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MECHANIZATION OF THE FIELD CULTIVATION PROCESS

У доповіді розглянуто механізацію процесів обробітку полів, її технологічні основи, економічну ефективність, вплив на навколишнє середовище та сучасні тенденції розвитку. Особливу увагу приділено сучасній сільськогосподарській техніці, технологіям точного землеробства, мінімальному та нульовому обґрунтуванню заробітку, а також впливу механізації на продуктивність сільського господарства.

Ключові слова: механізація сільського господарства, обробіток поля, трактори, системи обробітку ґрунту, точне землеробство, сталє сільське господарство.

The report scrutinizes mechanization of field crop growing, its technological underpinnings, economic efficiency, environmental effects, and current trends. Particular attention is paid to modern agricultural machinery, precision agriculture technologies, minimal and zero-revenue justification, and the impact of mechanization on agricultural productivity.

Keywords: agricultural mechanization, field cultivation, tractors, soil cultivation systems, precision agriculture, sustainable agriculture, no-till technology.

Agricultural mechanization is one of the main factors in ensuring high productivity and sustainability of crop production. The transition from manual labor to mechanized systems has increased productivity, reduced manual labor, and increased efficient land use.

1. Concept and Principles of Field Mechanization

Field mechanization encompasses the use of machines and equipment for performing agricultural operations, including:

Primary tillage

Secondary tillage

Seeding and planting

Fertilizer and pesticide application

Irrigation support

Harvesting.

According to the FAO, effective mechanization systems must be technically appropriate, economically feasible, environmentally sustainable, and socially inclusive [1]. They increase productivity while minimizing soil degradation, reducing greenhouse gas emissions, and optimizing input use.

The integration of these components ensures efficiency and precision. Therefore, it is important to investigate how mechanization affects specific field operations, starting with soil cultivation.

2. Tillage Systems

Tillage. Traditional tillage involves ploughing the field to a depth of 20-30 cm. It destroys plant

residues, weeds and prepares the soil for sowing. However, studies show that ploughing degrades soil quality, removing moisture and minerals from it [3]. Even when used worldwide, the decline in soil quality has led to the emergence of alternative tillage methods, such as no-till.

Reduced and minimal tillage. Reduced tillage limits soil disturbance by reducing the number and intensity of operations. Conservation tillage systems, as defined by the USDA, significantly reduce soil erosion and improve moisture retention [4]. Minimal tillage practices contribute to:

- Reduced fuel costs

- Reduced labor costs

- Improved soil aggregation

- Increased biological activity

Such systems are useful in hot climates where there is wind erosion and drought.

Conservation agriculture. No-till farming relies on direct seeding into uncultivated soil covered with crop residues. It is one of the main types of conservation agriculture [5]. Studies show that this type of tillage:

- Reduces soil erosion by 90%

- Increases carbon sequestration

- Improves water infiltration

However, such tillage requires specialized machinery and a well-thought-out weed management plan.

3. Farm Machinery

Choosing the right equipment to make these and other field operations possible is important.

Tractors. Tractors are the backbone of mechanized farming. They are the backbone of agriculture. Modern tractors are equipped with advanced technologies, including:

- GPS-based automatic steering systems

- Variable transmission

- Emission control

- Real-time productivity monitoring

According to AEM, innovations in tractor design have significantly reduced emissions and increased efficiency. High-horsepower tractors are used in mass production, while low-power tractors handle small and medium-sized farms.

Planting equipment. The latest seed drills provide uniform spacing between seeds and uniform planting depth. CIMMYT research shows that precision seeding has a significant impact on the growth process and crop quality. Modern seed drills include:

- Pneumatic seed distribution systems

- GPS synchronization

- Variable seed rate capability

Therefore, such technologies increase productivity and quality of the final product

Sprayers and fertilizer applicators. Mechanized sprayers provide efficient irrigation and fertilizer application, reducing the impact on the land. Variable Rate Technology (VRT) allows farmers to adjust the amount of fertilizer applied depending on the soil condition. As a result, this has a positive impact on the soil and yields.

4. Precision Agriculture

Looking at advances in agricultural technology, precision agriculture is the future of agriculture, and the integration of digital technologies such as GPS and sensors into field equipment will increase the speed, quality and efficiency of harvesting.

The European Commission states that digital farming technologies increase productivity while reducing resource consumption and pressure on the environment. Key technologies include:

- GPS and satellite guidance systems

- Geographic Information Systems (GIS)

- Soil and crop sensors

- Drones and remote sensing

- Farm management software

Precision farming allows for field-based management, where inputs are applied only where needed.

5. Economic impact of mechanization

Mechanization has a significant impact on the economy of agriculture. The World Bank states that agricultural mechanization contributes to rural economic development and poverty reduction . Economic benefits include:

- Reduced dependence on labor
- Increased speed of work
- Higher yields
- Increased profitability

However, high capital investment remains a barrier, especially for smallholder farmers. Access to credit, machinery sharing programs, and government support mechanisms are essential for the inclusive development of mechanization.

6. Environmental and sustainable considerations

Mechanization increases efficiency, but also creates environmental problems:

- Soil compaction
- Fuel consumption
- Gas emissions

FAO insists on safe agriculture and mechanization to reduce the impact of agriculture [1]. Sustainable development includes:

- Controlled farming
- Reduced tillage
- Energy-efficient machinery
- Integration of renewable energy sources

Modern hybrid and electric agricultural machinery is a promising direction for reducing emissions.

7. Future Trends in Field Mechanization

Technological progress rapidly reshapes agriculture. According to industry analyses by AEM, automation and robotics are becoming central elements of agricultural innovation [5]. Emerging trends include:

- Autonomous tractors
- Robotic weed control systems
- Artificial intelligence-based crop monitoring
- Electric and hybrid power systems
- Smart data platforms for farm management

Automation reduces labor requirements and improves precision. Artificial intelligence enables predictive analytics, optimizing planting schedules and input management. The integration of robotics and AI is expected to significantly transform field operations in the coming decades.

Modern mechanization integrates new digital technologies and precision farming tools. Conservation agriculture and efficient tillage systems contribute to environmental protection and long-term soil fertility. Despite challenges such as high investment costs and environmental risks, the development of automation, robotics and artificial intelligence predicts a more sustainable and efficient future for global agriculture.

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