

Integration of modern land reclamation equipment into the system of precision agriculture using MZURI technology in the south of Ukraine

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Abstract. The purpose of this study was to investigate the possibilities of increasing the efficiency of agricultural production in southern Ukraine by using modern land reclamation equipment in combination with precision farming technology to improve soil water regime and the sustainability of agroecosystems. The study employed an experimental approach with variations in tillage and irrigation, determination of physical and water properties of the soil, root system development and plant condition, yield, resource costs, and economic indicators for a comprehensive assessment of the effectiveness of agricultural technologies. The study found that strip tillage, a field-based precision tillage system with row planting, combined with Netafim Uniram drip irrigation provided the greatest soil moisture at 0-20 cm and 20-40 cm (28 m³/ha and 24 m³/ha, respectively), reduced soil density to 1.26 g/cm³ and increased capillary water capacity to 27 m³/ha. The depth of the root system reached 110 cm, while the normalised difference vegetation index was 0.82. Yields reached 10.8 t/ha, water use efficiency (WUE) was 3.09 kg/m³, net profit was 21,000 UAH/ha, and profitability was 62%. The variant using the Bauer Rainstar E precision field system with row spacing and precision sprinkling showed a yield of 10.5 t/ha, slightly below the maximum result, but greater than the control. The field system of precision cultivation with row planting without land reclamation yielded 9.5 t/ha, while conventional irrigation (control) showed the lowest results – 8.9 t/ha. The data revealed that the integration of strip-till with modern irrigation systems increases the productivity and economic efficiency of maize

Keywords: dry conditions; irrigation; yield; water saving; energy consumption

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INTRODUCTION

The southern regions of Ukraine are characterised by challenging climatic conditions, including low natural moisture levels, hot temperatures, and frequent droughts, which negatively affect the productivity of agricultural land. Due to the growing shortage of water resources, soil water management requires increased attention. Precision farming technologies, which include minimal tillage, localised fertilisation, and automated management of agricultural processes, are becoming key to ensuring stable yields and preserving soil fertility. One of the most promising innovations is the MZURI technology (a precision tillage system with row planting), which combines energy and water saving with increased agronomic efficiency. Combined with modern land reclamation measures, this technology opens new opportunities for adapting agricultural production to the arid conditions in southern Ukraine.

The problem of effective water management in the arid regions of southern Ukraine continues to be urgent due to the lack of natural moisture and soil degradation. B. Hailu & H. Mehari (2021) investigated the impact of fertigation on plant development in arid conditions. The researchers found that the use of this technology not only increases yields, but also optimises fertiliser use, reducing fertiliser losses. The researchers emphasised that fertigation creates a more even supply of nutrients to plants, which is crucial in conditions of limited soil moisture. Y. Sha *et al.* (2024) addressed the use of deep rippers to accumulate moisture in the root system. The study showed that this technology promotes deeper root penetration and improves water supply for crops in arid regions. Additionally, loosening reduces soil compaction, which increases the efficiency of irrigation use and contributes to more stable plant growth. Y. Lu *et al.* (2022) highlighted the role of the global positioning system (GPS) in precise fertilisation and irrigation control. Accurate positioning enables an even distribution of resources, which increases the efficiency of their use and reduces costs. The study also showed that the integration of GPS technology with modern irrigation systems reduces the environmental impact on the agricultural system.

J. Huang *et al.* (2021) noted that the combination of reclamation measures with strip-till reduces soil erosion. This helps to maintain fertility and a stable water balance, which is critical in arid regions. The researchers also emphasised that this combination of technologies improves the physical properties of the soil, which positively influences the development of the root system of crops. V. Havrysh *et al.* (2021) explored the possibility of using a hybrid power source with a variable frequency drive to automatically move irrigation equipment. The

researchers showed that such a system increases energy efficiency and ensures stable operation of the equipment under variable power supply conditions. Additionally, automated movement contributes to more precise irrigation and more uniform water supply to plants, which increases the efficiency of agricultural production. I. Biluk *et al.* (2020) addressed the use of adaptive control in complete electric drives to ensure stable operation of industrial systems. The study found that this approach can improve the accuracy and reliability of drives under variable loads and operating conditions. This is crucial for automated irrigation and soil cultivation systems, where the stability of the equipment directly affects the uniformity of water and nutrient supply. J. Cuaran & J. Leon (2021) demonstrated the benefits of remote monitoring using drones. Due to the prompt detection of plant stress conditions, agrotechnical measures can be adjusted accordingly, which increases crop productivity. This study confirmed the effectiveness of integrating remote monitoring technologies into precision farming systems to increase yields and resource efficiency.

S. Getahun *et al.* (2024) emphasised the need to adapt technologies to local soil and climatic conditions. Adapting to concrete conditions can stabilise yields and increase the efficiency of precision agriculture. The researchers noted that consideration of the local soil and climate characteristics is a key factor in optimising irrigation and fertilisation. X. Fu & H. Niu (2023) pointed out that reducing energy costs with the introduction of modern reclamation systems increases the economic efficiency of production. Lower energy costs can increase profitability and ensure stable productivity of agricultural systems. The cited study emphasised that optimising energy consumption is a vital aspect of sustainable farming, especially in regions with limited access to resources. S. Alharbi *et al.* (2024) investigated an integrated approach to soil water management. Better control of the water balance ensures stable productivity of agricultural systems and improves water supply to plants in arid regions. This confirms that the integration of modern irrigation technologies and precise water management directly affects resource efficiency and crop yields. The findings of these studies confirmed the positive impact of an integrated approach on moisture conservation, yield increase, and energy efficiency of agricultural production in drought conditions. At the same time, there are gaps in the study of the adaptation of these technologies to the specific soil and climatic conditions of the southern region of Ukraine, as well as in the development of integrated methods for monitoring and managing reclamation systems in real agroecosystems. This requires further research to optimise

the implementation and increase the sustainability of agricultural production in an arid climate.

The purpose of this study was to assess the effectiveness of the introduction of land reclamation equipment into the precision farming system using the MZURI technology to increase the productivity and stability of agrocenoses in the region. The objectives of the study were to investigate the influence of tillage technologies on the physical and chemical properties of the soil; to assess the effect of these technologies on the development of the root system and vegetative performance of plants; and to conduct economic and resource analysis by determining the consumption of water, fertilisers, and fuel and calculating key economic indicators such as net profit and profitability ratio.

MATERIALS AND METHODS

The study was conducted from April to August 2024 at the farm “Dzhondir-B”, located in Bolhrad district of Odesa region, which is part of the Southern Steppe of Ukraine. This farm was chosen due to its location in the Southern Steppe zone with typical soil and climatic conditions for the region, which ensured the representativeness of the results. A 12-hectare plot was allocated for the study, which was divided into four replications of 3 ha each, enabling the assessment of the impact of different tillage and irrigation technologies on the productivity of mid-season maize (*Zea mays* L.), a hybrid selected for its adaptability to the Southern Steppe and stable yields in the study area. The soils of the site were represented by southern medium loamy chernozem with a humus content of 2.8%, and the weather conditions of the season were characterised by an average annual rainfall of about 320 mm and an average temperature of the growing season of +22.4°C with possible rain-free periods of up to 50 days (Hydrometeorological centre..., n.d.).

The study followed international and national ethical standards for conducting experiments with plants and soils, in particular, the principles of Convention on Biological Diversity (1992). All agrotechnical tests were conducted without compromising the biological integrity of plants and soil ecosystems. The principles of rational use of natural resources and sustainable soil management were applied, which was emphasised in studies on bioeconomics and soil protection in Ukraine (Petrukha *et al.*, 2024; Tretiak *et al.*, 2024). Additionally, methodological approaches to minimising the negative impact on soil properties during experiments, recommended in the context of military and environmental risks, were considered (Andrews *et al.* 2004). Adherence to these ethical standards ensured the reliability, safety, and representativeness of the findings. The tillage

and irrigation technologies included four variants that helped to compare conventional and conservation approaches in terms of their impact on soil properties, plant development, and yields. The first option involved conventional irrigation by sprinkling with continuous tillage at 12–14 cm, which served as a control option for comparison with other technologies. The second variant implemented strip tillage without land reclamation with simultaneous sowing using a MZURI Pro-Til 3T seeder (UK), which helped to assess the effectiveness of the resource-saving approach. The third variant combined strip-till with Netafim Uniram™ drip irrigation (Israel) with built-in compensating emitters for precise water dosing, and the fourth variant involved strip-till combined with a Bauer Rainstar E sprinkler (Austria) to evaluate modern mechanised technologies.

Soil moisture at depths of 0–20 cm and 20–40 cm was determined using Soilmoisture Equipment Corp. tensiometers (USA) installed at the points of each experiment to obtain data on the soil water regime during the growing season. Soil density was measured by the cylinder method using an Eijkelkamp drill (Netherlands), which helped to assess the impact of different tillage technologies on soil structure. Capillary moisture capacity was determined in the laboratory using soil samples from the relevant layers. The depth of the root system was recorded with a RootMeter proflometer (Germany) during critical phases of plant growth. The dynamics of the normalised difference vegetation index (NDVI) was recorded by a DJI Phantom 4 Multispectral drone (China) to assess the condition of plants and photosynthesis intensity. The yield was determined by weighing on a CAS CI-2001A scale (South Korea) after harvesting. Water and fertiliser consumption was monitored by Maddalena Woltman meters (Italy), water loss through evaporation was determined by ETgage® Model A sensors (USA), and fuel consumption was recorded by Flowmate fuel meters (Japan), which helped to comprehensively assess the effect of the applied technologies on water regime, soil physical properties, plant development, and economic efficiency.

Water use efficiency (*WUE*) was calculated as the ratio of yield to total water consumption for transpiration and evapotranspiration (1):

$$WUE = \frac{Y}{ET}, \quad (1)$$

where *Y* is the yield (kg/ha); *ET* is the total water consumption for transpiration and evaporation (m³/ha).

To assess the economic efficiency, net profit was calculated as the difference between the value of gross output and total costs (2):

$$NP = G - C. \quad (2)$$

Profitability was calculated using the following formula (3):

$$CR = \frac{NP}{C} \times 100\%, \quad (3)$$

where NP is the net profit; G is the gross production value; C is the total costs (UAH/ha).

Statistical processing of the data was performed using one-factor analysis of variance (ANOVA) to compare the average yield, WUE , NP , and CR between the variants. In case of violation of the assumptions of normal distribution or homogeneity of variances, the non-parametric Kruskal-Wallis test was used. The analysis was conducted in the R software environment (version 4.3.0), with data reliability checks for omissions and abnormal values. The level of statistical significance was set at $p < 0.05$.

RESULTS

Analysing the efficiency of modern agricultural technologies requires a comprehensive approach, as the effectiveness of maize cultivation is determined not by one single parameter, but by the interaction of several interrelated factors. First and foremost, the physical properties of the soil – its moisture content, density, and capillary water capacity – play a significant role, as they shape the water-air regime and create the basis for the development of the root system. The depth of root penetration directly depends on these characteristics: looser and more moist soil provides plants with access to moisture and nutrients at different levels of the profile. As a result, vegetative development changes, which is reflected in the NDVI index, an integral indicator of photosynthetic activity and leaf condition. NDVI correlates with yield, which is the final criterion for the effectiveness of agrotechnical solutions. Therewith, the resource component should also be considered, which determines the economic feasibility of implementing a particular technology. It includes water and fertiliser consumption, the level of their losses, and fuel consumption, which together form the cost of production and affect the profitability of the farm. Thus, to objectively assess the effectiveness of agricultural technologies, it is necessary to simultaneously consider soil, biological, and economic indicators, identify correlations between them and determine which technologies provide the optimum balance between yield, resource efficiency, and sustainability.

Conventional irrigation in the control variant provided relatively low moisture content – 22 m³/ha in the top layer and 18 m³/ha in the deep layer. This result

is conditioned by the intense disturbance of the soil structure during continuous cultivation: the surface layer dries faster, and water is absorbed unevenly, which reduces the ability of the soil to retain moisture in critical horizons for the root system. In the MZURI variant without reclamation, where belt cultivation with simultaneous sowing was used, an increase in moisture content of up to 25 m³/ha in the top layer and 20 m³/ha in the deeper layer was observed. This is because belt cultivation disturbs the soil only in the rows, leaving the row spacing relatively stable and less compacted. This partial disturbance of the structure reduces evaporation and improves the capillary supply of water to the roots. The greatest moisture values were recorded when MZURI was applied in combination with Netafim Uniram™ drip irrigation – 28 m³/ha in the top layer and 24 m³/ha in the deep layer. Drip irrigation provides a point supply of water without unnecessary losses due to evaporation and penetration into unnecessary horizons, which allows plants to use the available moisture more efficiently. Furthermore, uniform moistening of the root-bearing horizons promotes better root development and stabilises the soil microstructure. The Bauer Rainstar E precision sprinkler variant provided an analogous moisture level of 27 m³/ha, demonstrating that the combination of belt cultivation with localised water application also contributes to moisture conservation, although some water may be lost to evaporation if irrigation is less precise.

The control variant with conventional irrigation and continuous cultivation had a density of 1.32 g/cm³. This high value indicates a more compacted soil structure, which is a consequence of the intense mechanical impact of cultivation. Compaction restricts porosity, reduces aeration, and inhibits the movement of water into deeper horizons, which negatively affects root development and water use efficiency. In the MZURI variant without reclamation, the density decreased to 1.28 g/cm³, reflecting improved structural stability of the soil. This is caused by the use of strip tillage, which disturbs only a part of the soil profile and leaves the row spacing relatively undisturbed. Lower compaction promotes better aeration, facilitates capillary water movement, and provides favourable conditions for the growth of the maize root system. Even lower density values were observed in the variants with MZURI combined with Netafim Uniram™ drip irrigation and Bauer Rainstar E precision sprinkling – 1.26 g/cm³ and 1.25 g/cm³, respectively. This significant reduction in density reflects the increased porosity and aeration of the soil, which provides optimum conditions for water penetration, nutrient transport, and the development of a branched root system. The combination of belt

cultivation with precision water supply or deep loosening allows maximising the physical properties of the soil, combining minimal mechanical disturbance with efficient water supply.

In the control variant with conventional irrigation, the capillary water capacity was 21 m³/ha. This limited water retention is explained by soil compaction and intense mechanical impact during continuous tillage. The disturbed structure reduces porosity and inhibits the uniform infiltration of water into deeper horizons, which makes it difficult for plants to access moisture during dry periods. The use of MZURI without reclamation increased the capillary water capacity to 24 m³/ha, which demonstrates an improvement in soil structure and its ability to store moisture. Belt tillage disturbs only a part of the soil profile, leaving the row spacing relatively undisturbed, which reduces compaction, increases porosity, and facilitates more efficient water

movement to plant roots. Even greater values were obtained in the variants with a combination of MZURI and modern irrigation systems: Netafim Uniram™ drip irrigation provided 27 m³/ha, while Bauer Rainstar E precision sprinkling – 26 m³/ha. This demonstrates the effective preservation of water in the soil due to the point supply of moisture and the optimisation of soil physical properties. Drip irrigation minimises water loss due to evaporation, evenly moistens the root horizons, and creates favourable conditions for the development of a powerful root system. Summarising the results of the preliminary analysis, the study assessed changes in the moisture content of the top and deep soil layers, its density, and capillary moisture capacity, which helped to comprehensively compare the effectiveness of different tillage and irrigation technologies in providing plants with moisture and creating favourable conditions for the development of the root system (Table 1).

Table 1. Key physical properties of the soil under different tillage and irrigation options

Technology variant	Moisture content, m ³ /ha (top layer/depth)	Density, g/cm ³	Capillary moisture capacity, m ³ /ha
Control (conventional sprinkling)	22/18	1.32	21
MZURI without land reclamation	25/20	1.28	24
MZURI + Netafim Uniram™ drip irrigation	28/24	1.26	27
MZURI + precision sprinkling Bauer Rainstar E	26/22	1.25	26

Source: compiled by the authors of this study

The analysis of the data obtained showed a close relationship between the three indicators – with a decrease in soil density, there is a simultaneous increase in moisture in the upper and deep layers and an increase in capillary moisture capacity. In the control variant with a density of 1.32 g/cm³, the lowest values of moisture content (22/18 m³/ha) and water capacity (21 m³/ha) were recorded, indicating limited infiltration and water retention. The transition to MZURI without reclamation reduced the density to 1.28 g/cm³, which gave an increase in moisture content (25/20 m³/ha) and capillary water capacity (24 m³/ha). The best result was obtained in the MZURI variant with drip irrigation – the minimum density

of 1.26 g/cm³ was accompanied by the greatest values of moisture (28/24 m³/ha) and moisture capacity (27 m³/ha). A comparable trend, albeit slightly lower, was shown by the variant with precision sprinkling (26/22 m³/ha at a density of 1.25 g/cm³). Thus, all three indicators demonstrated a consistent trend: a decrease in soil density creates conditions for the accumulation and better retention of moisture, which ensures uniform water supply to the root system and increases irrigation efficiency. To determine the conditions for the development of the maize root system, the relationship between soil density and root penetration depth under different tillage and irrigation technologies was investigated (Fig. 1).

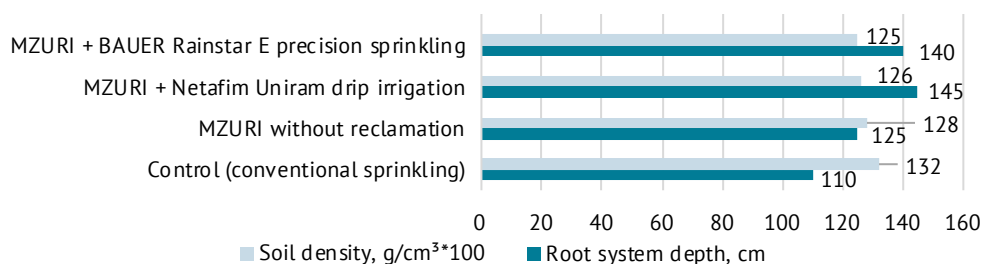


Figure 1. Effect of soil density on the depth of the maize root system

Source: compiled by the authors of this study

The analysis of the results revealed a clear relationship between soil density and the development of the maize root system. In the control variant with conventional sprinkling, the greatest soil density was recorded (1.32 g/cm³), which limited root penetration to a depth of 95 cm. This combination of indicators reflects excessive compaction of the soil profile, which reduces porosity, impairs water and air permeability, and leads to limited access of plants to moisture and nutrients in deeper horizons. In the MZURI variant without reclamation, a reduction in density to 1.28 g/cm³ increased the depth of the root system to 102 cm. This confirms that even a moderate reduction in compaction promotes more active root growth in depth, which improves their ability to use soil moisture. The most pronounced effect was

observed when combining MZURI technology with Netafim Uniram™ drip irrigation, where the density decreased to 1.26 g/cm³ and the root system reached 110 cm. An analogous result was obtained in the Bauer Rainstar E precision sprinkler variant (1.25 g/cm³; 108 cm). Thus, there is a stable inverse relationship: as soil density decreases, the depth of root penetration increases. This confirms that optimisation of soil physical properties in combination with modern irrigation systems creates conditions for deeper root development, which increases *WUE* and nutrient uptake, ensures drought resistance of maize, and contributes to greater yields. To assess the vegetative state of plants and its impact on productivity, the study analysed the dynamics of the NDVI index in combination with maize yield (Fig. 2).

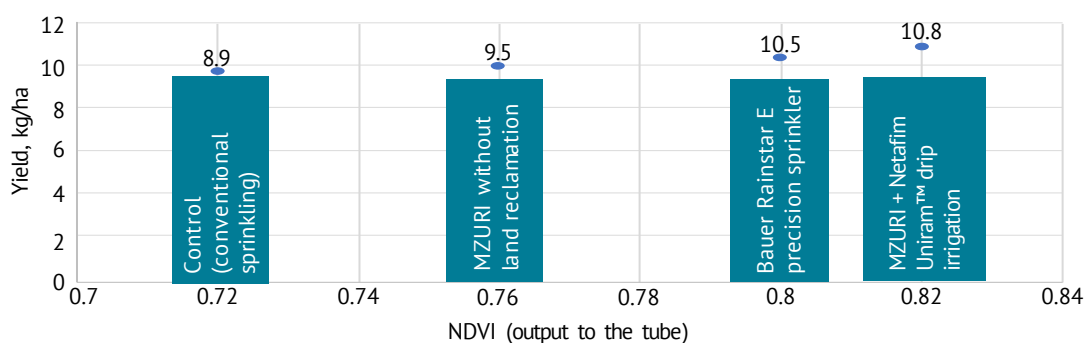


Figure 2. Relationship between NDVI index and maize yield under different technologies

Source: compiled by the authors of this study

The analysis of the obtained results revealed a close relationship between the dynamics of NDVI and maize yield. In the control variant with conventional sprinkling, the lowest NDVI values were observed at all vegetation stages (0.58–0.72), which was reflected in the minimum yield of 8.9 t/ha. This is explained by soil compaction and uneven distribution of moisture, which limits the development of the root system and reduces *WUE* and nutrients. The use of MZURI without reclamation contributed to an increase in NDVI (up to 0.76 at the tube stage) and a yield increase of up to 9.5 t/ha, which indicates improved water and nutrient supply due to more favourable soil physical properties. The greatest NDVI values (0.82) were recorded in the MZURI variant with drip irrigation, which correlated with the maximum yield of 10.8 t/ha. A comparable result was

shown by precision sprinkling with Bauer Rainstar E (NDVI up to 0.8; yield 10.5 t/ha), which confirms the effectiveness of modern localised irrigation technologies. Thus, there is a direct correlation: an increase in NDVI at all stages of the growing season is accompanied by an increase in yield, while optimisation of water supply and improved soil aeration create conditions for more intensive plant growth. This proves that the integration of innovative tillage and irrigation technologies ensures not only a stable increase in NDVI, but also a sustainable increase in maize productivity in the southern steppe. To assess the feasibility of introducing modern tillage and irrigation systems, the study calculated the economic efficiency of agricultural technologies, as well as *WUE*, which reflects the productivity of the moisture used (Table 2).

Table 2. Water, fertiliser, and fuel consumption for different cultivation and irrigation technologies

Technology variant	Water, m ³ /ha	Water losses, m ³ /ha	Fertilisers, kg/ha	Fuel, l/ha
Control (conventional sprinkling)	4,200	480	180	6.5
MZURI without land reclamation	3,800	360	175	5
MZURI + Netafim Uniram™ drip irrigation	3,500	250	170	5.8
MZURI + precision sprinkling Bauer Rainstar E	3,600	270	172	6

Source: compiled by the authors of this study

The analysis of the table shows a clear relationship between tillage technologies, irrigation systems, and resource use efficiency. In the control variant with conventional sprinkling, water consumption was 4,200 m³/ha, water losses were 480 m³/ha, fertiliser was 180 kg/ha, and fuel was 6.5 L/ha. This suggests a prominent level of resource intensity associated with continuous cultivation and uneven distribution of water, which leads to excessive losses and low efficiency. The use of MZURI technology without reclamation reduced water consumption by up to 3,800 m³/ha, losses by up to 360 m³/ha, fertiliser by up to 175 kg/ha, and fuel by up to 5 L/ha, demonstrating savings due to the localisation of strip tillage and simultaneous sowing. The combination of MZURI with Netafim Uniram™ drip irrigation provided the lowest water consumption (3,500 m³/ha) and minimum water loss (250 m³/ha), while reducing fertiliser application to 170 kg/ha, although fuel consumption increased slightly to 5.8 L/ha due to irrigation system maintenance. The Bauer Rainstar E precision sprinkler variant showed intermediate results: water consumption of 3,600 m³/ha, water loss of 270 m³/ha, fertiliser – 172 kg/ha, and fuel – 6 L/ha.

Overall, there is a direct correlation between the accuracy and localisation of irrigation and resource

savings: the more precisely water and fertiliser are applied, the lower the losses and the lower the costs. Additionally, the integration of MZURI reduces fuel costs by reducing the intensity of tillage, and the combination with drip or precision sprinkling ensures a balance between energy consumption and the efficiency of water supply and plant nutrition. Thus, the integrated use of strip tillage and modern irrigation systems increases resource efficiency and contributes to sustainable farming (Shebanin *et al.*, 2025). For a comprehensive assessment of the effectiveness of agrotechnologies, economic indicators such as *NP* and *CR* were analysed in combination with the *WUE* indicator. *WUE* was calculated using the formula (1) as the ratio of maize yield (*Y*, kg/ha) to total water use (*ET*, m³/ha), including water applied through irrigation and the effective fraction of precipitation actually available to plants. Two key indicators were determined in the experiment: net profit (*NP*, UAH/ha) and profitability (*CR*, %), which were calculated using formulas (2)-(3). This helped to simultaneously assess the financial return and water efficiency of different tillage and irrigation options, which is essential in the arid Southern Steppe (Table 3).

Table 3. Economic efficiency of agricultural technologies and water efficiency

Technology variant	<i>NP</i> , UAH/ha	<i>CR</i> , %	<i>WUE</i> , kg/m ³
Control (conventional sprinkling)	15,200	45	2.12
MZURI without land reclamation	17,000	50	2.5
MZURI + Netafim Uniram™ drip irrigation	21,000	62	3.09
MZURI + precision sprinkling Bauer Rainstar E	20,000	58	2.92

Source: compiled by the authors of this study

The analysis of the presented data revealed a clear correlation between economic efficiency and water efficiency of the applied technologies. Compared to the control, the use of MZURI without land reclamation increases net profit by 1,800 UAH/ha and profitability by 5%, while increasing *WUE* to 2.5 kg/m³, which indicates a more rational use of water and resources. The combination of MZURI with drip irrigation delivers the greatest *NP* of 21,000 UAH/ha, *CR* of 62%, and *WUE* of 3.09 kg/m³, demonstrating that point-of-use water delivery simultaneously increases financial returns and water productivity. The Bauer Rainstar E precision sprinkler variant also significantly outperformed the benchmarks, although slightly behind drip irrigation, with *NP* 20,000 UAH/ha, *CR* 58%, and *WUE* 2.92 kg/m³. The increase in profitability and profitability correlates with the increase in water efficiency, which confirms the effectiveness of integrating modern tillage technologies and localised or precision irrigation to optimise resources and economic outcomes. MZURI technology

in combination with Netafim Uniram™ drip irrigation demonstrates the greatest efficiency among all the tested options, as it provides the best performance by all criteria. It helps to improve the physical and chemical properties of the soil, increases the depth and weight of the root system, supports uniform plant development, which is reflected in high NDVI values, increases yields and reduces water and fertiliser consumption. Additionally, this technology allows achieving better *WUE* and provides a considerable increase in economic return, net profit, and profitability. Taken together, this makes MZURI with Netafim Uniram™ drip irrigation the most optimum solution for resource-saving and cost-effective maize cultivation in the Southern Steppe.

The analysis of all the studied indicators revealed a close relationship between the physical properties of the soil, the development of the root system, vegetation indices, yield, and economic results of production. Reducing soil density in the variants with minimal tillage and reclamation measures is accompanied by an

increase in moisture and capillary water capacity, which creates favourable conditions for the development of a deeper root system of maize. This provides better access to water and nutrients, which is confirmed by greater NDVI values and greater yields in drip and precision irrigation. At the same time, resource consumption has a clear link to economic efficiency: reduced consumption of water, fertiliser, and fuel directly translates into lower production costs and increased profitability. Specifically, MZURI's drip irrigation and precision sprinkler technologies combine optimum soil moisture and density with efficient use of resources to achieve the greatest net profit, profitability, and *WUE*. Thus, the results showed a systemic effect: improved soil conditions lead to more active root development, which increases water and nutrient supply, which is reflected in greater NDVI and yields, while economic efficiency increases due to more efficient use of resources. This sequence confirms that land reclamation technologies can simultaneously ensure environmental sustainability and economic benefits for agricultural production.

DISCUSSION

A study of the integration of MZURI technology into a precision farming system in the south of Ukraine found that strip-till improved soil moisture retention. The use of minimal tillage and localised fertilisation helped to reduce evaporation and erosion, which was particularly significant due to the low rainfall and hot temperatures in the region. Preserving the soil structure also positively influenced its aeration and water permeability, which together maintained soil fertility. G. Taye *et al.* (2024) also studied this problem, confirming that the analysis of the impact of technology on moisture conservation and soil structure improvement shows that modern agricultural practices help reduce evaporation and erosion. Improving the soil structure increases its permeability and ability to retain moisture. This creates more favourable conditions for plant growth and increases their resistance to drought. M. Rozewicz *et al.* (2024) also showed that agrophysical changes in the soil when using strip-till technology demonstrate an improvement in the porosity and aeration of the topsoil. This method reduces compaction and promotes the development of the root system, which positively influences crop productivity. The introduction of strip-till increases resource efficiency and yield stability. M. Li *et al.* (2024) confirmed that the integration of strip-till with precise local application of water and fertiliser increases resource efficiency and yield stability in dry conditions. The introduction of these technologies also reduces the risk of soil erosion and degradation in the long term. Additionally, the adaptation of

agricultural practices to specific climate and soil conditions ensures an optimum balance between productivity and ecosystem conservation. Notably, the implementation of moisture conservation technologies is not always a one-size-fits-all solution and requires adaptation to concrete climatic conditions and soil types. The effectiveness of such methods depends on the right combination of agricultural practices and regular monitoring of soil conditions. Therefore, an integrated approach to soil management is key to achieving sustainable results in agriculture.

Additionally, the introduction of modern reclamation equipment, including drip irrigation with automatic control, demonstrated the efficient use of water resources. Automation of irrigation using GPS and humidity sensors reduced excessive water consumption and ensured optimum conditions for plant growth. Localised fertilisation through fertigation systems increased the efficiency of plant nutrition, reducing the negative environmental impact. A. Abioye *et al.* (2023) concluded that the evaluation of the efficiency of automated drip irrigation shows a considerable reduction in water consumption due to the precise dosing of moisture according to plant needs. This system avoids waterlogging and reduces losses due to evaporation and runoff. As a result, crop productivity increases and the pressure on water resources decreases. A. Jiménez *et al.* (2022) found that the use of smart irrigation systems using GPS and IoT opens new opportunities for real-time monitoring of field conditions. These technologies allow accurately identifying areas with different water needs and automatically adjusting the irrigation regime. This approach contributes to a noticeable increase in water conservation and agricultural production efficiency. M. Seyar & T. Ahamed (2024) additionally showed that the integration of soil moisture sensors and automatic irrigation control systems provides more uniform moisture and reduces energy consumption for water supply. This enables optimised resource use on a farm-wide basis. Furthermore, the use of intelligent irrigation systems helps reduce the risk of plant stress during dry periods. These results confirm the study presented above, as automated drip irrigation does provide more precise water management. It allows adapting the water supply to the changing needs of plants in different growth phases, which reduces overall water consumption. Thus, the introduction of such systems is a major step towards the sustainable use of water resources in agriculture.

The use of strip-till technology helped to improve moisture storage in deeper soil layers. This was essential for providing plants with water during dry periods, which is typical for the southern regions of Ukraine.

Furthermore, such measures helped to reduce soil compaction and improve soil structure, which positively influenced the development of the root system of crops. M. Pulido-Moncada *et al.* (2021) showed that the destruction of compacted soil layers improves its water permeability. This increases the accumulation of moisture in deeper horizons and reduces its loss through surface runoff. As a result, the availability of water to the root system of plants increases, which positively influences their development and yield. Additionally, the efficiency of soil cultivation largely depends on the technical characteristics and design parameters of machine and tractor units. V. Hruban *et al.* (2025) showed that optimisation of the design parameters of rotary tillage units under variable loads can increase their stability and productivity. It was established that the optimum angle of attack of the working bodies (20-30°C) reduces soil resistance and contributes to an even distribution of loads. Changing the curvature radius of the working elements reduces stress concentration and increases their durability. The use of special alloy steels containing chromium and manganese increases wear resistance, reduces maintenance requirements, and extends the service life of the units. A crucial design solution was the introduction of rubber shock absorbers at the mounting points, which reduced the amplitude of vibrations and increased the stability of the equipment. As a result, the improved machines ensure uniform distribution of the tillage depth, reduce soil compaction, save fuel, and improve crop growth conditions.

Y. Yang *et al.* (2023) concluded that a combination of different tillage methods optimises soil physical properties. This approach contributes to the development of a more stable structure that better retains moisture and prevents erosion. This improves the soil's water-saving properties, which is essential for maintaining productivity even in dry conditions. S. El-Hendawy *et al.* (2022) also noted that the use of strip-till in combination with mulching the soil surface reduces evaporation and promotes more even water penetration. This helps to create optimum conditions for the development of the root system even during long periods of dry weather. Additionally, this integration of agronomic practices increases plant resistance to drought and improves overall yields. These findings are consistent with the theses presented in the previous section, as they confirm the effectiveness of measures aimed at improving water permeability and increasing soil moisture reserves. They demonstrate that removing compacted layers contributes to a more even distribution of water and reduces the risk of water loss. This underlines the significance of such mechanisms for ensuring a stable water balance and increasing yields in the face of climate change.

The use of precision farming systems enabled high-precision monitoring of field conditions using mapping, UAVs, and sensors. This allowed differentially controlling irrigation and fertilisation rates depending on the concrete conditions of each field. As a result, the overall efficiency of resource use increased and losses were reduced, increasing the economic viability of the technology in the region. E. Bwambale *et al.* (2022) also confirmed that the use of precision farming technologies to monitor soil moisture and fertility enables real-time, detailed data on field conditions. This allows promptly responding to changes and optimising agronomic practices, which increases overall production efficiency. The use of such technologies contributes to a more rational use of resources and reduces losses. M. Padhiary *et al.* (2024) also found that the use of GPS navigation and unmanned aerial vehicles provides accurate and adaptive irrigation and fertilisation management. These tools can create maps of fields with different cultivation intensities that factor in the local soil and vegetation characteristics. This helps to increase yields and water conservation, while reducing the negative impact on the environment. H. Shahab *et al.* (2025) showed that the integration of sensor networks and real-time data analysis allows predicting plant water and nutrient needs with high accuracy. This helps to plan agrotechnical measures based on the actual condition of plants and soil, rather than on standard regulatory values. The use of such integrated approaches increases the efficiency of resource conservation and yield stability. Comparing the data obtained during the research, it can be concluded that precision farming technologies markedly increase the efficiency of water and fertiliser use. They allow not only controlling soil conditions but also adapting agrotechnical measures to the concrete conditions of each site. Thus, the introduction of such innovative approaches is a key factor for sustainable agricultural development.

The benefits of integrating MZURI technology with modern land reclamation systems in southern Ukraine resulted in a considerable increase in yields while reducing the cost of fuel and lubricants, water, and fertilisers. Additionally, the integrated approach contributed to the improvement of the ecological state of agricultural landscapes: erosion was reduced, soil fertility was maintained, and the system became more resilient to climate challenges such as droughts. G. Branca *et al.* (2021) concluded that the integration of modern technologies into agricultural production in the southern region brings significant economic benefits by increasing yields and reducing input costs. At the same time, it helps to reduce negative environmental impacts through the rational use of water and preservation of

soil fertility. This approach helps ensure the sustainable development of the agricultural sector without depleting natural resources. S. Haque *et al.* (2025) found that climate resilience of agricultural systems increases due to the integrated application of modern land reclamation and precision technologies that enable adaptation to changing weather conditions. They help to improve the water-saving properties of the soil and optimise fertiliser application, which reduces the risks of droughts and floods. As a result, the agricultural sector is becoming more resilient and prepared for the challenges of climate change. A. Djalilov *et al.* (2022) showed that the integration of strip-tills with automated irrigation systems can markedly increase the efficiency of water and fertiliser use. This leads to reduced energy consumption and increases economic profitability of production. Furthermore, the integrated use of such technologies maintains yield stability and contributes to the long-term preservation of soil fertility in arid conditions.

When analysing the results of the conducted study, it is clear that the economic benefits of introducing the latest technologies are directly related to their environmental efficiency. The rational use of resources reduces production costs while reducing the negative impact on the environment. This underlines the significance of a comprehensive approach to agricultural modernisation, especially in the southern region with its specific climate challenges. At the same time, the study found that the application of this technology required extensive initial investment in specialised equipment and training. It also took some time for soils and plants to adapt to the new cultivation conditions, during which a temporary decline in yields was observed. However, considering the long-term benefits, overcoming these barriers seemed to be fully justified and promising for the development of agricultural production in the southern regions of Ukraine.

CONCLUSIONS

The results of the study revealed that the use of strip tillage and various irrigation systems significantly affected the water regime, physical properties of the soil, root system development, productivity, and economic efficiency of maize cultivation. The greatest soil moisture was recorded in the MZURI + drip irrigation (Netafim Uniram™) variant: at a depth of 0-20 cm – 28 m³/ha, 20-40 cm – 24 m³/ha, while the control variant had 22 m³/ha and 18 m³/ha, respectively. Soil density decreased in all MZURI variants, with the lowest value of 1.25 g/cm³ observed in the MZURI + Bauer

Rainstar E precision sprinkler variant compared to the control at 1.32 g/cm³. The capillary water capacity increased to 27 m³/ha under drip irrigation, which was 6 m³/ha greater than the control. The depth of the root system was maximum in the drip irrigation variant – 110 cm, while in the control it was 95 cm. The NDVI in the dynamics of growth was also greater in the variant of Netafim Uniram™ – 0.82 against 0.72 in the control, reflecting a better vegetative state of the plants. Maize yield was the greatest in drip irrigation – 10,800 kg/ha, which is 1,900 kg/ha more than in the control. Water consumption was optimum for strip-till with drip irrigation at 3,500 m³/ha versus 4,200 m³/ha in the control, while water losses were reduced to 250 m³/ha (control: 480 m³/ha). Fertiliser consumption was also slightly reduced to 170 kg/ha. Fuel consumption stayed relatively low at 5.8 L/ha in the Netafim Uniram™ variant, while the control used 6.85 L/ha.

WUE was greatest in drip irrigation at 3.09 kg/m³, which was 0.97 kg/m³ greater than the control. The economic efficiency was also greater: the net profit in this variant was 21,000 UAH/ha with a profitability of 62%, while the control provided 15,200 UAH/ha and 45%, respectively. The MZURI + precision sprinkling variant also showed a significant improvement over the control, but slightly lower than the drip irrigation, with a yield of 10,500 kg/ha, WUE of 2.92 kg/m³, and a net profit of 20,000 UAH/ha. Thus, the study confirmed that the use of strip tillage in combination with Netafim Uniram™ drip irrigation provides the best indicators of water regime, soil physical properties, root system development, yield, and economic efficiency among all tested variants. The limitation of this study was that its findings were based mainly on short-term experiments, which may not fully reflect the real conditions of long-term application of the technology in diverse soil and climatic zones. For further development of the topic, it is necessary to investigate the long-term impact of integrating MZURI technology with modern land reclamation equipment on soil quality and biodiversity of agroecosystems in the southern regions of Ukraine.

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Інтеграція сучасної меліоративної техніки в систему точного землеробства за технологією MZURI в умовах півдня України

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Анотація. Мета дослідження полягала у вивченні можливостей підвищення ефективності сільськогосподарського виробництва на півдні України шляхом використання сучасної меліоративної техніки у поєднанні з технологією точного землеробства для покращення водного режиму ґрунтів і стійкості агроєкосистем. У дослідженні застосовано експериментальний підхід із варіацією обробітку ґрунту та зрошення, визначенням фізико-водних властивостей ґрунту, розвитку кореневої системи й стану рослин, урожайності, ресурсних витрат і економічних показників для комплексної оцінки ефективності агротехнологій. Встановлено, що стрічковий обробіток ґрунту, польова система точного обробітку з рядковим розташуванням рослин, у поєднанні з краплинним зрошенням Netafim Uniram забезпечував найвищу вологість ґрунту на 0-20 та 20-40 см (28 та 24 м³/га), знижував щільність ґрунту до 1,26 г/см³ і підвищував капілярну вологоємність до 27 м³/га. Глибина кореневої системи досягала 110 см, а нормалізований різницевий вегетаційний індекс становив 0,82. Урожайність сягала 10,8 т/га, ефективність використання води (WUE) – 3,09 кг/м³, чистий прибуток – 21 тис. грн/га, рентабельність – 62 %. Варіант з використанням польової системи точного обробітку з рядковим розташуванням рослин та точного дощування Bauer Rainstar E показав урожайність 10,5 т/га, що дещо нижче максимального результату, проте перевищувало показник контролю. Польова система точного обробітку з рядковим розташуванням рослин без меліорації дала урожайність 9,5 т/га, тоді як традиційне зрошення (контроль) демонструвало найнижчі результати – 8,9 т/га. Дані засвідчили, що інтеграція стрічкового обробітку з сучасними системами зрошення підвищує продуктивність і економічну ефективність кукурудзи

Ключові слова: посушливі умови; зрошення; урожайність; водозбереження; енерговитрати