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# DEVELOPING A COMPOSITE ECONOMIC EFFICIENCY INDEX FOR UKRAINE'S AGRICULTURAL POST-WAR TRANSFORMATION: RECYCLING, BIOENERGY, AND EXPORT-IMPORT REGULATORY MECHANISMS

*The object of this research is Ukraine's agricultural sector undergoing structural transformation towards sustainable development. The analysis focuses on three interconnected dimensions of this transformation: agricultural recycling, bioenergy development, and regulatory mechanisms supporting sustainable change, including export-import governance. The research addresses the lack of integrated quantitative tools capable of assessing the effectiveness of agricultural transformation across these dimensions under wartime conditions and within the context of Ukraine's European integration agenda. Since February 2022, the Ukrainian agricultural sector has faced unprecedented challenges resulting from military aggression. Total losses have been estimated at 80.1 billion USD, the area of cultivated land has decreased by approximately 1.9 million hectares, and traditional maritime export routes have become vulnerable to external disruptions. Drawing on verified data from the World Bank, the United States Department of Agriculture (USDA), the Food and Agriculture Organization (FAO), and the European Parliamentary Research Service, a Composite Economic Efficiency Index (EEI) was developed to evaluate the sector's transformation. The index combines four dimensions: the Trade Efficiency Index (TEI,  $w = 0.30$ ), the Bioenergy Efficiency Index (BEI,  $w = 0.25$ ), the Recycling Efficiency Index (REI,  $w = 0.25$ ), and the Green Economy Index (GEI,  $w = 0.20$ ). The EEI declined from 0.447 in 2021 to its lowest value of 0.337 in 2022, reflecting the immediate impact of the war. Subsequently, the indicator recovered and reached 0.468 in 2024. However, this recovery has been uneven across the analyzed dimensions. While the TEI increased to 0.96, the BEI (0.090) and REI (0.250) remained substantially below their projected 2030 benchmark levels. These findings suggest that the restoration of export volumes through the Grain Corridor should not be interpreted as evidence of deep structural transformation. Without targeted investments in biomethane production, recycling infrastructure, and circular economy initiatives, the sector largely continues to follow its pre-war commodity-export model. Under conditions of a legally secured multilateral framework for the Grain Corridor and consistent government support for scaling bioenergy production, the EEI could increase to approximately 0.55 by 2030. The proposed approach and obtained results may support strategic planning for the post-war recovery of Ukraine's agricultural sector and provide analytical input for negotiations related to the agricultural chapter of the country's accession process to the European Union.*

**Keywords:** agricultural sector transformation, bioenergy, circular economy, recycling, export-import regulation, sustainable development, biomethane.

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## 1. Introduction

Ukraine's agricultural sector has long been one of the key pillars of both the national economy and the global food system. Before February 2022, it accounted for about 10.9% of GDP, provided jobs for roughly 2.5 million people (around 14% of total employment), and generated 41% of all exports – about 27.8 billion USD out of a 68 billion USD total [1]. Ukraine was also a global leader in sunflower products, supplying around 40% of the world's sunflower meal and 35% of its sunflower oil, and ranked sixth among wheat exporters in the 2022/2023 marketing

year [2]. At the same time, this success was built largely on exporting raw agricultural commodities with limited value added. That structure was both strength and weakness: it made Ukraine highly competitive on global markets, but also left the sector exposed when maritime export routes were disrupted under military pressure. The full-scale Russian invasion in February 2022 exposed the sector to a combination of shocks on a scale it had never faced before. By the end of 2023, total damages and losses in agriculture were estimated at 80.1 billion USD. Most of this – about 87% (69.8 billion USD) – came from lost production, while direct physical destruction accounted for 10.3 billion USD [3].

The area of cultivated land shrank by roughly 1.9 million hectares, and 2,653 agricultural enterprises reported confirmed losses [4]. The destruction of the Kakhovka dam in June 2023 alone took about 0.58 million hectares out of irrigated farming [1]. Bringing the sector back will require major investment – around 56.1 billion USD for reconstruction and another 32 billion USD just for demining agricultural land [1]. Taken together, these figures show that this is not just a temporary crisis, but a deeper structural challenge that calls for a different approach to recovery.

Three transformation imperatives define this paradigm. First, Ukraine's EU accession negotiations (opened formally in December 2023) impose binding environmental, food safety, and circular economy requirements that the existing linear commodity-export model cannot meet. Second, the wartime energy crisis has dramatically elevated the economic case for domestic bioenergy: Ukraine's biomethane potential alone is estimated at 1 billion m<sup>3</sup>/year by 2030 [5]. Third, the disruption of traditional maritime export channels has exposed the fragility of existing trade regulatory arrangements and created the opportunity to design more resilient institutional mechanisms. Existing scholarship addresses each vector separately. Researchers [5] document Ukraine's bioenergy sector under conflict conditions but give insufficient attention to economic efficiency dimensions. Scientists [6, 7] analyze circular economy barriers but do not integrate trade regulatory analysis. FAO [8] and USDA [2, 9] cover trade disruption without addressing the bioenergy and recycling dimensions. This gap motivates the present research.

The regulatory dimension of this tripartite transformation has received limited attention in the literature. Most researches of Ukraine's wartime export channels focus mainly on logistics and food security issues. These channels include the Black Sea Grain Initiative (BSGI, July 2022 – July 2023), the EU Solidarity Lanes, and the post-BSGI Ukrainian Grain Corridor. Much less attention has been paid to the institutional design and economic efficiency of their regulatory frameworks. Researchers [10] provide one of the most systematic assessments of the BSGI as a crisis-management mechanism. Using trend analysis, they show that grain exports to low-income countries remained structurally insufficient throughout the initiative's operation. According to the authors, this problem was caused not by throughput limitations, but by the absence of binding distribution obligations within the regulatory framework. Scientists [11] examine the legal dimension of the BSGI in detail. Their research discusses the deliberate avoidance of the laws of armed conflict and the use of the initiative as a lawfare instrument. The authors demonstrate that the initiative's ambiguous legal status contributed to procedural disruptions, including vessel inspection delays and unilateral withdrawal. These factors ultimately led to the termination of the initiative.

Both researches point to the same key takeaway: temporary or improvised export solutions are not the same as stable institutions. Without a clear multilateral legal framework, backed by binding commitments from all sides, export flows remain vulnerable. This challenge becomes even more complex in the context of EU accession. In [12] estimates that fully aligning Ukraine's agricultural sector with EU rules would raise costs by about 5% for grain producers and 10% for livestock farms. At the same time, it would create demand for roughly 10.4 billion euros a year in support from the EU's agricultural budget – implying a long-term institutional shift that could take a decade.

Research [13] adds another layer and shows that improving efficiency – especially when environmental factors are taken into account – could help offset some of these costs. But that only works if the institutional environment is stable, which is exactly what remains uncertain during and after the war.

Taken together, these researches suggest that the main constraint on Ukraine's agricultural transformation is not just resources or technology, but the regulatory system itself – both in how exports are managed and how production standards are set. This is why the present research treats regulatory effectiveness as just as important as bioenergy and recycling.

In this research, regulation is seen as a broader institutional framework that supports agricultural change in several related areas. Regulatory mechanisms are looked at not only in terms of export-import governance but also through policy tools that promote recycling activities, support the circular economy, and encourage the development of bioenergy. This view shows how interconnected agricultural transformation is and ensures it aligns with the structure of the Composite Economic Efficiency Index proposed in this research.

*The object of research* is Ukraine's agricultural sector in the context of its structural transformation toward sustainability, covering three interrelated sub-systems: agricultural recycling, bioenergy development, and the regulatory mechanisms supporting sustainable agricultural transformation, including export-import governance.

*The aim of research* is to develop a Composite Economic Efficiency Index (EEI) for evaluating the transformation of Ukraine's agricultural sector and identifying policy priorities for the post-war recovery period of 2025–2032.

To achieve this aim, the following research objectives were defined:

- to analyze the transformation of Ukraine's agricultural sector under wartime conditions;
- to assess the development potential of recycling and bioenergy in the agricultural sector;
- to propose the structure of the Composite Economic Efficiency Index (EEI) incorporating export-import activities, recycling, bioenergy development, and post-war recovery priorities.

## 2. Materials and Methods

The research uses a mix of methods, combining statistical and comparative analysis with the construction of a composite index and a breakdown of efficiency across different sub-sectors. It covers the period from 2019 to 2024, which makes it possible to track three distinct stages: the pre-war baseline (2019–2021), the peak disruption in 2022, and the period of adjustment and partial recovery in 2023–2024. The trade efficiency benchmark is based on the 2020–2021 period, when export volumes reached record levels before the war. This provides a clear and relatively conservative reference point for assessing recovery.

The analysis relies on verified data from major institutional and academic sources [1, 5, 3], which have been reviewed in full. Additional information on export volumes and war-related losses was collected from several institutional sources. The main sources include the USDA Economic Research Service [2], the USDA Foreign Agricultural Service [9], the FAO information note published in July 2023 [8], and the 2025 CSIS report [14]. Indicators related to the circular economy are based on the work [6, 7, 15]. The regulatory aspects of the analyzed indicators go beyond just managing exports and imports. They also cover environmental regulations, requirements for a circular economy, support measures for renewable energy, and systems that promote the development of biomethane and bioenergy. As a result, agricultural transformation is assessed within a connected regulatory framework that includes trade, environmental, and energy policy tools.

## 3. Results and Discussion

### 3.1. Changes in Ukraine's agricultural sector during the war

Until 2022, Ukrainian agriculture was built largely around export activity and maritime trade routes. This approach worked effectively under stable conditions and ensured strong export revenues, but at the same time it created a high dependence on external logistics channels. After the start of the full-scale invasion, these weaknesses became much more visible. Agricultural production, transportation, cultivated land, and export operations were all affected simultaneously. The dynamics of agricultural exports and the Trade Efficiency Index (TEI) for 2019–2024 are presented in Table 1 and Fig. 1.

Table 1

Agricultural export dynamics and Trade Efficiency Index (TEI), Ukraine 2019–2024

Year	Grain exports (mmt)	Total agri. Exports (USD bn)	Share in total exports (%)	TEI (base 2020/2021 = 1.00)
2019	57.5	22.2	39.6	0.91
2020	63.1	22.5	45.0	1.00
2021	63.0	27.8	41.0	1.00
2022	34.6	18.7	38.2	0.67
2023	43.8	19.4	40.1	0.70
2024	60.3	23.1	41.2	0.96

Note: based on research [2, 9, 1, 14]

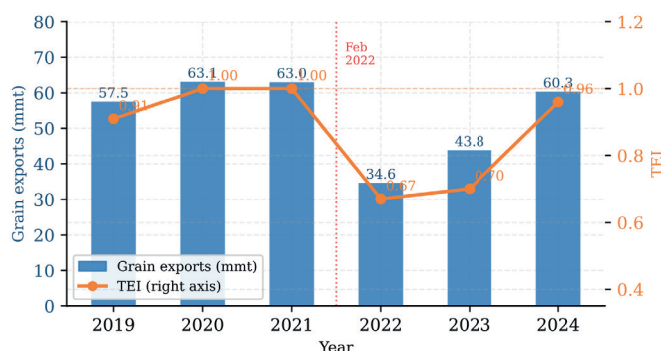


Fig. 1. Ukraine's grain export dynamics (mmt, left axis) and Trade Efficiency Index (TEI, right axis), 2019–2024. Dotted vertical line = start of full-scale invasion (based on research [2, 9, 14])

The sharpest decline can be observed in 2022. The TEI dropped from 1.00 in 2021 to 0.67. Several factors contributed to this reduction: blocked ports, destruction of infrastructure, mined farmland, and lower cultivated areas. By 2024, export activity had partly recovered, although the sector still remained highly dependent on wartime conditions and external risks. A considerable number of previous publications concentrated mainly on food security and export volumes [1, 2].

In this paper, greater attention is given to structural economic changes inside the agricultural sector itself. Such an approach makes it possible to evaluate not only export recovery, but also broader transformation processes taking place during the war period. The analysis should nevertheless be interpreted with caution. Statistical information for 2022–2024 is incomplete in several areas because the war disrupted regular data collection by the State Statistics Service of Ukraine. Additional researches may later provide a more detailed picture of regional recovery patterns and long-term economic losses.

### 3.2. Recycling and bioenergy development potential

Ukraine possesses significant technical potential in the fields of bioenergy and circular economy development. However, current implementation levels remain noticeably lower than the available capacity. Table 2 and Fig. 2 compare current bioenergy production with the projected technical potential for different categories.

The situation differs substantially across sectors. Solid biomass technologies are already relatively developed, while biomethane production is still limited despite its strategic importance for both Ukraine and the European energy market. The Recycling Efficiency Index (REI) also demonstrates that progress toward a circular economy model remains uneven. Wartime uncertainty reduced investment activity and slowed infrastructure development.

Table 2

Bioenergy potential by category, Ukraine (2024 vs. 2030 target)

Category	Share in current mix (%)	Current prod. (th. toe/yr)	Potential 2030 (th. toe/yr)	BEI (current/2030)
Solid biomass (straw, wood, energy crops)	70	3850	5200	0.740
Biogas (manure, residues, silage)	15	825	4200	0.196
Biomethane (upgraded biogas)	0.3	3	1000	0.003
Liquid biofuels (biodiesel, bioethanol)	15	825	1800	0.458
TOTAL	100	5503	12200	0.451

Note: compiled by authors based on research [5]; World Bioenergy Association (2023); European Biogas Association (2023). BEI = current production/2030 technical potential

At the same time, the combination of recycling systems with bioenergy technologies may create additional economic and environmental advantages, including lower waste volumes and stronger energy security. These directions have been examined separately in most cases [5–7]. The present analysis combines them within one economic efficiency framework, allowing the interaction between recycling and bioenergy processes to be assessed more comprehensively. Certain limitations also remain here. Environmental statistics during wartime are restricted, and some indicators are still unavailable. Further work in this area could focus on biomethane export scenarios, regional modelling, and investment mechanisms connected with post-war reconstruction.

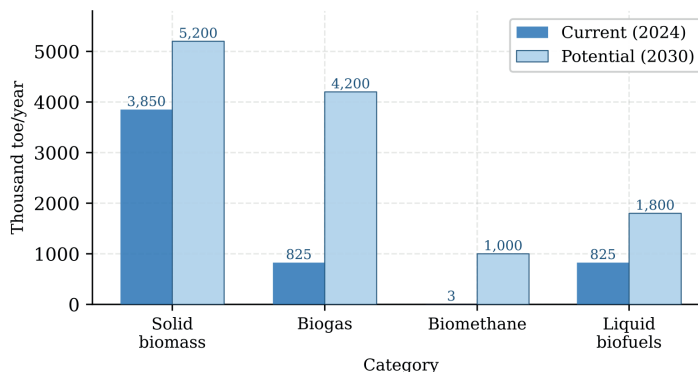


Fig. 2. Ukraine's bioenergy: current production versus 2030 technical potential by category, thousand toe/year (compiled by authors based on research [5])

### 3.3. Structure of the composite economic efficiency index (EEI)

The EEI is calculated as a weighted combination of four components:

$$EEI = w^1 \cdot TEI + w^2 \cdot BEI + w^3 \cdot REI + w^4 \cdot GEI, \tag{1}$$

$$EEI = 0.30 \cdot TEI + 0.25 \cdot BEI + 0.25 \cdot REI + 0.20 \cdot GEI.$$

Each of these indices reflects a different aspect of how the agricultural sector is functioning and adapting. The TEI (Trade Efficiency Index, weight 0.30) measures current export volumes against the pre-war benchmark of 2020–2021. The BEI (Bioenergy Efficiency Index, 0.25) compares actual bioenergy production to the technical potential projected for 2030, based on research [5]. The REI (Recycling Efficiency Index, 0.25) looks at how much agricultural waste is being processed through circular economy practices relative to the total waste generated. The GEI (Green Economy Integration Index, 0.20) combines several

factors: greenhouse gas emission intensity compared to 2019, the share of renewable energy used in agriculture, and how closely the sector aligns with EU circular economy standards. The weighting reflects how much each of these dimensions contributes to agricultural GDP and follows the general approach used in Organization for Economic Co-operation and Development compo site indicator methodology [16]. For 2022–2024, the *REI* and *GEI* values are based on the authors' own estimates, since the war disrupted the regular publication of environmental data by the State Statistics Service.

The dynamics of the *EEI* and its individual components for 2019–2024 are shown in Table 3 and Fig. 3. The results illustrate a substantial decline in 2022.

Table 3

Composite economic efficiency index (*EEI*), Ukraine, 2019–2024

Year	<i>TEI</i> ( $w = 0.30$ )	<i>BEI</i> ( $w = 0.25$ )	<i>REI</i> ( $w = 0.25$ )	<i>GEI</i> ( $w = 0.20$ )	<i>EEI</i>	Trend
2019	0.910	0.072	0.310	0.280	0.407	–
2020	1.000	0.074	0.320	0.295	0.441	↑
2021	1.000	0.076	0.330	0.310	0.447	↑
2022	0.670	0.065	0.190	0.275	0.337	↓
2023	0.700	0.078	0.215	0.285	0.356	↑
2024	0.960	0.090	0.250	0.300	0.468	↑

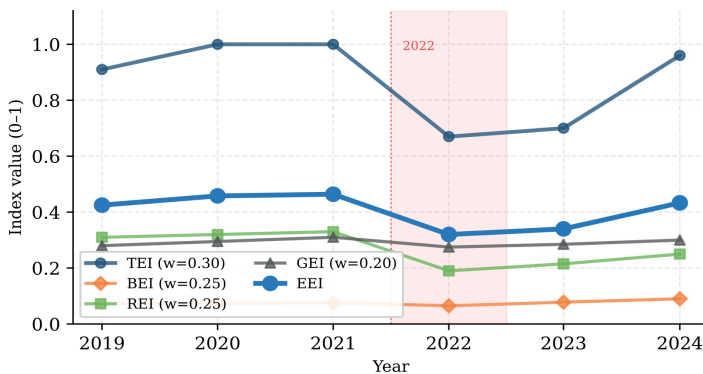


Fig. 3. *EEI* and sub-index dynamics, Ukraine 2019–2024 (formula (1)). Bold line = *EEI* composite; shaded band = peak disruption 2022 (authors' calculations)

### 3.4. Discussion

From 2021 to 2022, the *EEI* has dropped significantly from 0.447 to 0.337. By 2024, however, it has partially recovered to 0.468, which indicates a gradual recovery in agriculture. Nonetheless, this recovery was uneven since trade indicators were restored faster compared to recycling and bioenergy development. This paper highlights wartime export mechanisms that helped maintain Ukrainian agricultural exports during the full-scale invasion, including the Black Sea Grain Initiative (BSGI), the EU Solidarity Lanes, and subsequently the Ukrainian Grain Corridor. It has been revealed that export recovery not only requires the availability of transport infrastructure but also a proper institutional setting and reliable legal guarantees that could function in crisis conditions. Most previous papers have mainly focused on disruptions to logistics and supply chains [8, 10]. This paper uses a different approach to investigate the interrelation between trade regulations, environmental transformations, and energy transition in the context of agricultural exports. The findings show that post-war agricultural recovery relies on export-import regulation and the effectiveness of institutional systems that support recycling and bioenergy development. Specifically, expanding recycling infrastructure, putting circular economy practices into action, and encouraging biomethane production need dedicated regulatory tools. Thus, sustainable trans-

formation should be seen as the result of coordinated actions in trade, environmental, and energy sectors. According to the proposed recovery framework, there are three stages: stabilization (2025–2026), transformation (2026–2029), and integration (2029–2032). To achieve the goals outlined above, bioenergy production, recycling, and export-regulation institutions need to be developed. At the same time, the pace of recovery will remain dependent on geopolitical and macro-economic factors. An important point of the proposed framework is that it is not possible to judge regulatory effectiveness only by how export institutions perform. The long-term strength of the agricultural sector will also rely on how well public policy promotes investments in recycling infrastructure, backs the commercialization of biomethane technologies, and assists farms in adopting circular economy practices. In this context, trade regulation, bioenergy policy, and environmental governance should be viewed as interconnected rather than as separate policy areas.

Given the above, further researches should be dedicated to regional adaptation measures, investment efficiency, and long-term compatibility of the Ukrainian agricultural model with the objectives of the EU Green Deal. As has been shown above, Ukraine's export-oriented agricultural model creates both opportunities and risks. Dependence on raw commodities creates vulnerabilities regarding possible interruptions in maritime transportation; on the other hand, these difficulties can highlight the advantages of investing in recycling and bioenergy, which can provide considerable efficiency even with small investments.

This approach can be used for developing post-war recovery strategies, investment planning, and agricultural policies aimed at European integration. Also, it can be utilized as an analytical tool for defining regional priorities in agricultural modernization. The conversion of agricultural residues into biomethane through anaerobic digestion can help solve several challenges at the same time. It reduces dependence on energy imports, lowers fertilizer costs – which reached record levels in 2022 [8] – and supports soil quality by returning digestate to fields as organic fertilizer. The sharp decline in 2022 resulted from several interconnected factors. Large-scale disruptions affected farm operations across the country, with 2,653 agricultural enterprises reporting losses [4]. At the same time, many producers redirected financial resources away from long-term recycling investments toward immediate operational needs. Environmental regulations were also temporarily suspended under martial law.

**Practical Significance:** The research results can be used in the practical planning of Ukraine's post-war agricultural recovery. The proposed Composite Economic Efficiency Index (*EEI*) may serve as a tool for assessing structural changes in the agricultural sector and evaluating the effectiveness of policies related to bioenergy, recycling, and export regulation. The findings may also support decision-making in the preparation of recovery programs, investment strategies, and measures connected with Ukraine's integration into EU environmental and trade policies. In addition, the proposed approach may help identify priority areas for regional agricultural development. The proposed framework may also help policymakers coordinate trade, environmental, and energy regulations within a united agricultural transformation strategy.

**Research Limitations:** This research has been faced with several important limitations. Ongoing wartime conditions disrupted official statistical reporting during 2022–2024, which made it necessary to estimate certain environmental indicators using composite methods where direct statistical data were unavailable. In addition, geopolitical instability continues to influence logistics systems, investment activity, and export regulation mechanisms, which may affect the accuracy of the results. Future research would benefit from access to more detailed regional environmental statistics, allowing for a more precise application of the *EEI* methodology.

*Future Research Directions:* Further researches could adapt the Composite Economic Efficiency Index (*EEI*) for regional analysis and expand the range of sustainability indicators included in the model. Perspective directions also include evaluating biomethane export potential, assessing the economic efficiency of circular economy infrastructure, and examining the long-term alignment of Ukraine's agro-industrial sector with EU agricultural policy requirements. Additional attention should also be paid to the social dimension of transformation, including rural employment, regional economic resilience, and environmental sustainability during post-war reconstruction.

#### 4. Conclusions

1. This research examined the transformation of Ukraine's agricultural sector under wartime conditions. Due to seaport blockades, damaged infrastructure, mined agricultural land, and disruptions in logistics systems, the Trade Efficiency Index (*TEI*) decreased from 1.00 in 2021 to 0.67 in 2022. A similar trend was observed for the Composite Economic Efficiency Index (*EEI*), which declined by 24.6% over the same period, falling from 0.447 to 0.337. By 2024, the indicator had partially recovered to 0.468, indicating gradual stabilization within the sector. However, this recovery remains uneven. The *TEI* reached 0.96, while the *BEI* (0.090) and *REI* (0.250) still remain well below their potential levels. These findings suggest that restoring export volumes alone does not mean the agricultural sector has completed structural transformation. Without targeted investment in bioenergy and circular economy infrastructure, the sector continues to follow its pre-war pattern of commodity dependence.

2. The research evaluated the development potential of recycling and bioenergy in Ukraine's agricultural sector. The findings confirm that Ukraine has considerable technical potential for biomethane production, estimated at up to 1 billion m<sup>3</sup>/year by 2030, compared to projected EU demand of 35 billion m<sup>3</sup>/year. At the same time, the current level of implementation remains limited, which is reflected in the biomethane *BEI* value of 0.003 in 2024. The results also show that increasing biomethane production from 3 to 66 million m<sup>3</sup>/year could simultaneously reduce dependence on energy imports, lower fertilizer costs, improve soil organic matter, and create additional carbon credit revenues. An important advantage of this approach is that biomethane production can operate using existing gas infrastructure. The findings also indicate that expanding recycling and bioenergy infrastructure may support the transition toward a circular economy model and strengthen the long-term sustainability of the agricultural sector.

3. The research proposed the structure of the Composite Economic Efficiency Index (*EEI*) as an integrated quantitative framework for assessing the efficiency of agricultural transformation. The index comprises four components: Trade Efficiency Index (*TEI*,  $w = 0.30$ ), the Bioenergy Efficiency Index (*BEI*,  $w = 0.25$ ), the Recycling Efficiency Index (*REI*,  $w = 0.25$ ), and the Green Economy Integration Index (*GEI*,  $w = 0.20$ ). The proposed weighting reflects each dimension's contribution to agricultural GDP and is consistent with OECD composite indicator methodology. This structure enables simultaneous assessment of three regulatory dimensions – export-import governance, bioenergy development, and circular economy integration – which must be coordinated rather than managed in isolation for sustainable agricultural transformation to occur.

#### Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

#### Financing

The research was conducted without financial support.

#### Data availability

Quantitative calculations are provided as supplementary electronic material in the accompanying file *Agro\_Transformation\_Calculations.xlsx*. Data will be provided upon reasonable request.

#### Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in the creation of the presented work.

#### Authors' contributions

**Yehor Zhuk:** Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review and editing, Supervision; **Roman Rymar:** Investigation, Formal analysis, Data curation, Writing – original draft; **Rostyslav Melnychuk:** Investigation, Data curation, Formal analysis, Writing – original draft.

#### References

1. Ukrainian agriculture: From Russian invasion to EU integration (PE 760.432) (2024). *European Parliamentary Research Service*. Available at: [https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/760432/EPRS\\_BRI\(2024\)760432\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/760432/EPRS_BRI(2024)760432_EN.pdf)
2. Husby, M., Swearingen, B., Miller, M., Hansen, J. (2024). *Ukraine's rise in grain and sunflower seed market share limited by ongoing war*. Amber Waves. U.S. Department of Agriculture, Economic Research Service. Available at: <https://www.ers.usda.gov/amber-waves/2024/may/ukraine-s-rise-in-grain-and-sunflower-seed-market-share-limited-by-ongoing-war>
3. Zorya, S., Muliar, O., Nivievskiy, O. (2024). Priorities for agricultural support in Ukraine. *World Bank*. Available at: <https://documents1.worldbank.org/curated/en/099062524074615884/pdf/P1801981319afe091b8b71b-33b7a901d4e.pdf>
4. Pavelko, O., Lazaryshyna, I., Los, Z., Vasylieva, V., Kvasnii, L. (2024). The activities and development prospects analysis of the agricultural sector of Ukraine. *BIO Web of Conferences*, 114, 1031. <https://doi.org/10.1051/bioconf/202411401031>
5. Pimenow, S., Pimenowa, O., Moldavan, L., Udova, L., Wasilewski, M., Wasilewska, N. (2025). Transforming Agriculture into Energy: Unlocking Ukraine's Bioenergy Potential for Sustainable Post-Conflict Recovery. *Energies*, 18 (5), 1212. <https://doi.org/10.3390/en18051212>
6. Shvedun, V., Bulba, V., Bozhko, L., Kucher, L., Kholodok, V., Ihnatiev, O. (2023). Circular Economy in Ukraine on the Way to European Integration: Directions for Sustainable Management during the War and Post-War Recovery. *Journal of Environmental Management and Tourism*, 14 (1), 194. [https://doi.org/10.14505/jemt.v14.1\(65\).19](https://doi.org/10.14505/jemt.v14.1(65).19)
7. Shebanin, V., Shebanina, O., Kormyshkin, I., Drobotko, A., Potryvaieva, N. (2024). Circular economy of the agricultural sector: Strategies and challenges in the context of globalisation. *Scientific Horizons*, 27 (9), 148–161. <https://doi.org/10.48077/scihor9.2024.148>
8. The importance of Ukraine and the Russian Federation for global agricultural markets and the risks associated with the war in Ukraine (2023). *Food and Agriculture Organization of the United Nations*. Available at: <https://openknowledge.fao.org/server/api/core/bitstreams/4fce6098-a3ba-4742-b8f4-685454a5d409/content>
9. Grain and feed quarterly (GAIN Report No. UP2024-0022) (2024). *U.S. Department of Agriculture, Foreign Agricultural Service*. Available at: [https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Grain+and+Feed+Quarterly\\_Kyiv\\_Ukraine\\_UP2024-0022](https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Grain+and+Feed+Quarterly_Kyiv_Ukraine_UP2024-0022)
10. Ekleme, G., Yercan, F. (2025). Assessment of the Black Sea Grain Initiative: Crisis Management via Maritime Transportation. *Transport Policy*, 163, 199–218. <https://doi.org/10.1016/j.tranpol.2024.12.011>
11. Kormych, B., Averochkina, T., Kormych, L. (2024). Black Sea, grain, and two humanitarian corridors: unblocking Ukrainian shipping amid the Russian invasion. *Small Wars & Insurgencies*, 35 (8), 1360–1396. <https://doi.org/10.1080/09592318.2024.2384679>
12. Nivievskiy, O. (2024). EU integration of Ukraine – Assessing the challenges for agri-food public authorities. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4957056>

13. Halysia, O., Vracholi, M., Nivievskiy, O., Sauer, J. (2024). Assessing the Environmental Performance of Agricultural Production Using a Parametric Approach: An Application for Crop Producers in Ukraine. *Eastern European Economics*, 63 (4), 684–706. <https://doi.org/10.1080/00128775.2024.2368042>
14. Broyaka, A., Dankevych, V., Dodd, E., Welsh, C. (2025). *Blueprint for an agricultural recovery plan for Ukraine*. Center for Strategic and International Studies. Available at: [https://csis-website-prod.s3.amazonaws.com/s3fs-public/2025-06/250604\\_Broyaka\\_Blueprint\\_Recovery.pdf](https://csis-website-prod.s3.amazonaws.com/s3fs-public/2025-06/250604_Broyaka_Blueprint_Recovery.pdf)
15. Zavadskykh, H., Safonik, N., Moroz, E., Alekseieva, K., Honcharenko, I. (2025). Exploring the Potential of Circular Economy in Ukrainian Enterprises. *Grassroots Journal of Natural Resources*, 8 (1), 318–336. <https://doi.org/10.33002/nr2581.6853.080112>
16. *Agricultural policy monitoring and evaluation 2022: Reforming agricultural policies for climate change mitigation* (2022). OECD Publishing. <https://doi.org/10.1787/7f4542bf-en>

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