportunities
14. Prevents full realization of gains from improved production

5. Key Government Policies and Schemes

Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)

1. Launched in 2015 with motto "More Crop Per Drop"
2. Integrates drip, sprinkler, and micro-irrigation engineering
3. National mission for water use efficiency
4. Components -

    1. Accelerated Irrigation Benefit Programme (AIBP)
    2. Har Khet Ko Pani (irrigation to every field)
    3. Per Drop More Crop (micro-irrigation)
5. Subsidy support for micro-irrigation adoption
6. Aims to expand irrigation coverage and improve efficiency

Namo Drone Didi

1. Targets deployment of 14,500 drones by 2025-26
2. Drones provided to women Self-Help Groups (SHGs)
3. Primary use - Pesticide and fertilizer spraying
4. Financial support -
    1. Subsidies up to ₹8 lakh or 80% cost, whichever is less
5. Empowers women while promoting agricultural technology
6. Reduces chemical exposure for farmers
7. Improves precision in input application

PM Dhan-Dhaanya Krishi Yojana (Budget 2025-26)

1. Focuses on 100 low-productivity districts
2. Targets integrated development through -
    1. Mechanization of farm operations
    2. Irrigation infrastructure expansion
    3. Post-harvest support and storage
3. Aims to raise productivity in lagging regions
4. Comprehensive approach addressing multiple constraints

FARMS App (Farm Machinery Solutions)

1. Government's digital platform for agricultural mechanization
2. Digitizes Custom Hiring Centre (CHC) booking process
3. Connects farmers to over 26,000 service providers
4. Benefits -
    1. Reduces search costs for machinery rental
    2. Minimizes equipment idle time
    3. Transparent pricing and availability
    4. Real-time booking and tracking
5. Improves access to mechanization for small farmers

Agricultural Engineering Directorates

Parliamentary Committee recommendation -

1. Establish Directorates of Agricultural Engineering in each state
2. Dedicated body for mechanization policy implementation
3. Currently exist only in Madhya Pradesh and Tamil Nadu

Would provide -

4. State-level coordination and planning
5. Technical support and training
6. Monitoring and evaluation
7. Policy advocacy and implementation

Other Relevant Schemes

Sub-Mission on Agricultural Mechanization (SMAM) -

1. Financial assistance for farm equipment
2. Support for CHC establishment
3. Training and demonstration programs

PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha Evam Uthaman Mahabhiyan) -

4. Solar pumps for irrigation

5. Grid-connected solar power
6. Solarization of existing pumps

Parampara at Krishi Vikas Yojana (PKVY) -

7. Promotes organic farming
8. Includes appropriate mechanization

6. Way Forward

Promote Inclusive Mechanization

Expand Custom Hiring Centres (CHCs) -

1. Increase number and coverage across all districts
2. Provide range of equipment for all operations
3. Ensure affordability and accessibility
4. Women-led CHCs for inclusive development

Equipment rental models -

5. Uberization of farm machinery
6. Mobile apps connecting equipment owners with users
7. Dynamic pricing based on demand
8. Quality assurance and maintenance support

Farmer Producer Organizations (FPOs) -

9. Encourage collective ownership of equipment
10. Bulk purchase reducing per-unit cost
11. Shared maintenance and operational costs
12. Better bargaining power with suppliers

Last-Mile Delivery of Technology

Improve agricultural extension services -

1. Strengthen Krishi Vigyan Kendra's (KVKs)
2. Increase extension worker strength
3. Regular training and skill upgradation

Digital platforms -

4. Mobile-based advisories in local languages
5. Video demonstrations and tutorials
6. Chatbots and AI-powered assistance
7. Online consultations with experts

On-field demonstrations -

8. Farmer field schools
9. Technology demonstration plots
10. Hands-on training programs
11. Peer learning and farmer-to-farmer extension

Deploy "Agri-tech facilitators" -

12. Trained personnel at village level
13. Assist farmers in using modern equipment
14. Troubleshooting and basic maintenance
15. Bridge between technology providers and farmers

Smallholder-Centric Innovations

Develop low-cost machinery -

1. Affordable alternatives to expensive equipment
2. Multi-functional tools reducing number of implements
3. Local manufacturing and assembly
4. Use of indigenous materials

Small-scale equipment -

5. Sized appropriately for small landholdings
6. Power tillers instead of large tractors
7. Mini-harvesters and reapers
8. Portable equipment for easy transport

Region-specific machinery -

9. Suited for local crops and farming systems
10. Adapted to terrain (hilly, waterlogged, etc.)
11. Cultural and operational preferences
12. Traditional wisdom integrated with technology

Institutional Support and Convergence

Better scheme convergence -

1. Integrate Sub-Mission on Agricultural Mechanization
2. Coordinate with PM Krishi Sinchayee Yojana
3. Align with PM-KUSUM for solar-powered mechanization
4. Holistic farm development approach

Strengthen credit availability -

5. Dedicated agricultural machinery loans
6. Reduced interest rates and longer tenures
7. Collateral-free loans for small farmers
8. Credit guarantee schemes

Infrastructure development -

9. Expand cold chain and storage network
10. Improve rural road connectivity
11. Ensure reliable power supply
12. Strengthen market infrastructure

Research and development -

13. Support indigenous technology development
14. Encourage public-private partnerships
15. Test and validate technologies
16. Localize and adapt global innovations

Policy and Governance Reforms

1. Establish state-level Agricultural Engineering Directorates
2. Simplify subsidy disbursement mechanisms
3. Performance-based incentives for adoption
4. Quality standards and certification for equipment
5. Data-driven policy making using FARMS app analytics

7. Conclusion

Agricultural engineering is crucial driver of efficiency, sustainability, and resilience in Indian agriculture. Addressing challenges through inclusive mechanization, smallholder-centric innovations, institutional support, and technology convergence can transform farming sector, ensuring food security and farmer prosperity.

Source - https -//www.thehindu.com/education/how-agricultural-engineering-is-key-to-making-indian-farming-future-ready/article70911685.ece