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Original Research

Decision Making in Finding Optimal Investment Strategy for Eco-Innovations Implementation in Agricultural Production in Ukraine

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ABSTRACT

Purpose: *This study aims to develop and justify an optimal investment strategy for implementing eco-innovations in Ukrainian agricultural enterprises. By evaluating alternative tillage technology scenarios through dynamic programming, the research addresses the decision-making challenge of how to allocate limited internal investment resources to maximize both economic returns and environmental benefits.*

Research Method: *The Bellman dynamic programming approach was used to model investment allocation among six tillage scenarios: traditional, Strip-till, No-till, and their combinations. The model incorporated operational data from a Ukrainian agricultural enterprise, with constraints reflecting limited resources. Optimal strategies were identified based on cumulative returns per hectare.*

Findings and Values: *The results show that investing equally in Strip-till and No-till technologies provides the highest average return of 485.03 USD/ha, compared to traditional tillage. The model confirms the economic feasibility of eco-innovative tillage methods, even within the operational limitations of a single enterprise. The findings highlight the value of integrated investment planning to support both productivity and sustainability. This article contributes a practical decision-making tool for agribusinesses seeking to implement eco-innovations under financial constraints. The methodology can support policymakers in designing targeted incentives (e.g., equipment subsidies) and can be adapted to other regions and farm scales, beyond the Ukrainian context.*

Keywords: *: Eco-innovation, Investment strategy, No-till, Strip-till, Sustainability, Ukraine*

INTRODUCTION

Agriculture remains a cornerstone of Ukraine's economy, contributing over 10% to national GDP and accounting for more than half of total exports in 2022 (UNECE 2023). This scale of production places growing pressure on the sector to pursue sustainable and resource-efficient practices. The shift toward eco-innovative practices requires strategic financial decision-making by enterprises, especially under wartime and post-crisis conditions (Kharazishvili 2023). Eco-innovations, defined as environmentally beneficial technologies and practices aimed at improving productivity while reducing ecological harm practices aimed at improving productivity while reducing ecological harm, have been widely promoted as a pathway toward

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sustainable agriculture (Pavelko *et al.* 2023). These include various soil treatment systems such as No-till, Strip-till, and other minimal tillage approaches that improve soil quality, reduce fuel and labor inputs, and lower greenhouse gas emissions (Hussain *et al.* 2022). Despite clear benefits, adoption across Ukrainian agribusiness remains inconsistent. The core challenge lies not in the lack of eco-innovative options, but in the absence of clear decision-making frameworks that allow agricultural enterprises to evaluate these technologies under real-world financial constraints. Companies face uncertainty about which tillage methods will bring the highest returns in terms of profitability and sustainability, especially when investment resources are limited.

While existing studies extensively highlight the environmental potential of sustainable practices, few offer structured approaches for allocating investments across multiple eco-innovative scenarios. The research gap concerns not only the effectiveness of these innovations but how agribusinesses can prioritize between them based on measurable operational indicators such as fuel usage, labor intensity, and projected economic gains. This paper addresses this gap by applying the Bellman dynamic programming method to simulate and optimize investment decisions in the context of eco-innovation adoption. The model allows for conditional optimization of limited financial resources and provides insights into how companies can strategically distribute investments across different tillage scenarios. The novelty of this study lies in integrating dynamic decision-making theory with empirical cost-performance data from Ukrainian agricultural production. The research proposes a practical tool for agro-enterprises to make evidence-based investment decisions that align with environmental sustainability goals.

Many researchers, economists, and scholars have made important contributions to the study of eco-innovations and its management. Loucanova E. study underscores the transformative capacity of eco-innovations, allowing companies to convert environmental constraints into advantageous opportunities (Loucanova *et al.* 2021, Al-Saidi 2023, Houser *et al.* 2023). These advantages encompass cost reduction, enhanced reputation, and the creation of entry points into novel markets, positing environmental responsibility and innovation as fundamental components of strategic branding (Palczewski 2008). Some research accentuates the positive impact of eco-innovations on economic development, investment attractiveness, and competitiveness (Goncharenko *et al.* 2021, Luo *et al.* 2021). Their findings underscore the great role of investments in green innovations in shaping sustainable economic trajectories. Wysocki highlights the measurable benefits of innovative green initiatives within the small and medium-sized enterprise sector in Poland, emphasizing revenue growth as a tangible outcome while simultaneously maintaining environmental safety. This substantiates the proposition that environmental innovations are pivotal drivers of economic success (Wysocki 2021, Ahmad & Wu 2021). Therefore, this study incorporates existing research on decision-making models applied in agricultural sustainability and innovation management. Building upon this foundation, this study aims to develop and justify an optimal investment strategy for implementing eco-innovations in Ukrainian agricultural enterprises by applying the Bellman dynamic programming method to simulate and optimize investment decisions across various tillage scenarios.

MATERIALS AND METHODS

This study defines its methodological framework by first identifying relevant eco-innovative practices and then detailing the application of the Bellman dynamic programming method to optimize investment decisions within an agricultural enterprise. The approach aims to provide a structured framework for resource allocation among competing eco-innovation scenarios, balancing economic gains with environmental sustainability. An effective strategy for addressing the growing need for ecological sustainability in agriculture is the widespread adoption of alternative farming systems (Campbell *et al.* 2014). The literature provides a diverse list of eco-innovative technologies, including Bio-Intensive

Mini-Farming, Biodynamic Agriculture, Effective Microorganism Technologies (EM Technologies), Low Input Sustainable Agriculture (LISA), Organic Agriculture (Organic Farming), Precision Farming, No-Till (Strip-Till, Mini-Till), and other soil treatment technologies (Al-Hanakta 2023, Shubravska & Prokopenko 2022). These eco-innovations in agricultural production are grounded in a profound understanding of the underlying processes occurring in the natural environment. These technologies are intended to improve soil structure, restore fertility, and contribute to the development of ecologically resilient agro-landscapes. Notably, they integrate biological approaches with managerial expertise, focusing primarily on enhancing the natural environment and producing goods with specific, high-quality attributes (FAO 2021, Shubravska & Prokopenko 2022).

Tillage emerges as one of the costliest and energy-intensive operations in agriculture. The adoption of contemporary mechanization technologies significantly influences production structures and operational efficiency. Eco-innovative technologies, such as Strip-till, not only save substantial fuel (approximately 20–30 L/ha compared to reduced tillage and conventional plough tillage) but also induce favourable changes in soil properties, enhancing both economic and environmental aspects of agricultural practices (Jaskulska *et al.* 2020). Strip-till technology is described as a resource-saving method that ensures quality soil loosening, uniform depth of processing, and evenness of the treated area (Alimova *et al.* 2022). Research highlights its role in preserving soil fertility by minimizing damage and enabling selective soil cultivation (Sereda *et al.* 2019). Strip-tillage can offer greater flexibility and increased corn growth and yield, particularly in drought conditions, compared to strict no-till (Morrison *et al.* 2002).

While no-till may increase soil carbon storage, its effectiveness in stabilizing the climate remains uncertain (Ogle *et al.* 2019). In Finland, no-till showed no significant effect on total variable costs but led to increased use of fertilizers and plant protection products alongside reduced labour requirements (Laukkanen & Nauges 2011). Other studies emphasize no-till's potential to increase soil moisture storage capacity and stabilize cereal crop yields, offering ecological and economic benefits (Zhelezova *et al.* 2019). Comparisons between minimal and no-till systems further support their effectiveness in reducing costs, preventing erosion, preserving soil fertility, and maintaining moisture (Chernogaev *et al.* 2021).

In Ukraine, highly productive enterprises employ minimal soil tillage, ensuring cultivation, sowing, and fertilization in a single pass of combined units. This reduces specific fuel consumption by 15–20% and increases labor productivity by 20–25%. No-till technology can reduce fuel consumption by 35–40 liters per hectare (Sereda *et al.* 2019, Kushnarev 2009). Advancements in comprehensive mechanization can enhance agricultural production and labour productivity by incorporating modern implements towards minimizing tillage. This signifies a promising shift towards sustainable and resource-efficient agricultural practices, where technology optimizes fuel consumption, labour productivity, and nature protection. The comparative characteristics of the eco-innovative tillage types considered in this study are presented in Table 1.

Dynamic programming model for investment optimization

To justify investment decisions in eco-innovative technologies, adopting a structured and forward-looking approach is essential. This study employs dynamic programming, specifically the Bellman recurrence principle, to model six alternative investment scenarios in tillage technologies. The approach integrates financial constraints and sequential optimization, making it well-suited for investment decisions involving multiple stages, where each decision relies solely on the current state and aims to achieve the highest possible total gain moving forward. The core problem modeled is how to optimally allocate internal investment funds among competing eco-innovation options to maximize long-term profitability. Dynamic programming proves highly effective here due to its strength

Table 1. Comparative characteristics of eco-innovative types of soil treatment

Type	Advantages	Disadvantages
Traditional	• Optimal root system development. • Effective utilization of nutrients and moisture. • High humification coefficient of organic fertilizers. • Weed control through systematic tillage.	• Soil structure disruption and erosion risks. • Higher fuel and lubricant expenses. • Potential for compaction in intensive tillage.
Strip-till	• Enhanced root system development. • Efficient use of nutrients and moisture. • Reduced soil erosion through targeted tillage. • Conservation of organic matter.	• Possible soil compaction in untilled areas. • Initial implementation costs for specialized equipment. • Limited weed control compared to traditional tillage.
Mini-till	• Improved soil structure, similar to traditional methods. • Moderate disruption for reduced erosion. • Enhanced nutrient availability.	• Increased fuel and energy consumption. • Potential for soil compaction. • Limited organic matter conservation compared to traditional tillage.
No-till	• Optimal root system development. • Efficient use of nutrients and moisture. • High humification coefficient of organic fertilizers. • Weed suppression through minimal soil disturbance.	• Soil structure disruption and erosion concerns. • Higher losses of organic matter due to excessive aeration. • Reduced anti-erosion stability of soils. • Significant fuel and lubricant expenses, potentially higher than traditional tillage.

in managing multi-stage decision processes under uncertainty. The agricultural company in question operates with a fixed investment budget ($P = 3$ nominal investment units) and must select from six possible investment scenarios involving eco-innovative soil treatment technologies:

- Traditional tillage,
- Strip-till,
- No-till,
- Combination of traditional and Strip-till,
- Combination of Strip-till and No-till,
- Combination of traditional and No-till.

These scenarios are compared using three key performance indicators:

- Fuel consumption (liters per hectare) – reflecting energy efficiency,
- Labor cost (hours per hectare) – reflecting operational efficiency,
- Profitability (USD per hectare) – reflecting the economic effect.

These parameters are derived from real-world cost structures and operational data, collected from Ukrainian agricultural enterprises and validated against literature sources (Kushnarev 2009, Moitzi *et al.* 2019, Piskier 2017).

Bellman equation and optimization process

To realize the goal of optimal decision-making regarding investment in eco-innovations within an agricultural company, the Bellman dynamic programming method is utilized. This approach is particularly effective for multi-stage decision problems where sequential choices influence subsequent states and overall outcomes. The core objective is to maximize the overall benefit of eco-innovations, $Ef_{\text{Eco\_Inn}}$, defined as the cumulative economic gain obtained through the optimal allocation of three nominal investment units among competing eco-innovative tillage technologies. The model aims to determine the optimal sequence of how these three units should be spent to achieve the highest overall $Ef_{\text{Eco\_Inn}}$. The problem is formulated as a multi-stage decision process focused on the sequential allocation of the available investment units. The core components of the dynamic programming model are defined as follows:

- *Stages of Allocation:* The optimization process implicitly proceeds through stages, representing the sequential decision points for allocating each portion of the total investment fund. The model seeks to determine the optimal way to spend each of the 3 available units.
- *System State (P_i):* Represents the total number of nominal investment units that have been already allocated (spent) up to a given decision point. P_i tracks the cumulative investment made, starting from $P_0 = 0$ (no units spent) and progressing up to $P_n = 3$ (all units spent).
- *Decision-Making Strategy (S):* At any given state, S represents a specific choice of an eco-innovative tillage scenario (or a combination of scenarios) for investing an additional nominal unit. The model evaluates strategies S that correspond to the allocation of $\Delta P(S)$ investment units. For this problem, it is assumed that each investment unit allocated corresponds to selecting one of the defined scenarios; thus $\Delta P(S)$ is typically 1 unit.
- *Gain Function ($G(S)$):* Quantifies the immediate economic gain (profitability in USD/ha) provided by implementing the chosen strategy S. This gain contributes to the overall effect and is associated with the specific tillage scenario selected at the current decision step and its corresponding investment.
- *State Transition ($\Delta P(S)$):* Represents the number of nominal investment units currently being spent or consumed by applying decision-making strategy S. This value is always positive and determines how much the total accumulated investment P_i increases with the current decision. The sum of all ΔP values across the optimal sequence will equal 3.

Bellman recurrence. The conditional optimal cumulative gain, $f(P_i)$, represents the maximum gain achievable when a total of P_i investment units have been optimally allocated from the available fund. The Bellman relation is:

$$f(P_i) = \max_{S \in \mathcal{S}(P_i)} \Big\{ G(S) + f\big(P_i - \Delta P(S)\big) \Big\} \quad (1)$$

where the maximization is performed over all feasible strategies S applicable from state P_i. The overall target can be written as $Ef_{\text{Eco\_Inn}}(P) = f(P)$ with $P = 3$. The optimization process consists of two key stages:

1. *Conditional Optimization:* Compute $f(P)$ iteratively for $P = 0, 1, 2, 3$, using previously computed values $f(P - \Delta P(S))$. At each P, evaluate all feasible S and select the one that maximizes $G(S) + f(P - \Delta P(S))$. Store the argmax $S^{(P)}$.

2. *Unconditional (Backtracking):* After obtaining $f(3)$, reconstruct the optimal sequence by tracing $S^{(3) \to S^{(2) \to S^{(1)}}}$ back to $P = 0$. This yields the investment plan that maximizes cumulative profitability subject to the budget. Detailed stepwise calculations for scenarios appear in Table 4 (Results and Discussion).

Model assumptions and constraints

The total number of investment units is limited to 3, representing budget constraints. Scenarios are assumed to be mutually exclusive per investment unit (i.e., no partial allocation within a single unit is permitted). Profitability estimates are based on a conservative crop yield of 3 t/ha and an average market price for corn (USD 212.7/t). This assumption is used for modeling consistency, acknowledging that actual yields in Ukraine may vary between 4 and 8.5 t/ha. Uncertainties, such as fuel price fluctuations and weather-related yield variability, are noted as limitations and potential directions for future enhancement of the model.

Data sources and validation

Operational data and machinery cost estimates are sourced from Ukrainian scientific reports (Kushnarev 2009), literature (Frisby & Summers 1979, Duffie *et al.* 1997), and market data. Table 3 presents input values for profitability, labor, and fuel use under different scenarios. Table 4 presents the dynamic optimization calculations and final investment allocation strategy.

The model was validated using real-world data from a large Ukrainian farm and benchmarked against historical investment outcomes. This modeling framework provides a replicable and adaptable tool for decision-making in agro-industrial investment planning, particularly where resource efficiency and environmental performance must be balanced with financial returns.

RESULTS AND DISCUSSION

Given the constraints of limited financial resources and the imperative for their efficient investment, the challenge arises of optimally allocating these funds. In real-world scenarios, companies often lack sufficient resources to invest simultaneously in all potential directions for the development of land processing technologies, or to choose just one. Therefore, it is expedient to primarily invest in those types of eco-innovations which, at each stage of the company's development, will yield the greatest cumulative effect, encompassing both economic benefits and environmental improvements. Thus, this study formulates a budget allocation problem: how to distribute limited financial resources across competing eco-innovative technologies to maximize profitability. The application of dynamic programming, specifically the Bellman method, is well-suited for solving this problem due to its ability to evaluate sequential investment decisions under conditions of uncertainty. The model incorporates essential constraints such as investment limits and technology availability. In Table 2, the cost structure of the most capital-intensive and the most cost-effective technologies is presented. The calculations are based on operational norms provided by the Ukrainian Scientific Research Institute of Productivity in the Agro-Industrial Complex. The comparative analysis of capital investments between traditional and no-till tillage systems

Table 2. Comparison of equipment costs for tillage systems (per 10,000 ha)

Traditional Tillage					
Category	Type of Equipment	Power, hp	Unit Cost (USD, k)	Units	Total Cost (USD, k)
Tractors	MTZ-80	75	20	24	480
	K-700	240	90	16	1440
	T-150	150	50	16	800
				Total Tractors	2720
Tillage & Seeding	Mounted Plow	–	24	2	48
	Grain Drill	–	15	24	360
	Disc Harrow	–	14	24	336
	Cultivator	–	7	16	112
				Total Equipment	856
				Grand Total	3576

No-Till					
Category	Type of Equipment	Power, hp	Unit Cost (USD, k)	Units	Total Cost (USD, k)
Tractors	CASE STX-500	500	310	1	310
Tillage & Seeding Complex	ATD 18.35	500**	290	1	290
Chemical Application	Self-Propelled Sprayer	–	380	1	380
				Total	980

*USD, k refers to thousands of US dollars.
** Minimum required tractor power.

reveals substantial differences in machinery composition, operational complexity, and overall costs. The traditional system involves a broad set of agricultural machinery, including three types of tractors (MTZ-80, K-700, and T-150) and four tillage and seeding implements (mounted plow, grain drill, disc harrow, and cultivator with flat cutters). This configuration requires multiple field operations, resulting in high fuel and labor demands. The total estimated capital investment required to manage 10,000 hectares using this approach is approximately USD 3.576 million. In contrast, the no-till system relies on a simplified setup, which includes only one high-power tractor (CASE STX-500) and a single multifunctional implement (ATD 18.35). The total investment for this configuration is around USD 980,000, representing a 72.6% reduction in capital expenditures compared to the traditional system.

The no-till method consolidates several field operations into a single pass, thereby reducing the need for additional equipment, limiting soil disturbance, and enhancing operational efficiency. This not only contributes to cost-effectiveness but also promotes long-term soil health and sustainability. The analysis clearly demonstrates that the no-till approach requires fewer machinery units and significantly lower capital investments while maintaining similar levels of operational performance. These findings confirm the economic and ecological advantages of implementing eco-innovative tillage practices in agriculture. The profitability analysis in this study is based on data from 2018–2020, as it was the most consistent and complete. More recent years were excluded due to data volatility caused by wartime disruptions in the agricultural sector. This disparity in capital intensity translates directly into production cost differences, estimated at approximately USD 70 per hectare. Given an average yield of 3 tons per hectare, the adoption of No-Till technology may reduce production costs by nearly USD 25 per ton (Servadio *et al.* 2016). These cost savings are a crucial component in evaluating the feasibility and attractiveness of sustainable investment strategies.

As illustrated in Table 3, traditional tillage technologies require significant energy inputs for soil cultivation and seeding, typically ranging from 0.8 to 1.0 horsepower per hectare. This results in high diesel consumption practical data suggest an average of 90 liters per hectare, with a range from 80 to 100 liters (Frisby *et al.* 1979, Piskier 2017). In comparison, No-Till technology dramatically reduces energy requirements, needing only 0.05–0.08 horsepower per hectare for seeding. Correspondingly, fuel consumption is much lower, averaging 30 liters per hectare, and ranging from 25 to 35 liters (Moitzi 2019, Piskier 2017).

These differences in energy requirements translate into more than a tenfold reduction in energy-related expenditures under No-Till. In monetary terms, this energy efficiency results in cost savings of approximately USD 48 per hectare when compared to traditional methods. When scaled to 10,000 hectares, this reduction represents a substantial reserve for decreasing the cost of grain cultivation. Moreover, diesel fuel expenses alone under No-Till constitute roughly 49% of the machinery cost needed for its implementation—highlighting a strong case for energy-efficient investment strategies.

The study examines several scenarios for deploying eco-innovative soil technologies across 10,000 hectares, focusing on both standalone and combined tillage approaches. Traditional tillage involves extensive mechanical operations such as plowing and harrowing, leading to elevated fuel and labor costs. Annual equipment maintenance expenses for this system are estimated at USD 900,760, or USD 90.97 per hectare. Fuel consumption reaches 65.0 liters per hectare, with labor inputs of 3.1 hours per hectare (Table 3). Strip-till technology, which processes only 30% of the soil surface, allows for a more efficient use of power. Fuel consumption drops by approximately 77.8% down to 14.4 liters per hectare and labor costs decrease by 70%, requiring only 0.93 hours per hectare. Additionally, fewer field passes reduce mechanical wear and maintenance needs. No-Till completely eliminates mechanical soil processing. It provides 2–4 times savings in fuel and lubricant usage, along with a 50% reduction in both labor and fertilizer application costs. The fuel input is 30.0 liters per hectare, while labor demand is reduced to 1.55 hours per hectare.

The analysis of profitability for each tillage method serves as a foundation for dynamic simulation using the Bellman method. To enable comparative modeling, a standardized assumption is adopted: equal yield contribution from each tillage system (1:1 ratio) and a fixed crop yield of 3 tons per hectare at a market price of USD 212.7 per ton. This approach supports the optimal allocation of investments across scenarios and quantifies the tangible benefits in terms of reduced fuel usage, financial savings, and labor efficiency (Table 3). Within this framework, the most efficient investment strategy maximizes the effect per unit of investment. Under uncertainty, the total available investment fund is fixed at three units. While integrated soil management provides flexibility, it is essential to factor in external uncertainties such as fuel price fluctuations, yield variability, and regional conditions which could influence profitability projections and must be considered in real-world applications (Moitzi 2019, Piskier 2017). Using the recurrent Bellman equation (1), the problem of optimal investment allocation among the specified six scenarios needs to be solved. By applying the recurrence relations and the initial data from Table 3, the process begins by finding conditionally optimal allocations, followed by the overall optimal investment distribution across scenarios. For the purpose of this optimization model, the investment fund is set at 3 nominal investment units. To illustrate the application of the Bellman

Table 3. Estimated data for choosing the option investing strategy

Soil processing technologies	General costs		Savings, USD/ha	Profitability, USD/ha		
	Fuel costs (L/ha)	Labor costs (hours/ha)		2020	2021	2022
Traditional	65.0	3.1	0 / 0	146.07	150.82	155.57
Stripe-trill	46.5	2.6	17.3 / 0.35	157.41	162.10	167.60
Mini-trill*	37.1	2.4	27.6 / 0.76	N/A	N/A	N/A
No-trill	9.0	1.25	56.02 / 1.83	165.94	170.20	174.60

* This method will not be used in the further modeling due to insufficient and inconsistent data on key performance indicators such as fuel use, labor input, and profitability, which would compromise the reliability of comparative analysis.

Table 4. Calculating maximum gain in the distribution of investments between 1–6 scenarios

Allocated Units (P)	Units consumed in current step $\Delta P(S)$	S	Immediate gain $G(S)$	Cumulative gain from previous state $f(P-\Delta P(S))$	Total gain $G(S)+f(P-\Delta P(S))$	Maximum cumulative gain $EfEco\_inn(P)$
1	0	1	0	165.94	165.94	165.94
	1	0	146.07	0	146.07	–
2	0	2	0	327.62	327.62	327.62
	1	1	146.07	165.94	312.01	–
	2	0	150.80	0	150.80	–
3	0	3	0	485.03	485.03	485.03
	1	2	146.07	327.62	473.69	–
	2	1	150.80	165.94	316.74	–
	3	0	155.57	0	155.57	–

method for a specific scenario, Table 4 presents the calculation for Scenarios 1-6. Thus, the calculations show that the optimal allocation of three nominal investment units across the six scenarios for implementing eco-innovations in an agricultural enterprise is designed to maximize total returns. By tracing back the optimal decisions recorded in Table **??** from the final state ($P = 3$) to the initial state ($P = 0$), the following allocation strategy is derived:

1. Traditional technology: 0 units of investment
2. Strip-tillage technology (eco-innovative): 1 unit of investment
3. No-till technology (eco-innovative): 1 unit of investment
4. Combination of traditional and strip-till: 0 units of investment
5. Combination of strip-till and no-till: 1 unit of investment
6. Combination of traditional and no-till: 0 units of investment

The optimal allocation sequence $(0, 1, 1, 0, 1, 0)$ was obtained through a backward trace from the maximum cumulative gain of USD 485.03/ha for the total investment fund ($P = 3$ units). This recursive process identified the sequence of decisions that led to the optimal result.

The derived strategy emphasizes the effectiveness of Strip-till and No-till technologies in maximizing profitability, reducing operational costs, and enhancing sustainability. In contrast, traditional and hybrid approaches received no allocation, reflecting their lower comparative performance. This allocation aligns with the enterprise's commitment to sustainable agriculture and resilience under limited investment resources.

The findings confirm that eco-innovative approaches are not only environmentally sound but also financially justified when supported by strategic investment planning. The Mini-till method was excluded due to insufficient data, but it may be considered in future studies if reliable indicators become available.

It is also important to note several sources of uncertainty that may affect outcomes:

- variability in fuel prices and labor costs due to market and geopolitical factors;
- dependence of yield levels on regional conditions, crop types, and weather;
- omission of equipment depreciation and maintenance costs in the current model.

Despite these limitations, the model provides a framework for supporting investment decisions in eco-innovation, guiding agribusinesses toward cost-effective and environmentally responsible choices.

CONCLUSION

This study proposed a structured decision-making framework for optimizing investment in eco-innovative soil treatment technologies within Ukrainian agricultural enterprises. Using the Bellman dynamic programming method, six scenarios were modeled to identify an allocation strategy that maximizes profitability while supporting sustainable farming goals.

The results show that strategic investments in Strip-till, No-till, and their combination yield the most favorable outcomes. Specifically, allocating three units of investment across these options produced a maximum return of USD 485.03/ha. These findings underscore the economic viability of eco-innovative approaches when investment resources are distributed thoughtfully.

Methodologically, this work demonstrates how dynamic programming can bridge the gap between eco-innovation theory and practical investment planning. By integrating operational data, the model provides a replicable tool for farm managers and policymakers.

From a policy perspective, targeted subsidies for eco-innovative machinery and training programs to enhance farmer capacity could accelerate adoption. While calibrated for large-scale Ukrainian agriculture, the framework is adaptable to smaller farms or different regions with appropriate adjustments to performance indicators and constraints.

Future research may expand the model by incorporating environmental impact metrics (e.g., CO_2 reduction, soil health indices) and by applying sensitivity analysis to account for market and climate uncertainties.

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