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A Comparative View of Agri-Environmental Indicators and Stakeholders' Assessment of Their Quality

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Abstract: The degree to which economic goals have been prioritized over environmental and social objectives has caused dissatisfaction with conventional agricultural practices and stimulated the adoption of sustainable farming methods. One way to consider the multidimensionality of sustainable agriculture is to refer to indicators, more precisely, to agri-environmental indicators (AEIs). This study provides a comparative overview of the 28 AEIs of the European Union (EU) and those of the OECD and FAO, additionally revealing how these 28 indicators are reflected in the literature regarding agri-environmental indicators. Furthermore, since much of human behavior is influenced by perceptions, it was critical to reveal the stakeholders' assessment of the 28 AEIs based on four criteria ("Availability", "Relevance", "Target-oriented", and "Operational simplicity"). The stakeholders' opinions of the 28 AEIs were assessed using the evaluation matrix. The highest overall evaluation considering the four criteria was received by "Irrigation" and "Soil quality indicators". The study concludes that tripartite cooperation between stakeholders—farmers, agri-environmental researchers, and policymakers—is needed to successfully implement the AEIs of the EU.

Keywords: indicators; EUROSTAT; FAO; OECD; farmers; perceptions; agricultural system; sustainability

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1. Introduction

Sustainability in agricultural systems is one of the main references for international and national development goals aiming to advance more ecofriendly technologies and practices that can significantly contribute to food security [1], preservation of cultural services, local knowledge, alleviation of poverty [2,3], or mitigation of climate change [4,5]. The impact of human activity is profound and has become the dominant cause of environmental change [6]. As a result, scientists consider that Earth has entered the Anthropocene, a new human-dominated geological epoch [7]. To deal with these challenges and react to opportunities, the socio-agroecological transition [8,9] will need to adopt cutting-edge methods and technologies to use biodiversity, integrate agriculture in the landscape, and control biogeochemical substances in a closed-loop system [9]. These will sustainably impact land cultivation, production, and even supply chain management [10].

Even if urbanization is advancing rapidly, agriculture still stands as the basis of human life [5], and results in pressing issues for sustainability [11]. Research has continued to reveal the challenges of conventional agriculture, particularly in land-use change that causes biodiversity loss and the intensive use of agrochemicals, thus impacting soil fertility, GHG emissions, or water scarcity. Water demand, for example, is expected to increase due to population growth, and, in particular, the use of agricultural water will intensify to satisfy the heightened food demand [12].

This gloomy reality is a consequence of the industrial model of agriculture that views farms as factories and values fields, plants, and animals as production units [13]. Meeting the needs of the human population requires tremendous resources. The scientific literature often reports that sustainable agriculture produces much less than conventional systems; however, yield differences are highly contextual, depending on system and site characteristics [14]. However, an increasing number of people, especially from Western countries, feel that conventional agriculture is not meeting their expectations. Inappropriate animal welfare practices, health concerns, and environmental degradation are the narratives against conventional agriculture. The question is: "Can current agricultural practices feed the growing population equitably, healthily, and sustainably" [15]? In this widely debated context, there was an aim of bypassing the schism between agriculture and the environment through "sustainable agriculture", which is seen as a holistic model of development where production units are organisms having many complex, interrelated sub-organisms [13].

Based on this premise, this study focused primarily on agri-environmental sustainability. Since agriculture is an essential human activity, it must be addressed by developing and implementing interventions to improve its impact. One way to consider the multidimensional nature of sustainable agriculture is to refer to indicators [16]. As agriculture is closely linked to the environment, and because sustainable agriculture is oriented toward using mainly natural goods [10,17], the focus of the present paper is on agri-environmental indicators (AEIs).

Progress in the design of AEIs has been made by initiatives across the institutional spectrum, and many national AEIs are linked to agri-environmental sustainability frameworks adopted by governments at the highest level. One of the prominent criticisms is that these indicators have low capability to effectively counterbalance environmental destruction and unsustainable development, which threaten the well-being of all humanity. Furthermore, there is little research on the improvement of AEIs, and further development of sets of indicators, or even indicator-based research methods, is required to meet the sustainability targets of the agricultural system. Another gap often mentioned in the sustainability indicators literature is that the scientific information conveyed by the indicators is insufficient to produce a change in national decision making or individual behavior [18]. Therefore, effective AEIs must balance the practical needs of stakeholders with a theoretically sound understanding of agri-environmental sustainability. Consequently, the investigation of stakeholders' perceptions of AEIs is vital.

Regardless of the precision of the AEIs, which is a subject of debate, they remain a state-of-the-art instrument in assessing the sustainability of farming systems, providing valuable information and even datasets when two or more indicators are combined. Indicators help incorporate agri-environmental knowledge into decision making and help measure the progress toward sustainable development goals [19]. Practically, it is hard to manage what is not measured, and AEIs more efficiently address the nexus between agriculture and the environment [20]. Thus, AEIs are valued as the main ingredient in achieving future sustainable agriculture [20].

Despite the rich literature on the agri-environmental component of agricultural sustainability [21–24], a comparative view of the EU, OECD, and FAO indicators is not currently available. Therefore, the first objective of the present study was to mirror the 28 AEIs of the EU with those of the OECD and FAO, additionally revealing how these 28 indicators are reflected in the literature regarding agri-environmental indicators. Consequently, we performed a literature review on AEIs dedicated to measure sustainability in agriculture. The socio-economic dimensions of sustainable agriculture are beyond the scope of this paper, but the authors acknowledge their relevance in tracking the progress toward a sustainable agricultural system.

The second objective was to reveal stakeholders' assessment of the EU 28 AEIs, considering several sustainability criteria. At the national level, indicators in general, including AEIs, are often developed through stakeholder dialogue. This interactive process reflects stakeholders' opinions, values, and local specificity, and thus bridges the gap between practitioners and researchers seeking sustainability in this sector. The evaluation matrix was considered one of the best ways to weigh stakeholders' opinions about the 28 agri-environmental indicators, rating them based on a set of defined criteria.

The paper is organized as follows. The Introduction presents the opportunity for a scientific debate around agri-environmental indicators. The section "From sustainable agriculture to agri-environmental indicators: A conceptual framework" offers the conceptual lens that clarifies the terminology used in the present study. The Methodology focuses on how the systematic search of the AEIs literature was performed and the design of the evaluation matrix. The results are presented in Section 3, followed by a discussion of the findings. The final remarks are presented in the Conclusion.

From Sustainable Agriculture to Agri-Environmental Indicators: A Conceptual Framework

The degree to which economic goals have been emphasized over environmental and social goals has led to people's dissatisfaction with conventional agricultural practices and boosted sustainable farming methods. In response, a wide range of agricultural sustainability concepts have been developed under the terms "alternative", "regenerative", "biodynamic", "climate-smart", "organic", "low-input", "multifunctional", "integrated farm management", "free-range", or "sustainable" [25–32]. For the present study, the term "sustainable agriculture" [25] best encompassed the economic, social, and environmental aspects of the agricultural system. In light of previous research findings, we also considered that other concepts can add confusion and unnecessary complexity for farmers and other stakeholders by making differentiation harder [33].

Like the concept of "sustainable development", "sustainable agriculture" is challenging to interpret and conceptualize, thus complicating its use and implementation [34,35]. Furthermore, an absolute definition of sustainable agriculture is questionable, mainly because there are a range and number of stakeholders [36] with different values and beliefs, and many rural characteristics differ from region to region. Hence, it is important to continue exploring the meaning of agricultural sustainability as a time- and space-specific [37] work-in-progress concept. As perceptions about the definition of sustainable agricultural systems have multiplied, the scientific literature reports more than 70 definitions [10] of the sustainable agriculture concept [24,38–43].

The attempts to make sustainable agriculture operational rely on measuring and evaluating sustainability [22]. Similarly, indicator-based tools are the most commonly used methods for assessing the sustainability of a specific practice [44]. The indicator, seen as a variable, parameter, statistical value, or index [45], is utilized to portray a state or circumstances when direct measurements are not conceivable [46]. Furthermore, the indicator helps quantify and simplify information to better understand current conditions and future trends, monitor progress, and compare performance among regions [47].

A wide range of socioeconomic and environmental indicators have been developed [16,34,48–50] to measure the sustainability of agriculture. These helped farmers worldwide to make improvements in the use and management of nutrients, pesticides, energy, and water, and progress in adopting more environmentally beneficial practices, such as conservation tillage, soil nutrient testing, or manure storage [51]. Despite these improvements, there is still more to do, and sustainable agricultural practices will continue to play a significant role in protecting the environment. Thus, to fulfill the purposes of this study, sustainable agriculture was defined as agriculture that "over the long term, enhances the environmental quality and the resource base on which agriculture depends; provides for basic human food and fiber needs; is economically viable; and enhances the quality of life for farmers and society as a whole" ([52] cited by [53]). Practically, agricultural sustainability finally aims to preserve natural resources and the resilience of rural communities by promoting lucrative and community-friendly farming practices and methods [54].

The Organization for Economic Cooperation and Development (OECD) [55] was the pioneer in developing AEIs. At the European level, the European Commission Communication [56] reaffirmed the interest in developing agri-environmental indicators. In 2006, the document "Development of agri-environmental indicators for monitoring the integration of environmental concerns into the common agricultural policy" [57] served as a platform for developing the set of 28 AEIs. The Common Agricultural Policy (CAP) has identified, in turn, three main environmental goals (tackling climate change, enhancing biodiversity, and protecting natural resources), as they are reflected in the European Green Deal and the Farm-to-Fork Strategy [58]. These goals made EU agricultural practices more environmentally and climate friendly [59], and at the same time CAP aims to provide farmers with effective risk management tools and to increase the productivity of production factors [60]. The 28 AEIs are standardized reference points that practically reflect the environmental concerns of the CAP at the EU, national, and regional levels.

Fernandes and Woodhouse [61] define AEIs as "estimators of the impact of agricultural practices on the agroecosystem". Yli-Viikari et al. [62] consider the AEIs as "tools to address current development paths of agricultural production in broader terms". The AEIs can help farmers adapt their agricultural practices to be environmentally friendly [61]. At the broader regional/national level, AEIs can inform the effectiveness of agri-environmental programs and support policy decisions [63].

As many studies have acknowledged [64–66], AEIs must address the following aspects: description or explanation of the state of spatial systems and its deviation from the natural state; impact assessment of the effect of particular actions on the state of spatial systems and its deviation from the natural state; prediction of future conditions of spatial systems under various scenarios of socio-economic or environmental change; and monitoring to keep track of changes in the state of spatial systems and to support appropriate corrective actions. Nonetheless, the literature dedicated to AEIs highlights several limitations associated with their use. For example, one limitation of the AEIs is data availability and collection [67].

The focus of the present paper was on the 28 AEIs developed at the EU level (Table A1, Appendix A). The 28 AEIs were selected due to their advantages compared to other AEIs indicators. For example, AEIs (operational in the EU) have the advantage that the data for their calculation can be easily obtained, considering the applied methodology; additionally, they can provide information about agricultural pressures, as inputs of matter and energy, which can then lead to outputs expressed in terms of the environmental state and ecosystem functioning [68].

2. Materials and Methods

As stated in stated by Elliot [69], it is a challenge to maintain a systematic and up-to-date review; however, failing in this aim results in a loss of the review's accuracy and utility. Therefore, the authors of the present study performed a systematic search of the relevant literature in the main databases—SpringerLink Journals (Springer), Scopus (Elsevier), PROQUEST Central, ScienceDirect Freedom Collection (Elsevier), Wiley Journals, Web of Science–Core Collection, Emerald Management EJournals, and Reaxys. These were available through the Enformation platform. Furthermore, once a paper was identified, its citations were further searched for on Google Scholar. Following Wohlin's [70] approach, to ensure that all relevant papers were captured, a snowball search of papers that met the criteria of "backward snowballing", "forward snowballing", and "inclusion/exclusion" was performed (Figure 1).

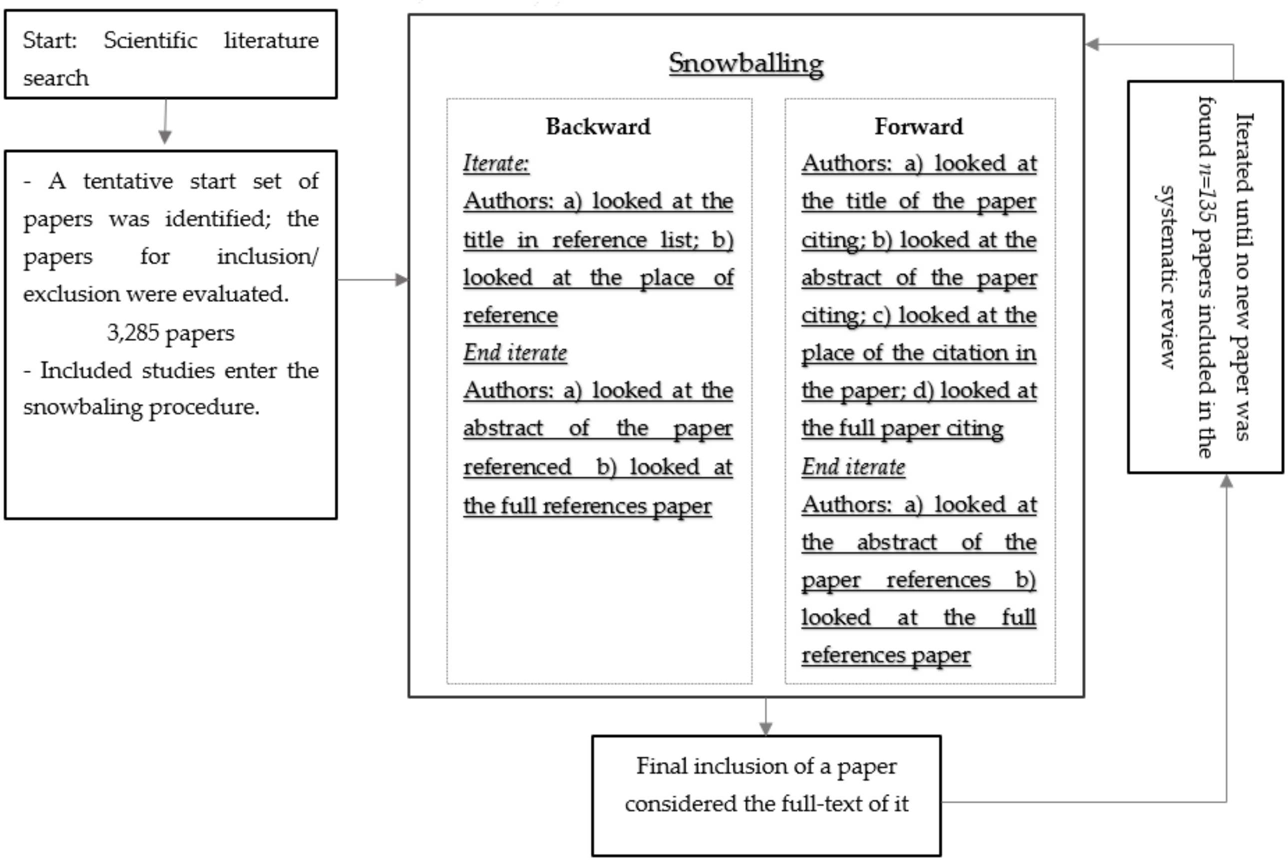

Figure 1. Snowballing procedure. Source: [adapted after [70]].

The search in the databases mentioned above was operationalized as follows: the search considered the paper's titles and abstracts containing a single or combined keyword—"sustainability indicators", "farm indicators", and "agri-environmental indicators"—and the reference period was 1992–2021. The search was restricted to papers written in English.

This initial search captured 3285 papers, of which 2029 were duplicated (the same papers), resulting in 1256 for further screening and eligibility, as shown in Figure 1. The inclusion criteria included some of the following: (i) they were original research papers with empirical data collected through questionnaires, interviews, or focus groups; (ii) the papers contained a quality assessment (of strengths and weaknesses) of agri-environmental indicators; (iii) reports elaborated for international organizations such as FAO or EUROSTAT were considered relevant; (iv) they included at least three agri-environmental indicators; and (v) they included indicators to evaluate farm sustainability.

Furthermore, studies were excluded if the agri-environmental indicators were limited to a narrow geographical area (e.g., a small country region). Once these criteria were applied, the number of papers included in the review was 97. Additionally, 38 other scientific papers were identified through the snowball sampling criteria that met the inclusion parameters. Therefore, the final number of documents retained for the systematic review was 138 (Figure 2). Most of the studies selected for the present review (68.14%) focused on Europe, followed by North America (16.3%), Asia (6.67%), the Middle East (5.19%), Africa (2.22%), and South America (1.48%).

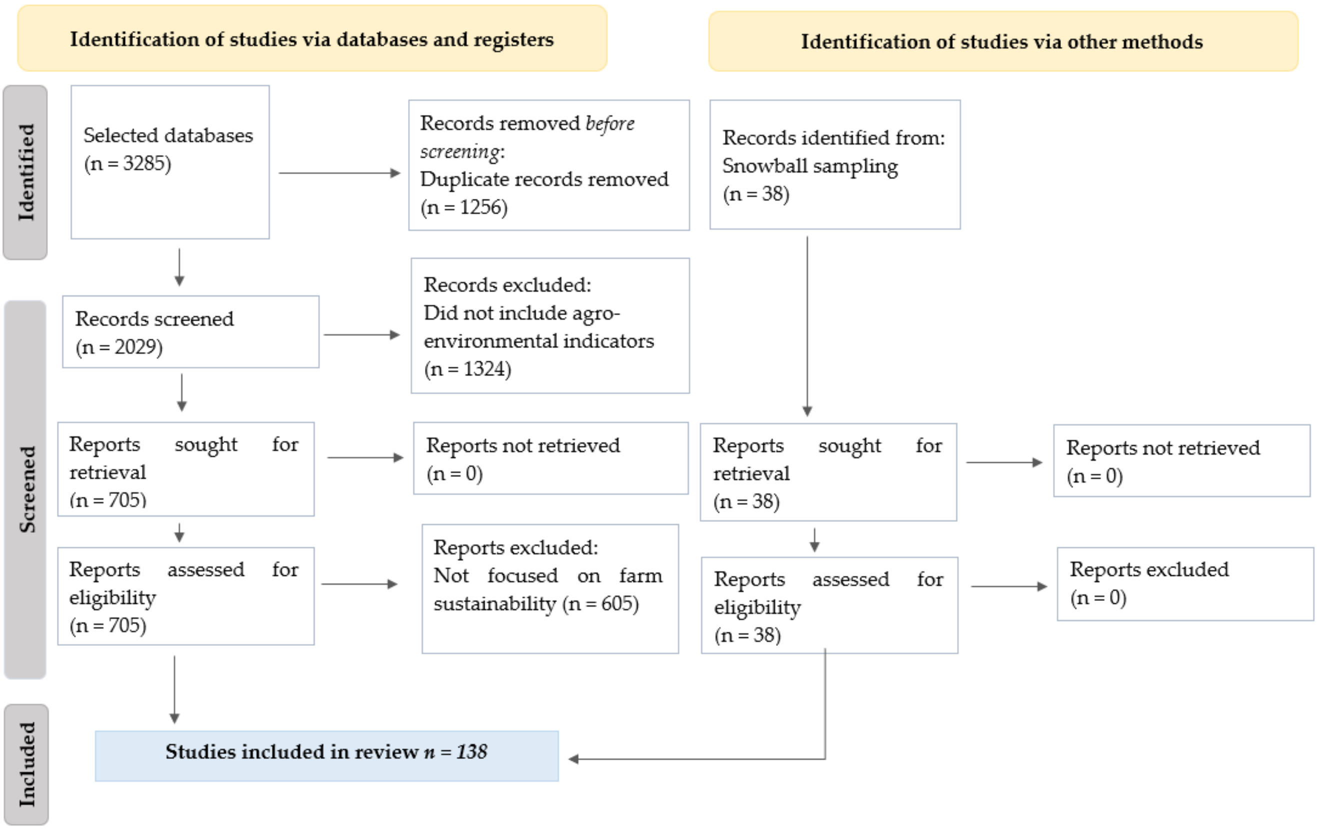

Figure 2. Flow diagram of the literature search process. Source: Authors' elaboration.

The evaluation matrix was selected for analysis to respond to the second objective because it is suitable for subjective criteria, such as those used in the present case. In this paper, criteria are those principles or standards by which agri-environmental sustainability may be judged or decided. Furthermore, the criteria used for evaluating the indicators are relevant for the reliability of sustainability assessment [71].

The 28 AEIs were evaluated through a focus group comprising 15 participants, selected from farmers (from Cluj County, Romania), policymakers (from local administration, Cluj County, Romania), and agri-environmental researchers (from the Faculty of Environmental Science and Engineering and Faculty of Agriculture, from two universities in Cluj-Napoca city, Romania), with five persons from each group. The group of participants was formed by convenience, and the participation was voluntary. The indicators are those included in Table A1. They were extracted from Eurostat [72].

In the first stage, participants had to vote on the number of criteria to be used for the assessment of the AEIs. They had to select a number from 1 to 10, and the average number resulting from their votes was four. They also had to decide whether they wanted the criteria to have equal or different weights, and the majority preferred equal weights.

In the next stage, participants received a list with all 12 core (general) criteria extracted from the review by Pires et al. [73] and an explanation of their meaning. Then, each participant had to choose four evaluation criteria, and those that obtained the highest number of votes were "Availability", "Relevance", "Target-oriented", and "Operational simplicity".

These criteria were defined as follows: "Availability" is the degree to which the data required for the indicator is easy or possible to obtain at a reasonable cost [73–75]. "Relevance" is the degree to which an indicator is related to the investigated issue [*as per* [73]]. "Target-oriented" implies having a threshold and/or target against which to compare the indicators [74]. Finally, "Operational simplicity" is the quality of being simple to manage and analyze [71].

Each indicator was evaluated on an 11-point scale (0 = the weakest performance, 10 = the highest performance) based on the four criteria mentioned above. The 11-point scale was preferred because it is a more powerful scale in discriminating compared to a scale with a lower number of points. In addition, it improves data analysis and increases the reliability of the data [76,77]. The participants received the following request: "Please evaluate on a scale of 0 to 10 the availability of the following AEIs". This request was repeated for each criterion. Many criteria are listed in the sustainable agricultural literature [71,78–80]; however, for the present study, the authors opted to refer to Pires et al.'s [73] contribution since it is a detailed synthesis of the scientific literature performed to organize the criteria in the field of sustainability.

3. Results

The present systematic review offers a clearer picture of AEIs and how they are reflected in primary strategic documents and the sustainability literature. Thus, Table 1 presents the correspondence between the EUROSTAT set of indicators and those of the OECD and FAO, along with the scientific literature where they are explained, discussed, or analyzed.

Table 1. Mirroring the EUROSTAT set of AEIs with those of the OECD and FAO, and the reviewed literature.

No.	Eurostat Indicators	OECD Indicators	FAO Indicators	Studies
1.	Agri-environmnetal commitments	Not defined	Not defined	[81–85]
2.	Agricultural areas under Natura 2000	Not defined	Proportion of habitat types	[86–89]
3.	Agricultural training of farm managers	Farmer education	Not defined	[90–94]
4.	Area under organic farming	Organic farming	Not defined	[87,94–96]
5.	Mineral fertilizer consumption	Nutrient use	Total fertilizer consumption	[97–103]
6.	Consumption of pesticides	Pesticide use	Pesticide use	[100,104–108]
7.	Irrigation	Irrigation and water management	Irrigations	[109–114]
8.	Energy Use	Energy use and biofuel production	Energy use per agricultural output	[2,115–123]
9.	Land use change	Change in agricultural land	Change in agricultural land use	[124–129]
10.1	Cropping patterns	Not defined	Cropping patterns	[102,130–133]
10.2	Livestock patterns	Not defined	Not defined	[130,134–137]
11.1	Soil cover	Soil cover	Soil health	[48,111,125,138–140]
11.2	Tillage practices	Not defined	Tillage practices	[102,131,141–143]
11.3	Manure storage	Not defined	Not defined	[144–146]
12.	Intensification/Extensification	Not defined	Not defined	[87,125,130,147,148]
13.	Specialization	Not defined	Not defined	[48,111,149–152]
14.	Risk of land abandonment	Not defined	Not defined	[48,93,111,140,153,154]
15.	Gross nitrogen balance	Nitrogen balance	Not defined	[119,142,151,155,156]
16.	Risk of pollution by phosphorus	Not defined	Not defined	[157–161]
17.	Pesticide risk	Pesticide risk	Not defined	[162–166]
18	Ammonia emissions	Not defined	Not defined	[167–171]
19	Greenhouse gas emissions	Gross agricultural greenhouse gas emissions	Emission shares	[62,65,100,103,119,172–177]
20	Water abstraction	Not defined	Proportion of renewable freshwater resources abstracted	[66,178–181]

Table 1. *Cont.*

No.	Eurostat Indicators	OECD Indicators	FAO Indicators	Studies
21.	Soil erosion	Risk of soil erosion by water/Risk of soil erosion by wind	Erosion control practices	[37,147,156,180,182,183]
22.	Genetic diversity	Genertic diversity	Not defined	[107,183–186]
23	High Nature Value farmland	Not defined	Not defined	[87,132,180,187,188]
24.	Production of renewable energy	Not defined	Not defined	[189–193]
25.	Population trends of farmland birds	Not defined	Not defined	[194–198]
26.	Soil quality	Not defined	Soil health	[107,131,156,180,199]
27.1	Water Quality- Nitrate pollution	Water quality risk indicator	Not defined	[119,200–203]
27.2	Water Quality-Pesticide pollution	Water quality risk indicator	Not defined	[67,156,204–206]
28	Landscape-state and diversity	Environmental features and land use patterns	Not defined	[207–211]

To address the second objective of the study, the authors evaluated the opinion of stakeholders about a set of indicators using several sustainability criteria. More precisely, the evaluation matrix weighed the opinions of farmers, policymakers, and agri-environmental researchers about the 28 agri-environmental indicators, rating them based on four criteria.

The highest overall evaluation considering the four criteria was received by "Irrigation" and "Soil quality", whereas the "Agri-environmental commitments" and "Risk of land abandonment" ranked the lowest (Table 1, Figure 3). "Irrigation" and "Soil quality", despite having the highest overall evaluation, received a very low evaluation from policymakers in a comparative context among stakeholders (Table 2).

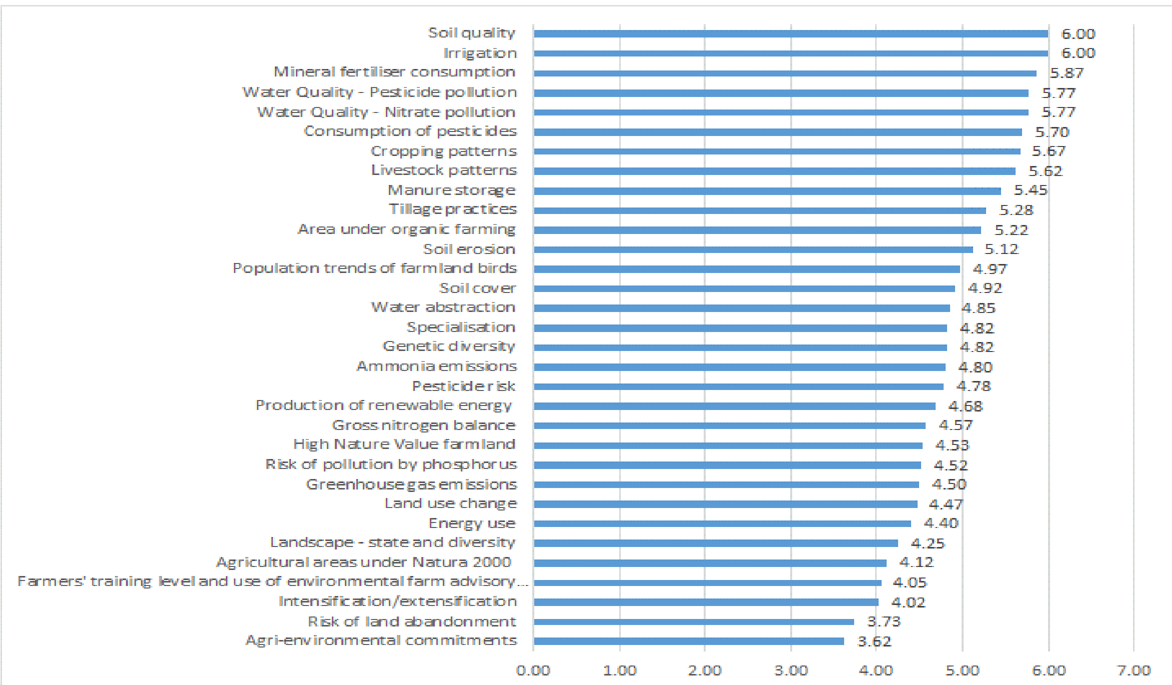

Figure 3. Indicator ranking from highest to lowest evaluation considering the average evaluation (all stakeholders and all criteria). Source: Authors' elaboration.

Table 2. The assessment of each indicator by criterion and the overall average evaluation.

Agri-Environm. Indicators	Criteria				
	Availability *	Relevance *	Target-Oriented *	Operational Simplicity *	Overall Evaluation **
Agri-environmental commitments	2.1	8.7	5.9	4.4	3.6
Agricultural areas under Natura 2000	4.3	8.0	6.6	4.3	4.1
Farmers' training level and use of environmental farm advisory services	2.8	8.5	6.5	6.7	4.1
Area under organic farming	4.8	9.3	6.4	9.2	5.2
Mineral fertiliser consumption	5.0	9.2	8.5	8.9	5.9
Consumption of pesticides	4.9	9.3	8.1	8.6	5.7
Irrigation	5.0	9.3	9.7	8.5	6.0
Energy use	3.6	8.1	5.4	6.9	4.4
Land use change	4.7	8.1	6.0	5.1	4.5
Cropping patterns	6.2	8.9	5.8	9.6	5.7
Livestock patterns	6.2	8.6	5.8	9.7	5.6
Soil cover	3.4	9.3	7.0	7.3	4.9
Tillage practices	4.1	9.3	6.9	8.7	5.3
Manure storage	4.0	8.7	7.5	9.4	5.5
Intensification/extensification	3.7	7.4	5.5	5.9	4.0
Specialisation	5.1	7.0	5.9	8.9	4.8
Risk of land abandonment	3.7	6.2	5.8	4.7	3.7
Gross nitrogen balance	5.2	8.1	6.9	5.8	4.6
Risk of pollution by phosphorus	4.7	7.8	6.8	4.3	4.5
Pesticide risk	5.2	8.3	5.7	6.8	4.8
Ammonia emissions	5.3	8.3	7.5	5.4	4.8
Greenhouse gas emissions	4.4	7.9	7.7	5.4	4.5
Water abstraction	4.6	9.1	7.2	6.2	4.9
Soil erosion	5.0	9.3	7.5	6.5	5.1
Genetic diversity	5.7	8.5	7.1	5.4	4.8
High Nature Value farmland	5.6	8.5	6.7	5.2	4.5
Production of renewable energy	5.3	7.2	6.9	7.2	4.7
Population trends of farmland birds	5.5	8.3	7.0	6.3	5.0
Soil quality	6.7	10.0	7.4	8.5	6.0
Water Quality-Nitrate pollution	6.1	10.0	8.0	7.5	5.8
Water Quality-Pesticide pollution	6.1	10.0	8.0	7.5	5.8
Landscape-state and diversity	4.8	7.7	5.8	5.5	4.3

* These scores were calculated by summing the evaluations for each indicator given by all participants considering one criterion and dividing the sum by the number of participants (15) [212]. ** This score was calculated by summing the evaluations for each indicator given by all participants for all criteria and dividing the sum by 60 (the number of participants × the number of criteria).

The evaluation of each indicator, performed by the three stakeholder groups considering all the criteria mentioned above, is represented in Table 3. It can be observed that agri-environmental researchers generally assessed each indicator with higher scores than the other two groups—farmers and policymakers. Conversely, policymakers offered significantly lower scores for each indicator than farmers and agri-environmental researchers. Farmers assigned higher scores for indicators targeting the agricultural operations and farm infrastructure (e.g., "Irrigation", rated 7.15, followed by "Manure storage", rated 6.35, and "Mineral fertilizer consumption" and "Consumption of pesticides", both rated 6.6). The differences between the stakeholders' perceptions of each indicator may be a problem. These differences are a huge challenge in creating and adopting a set of indicators at the local level, that can be agreed upon and accepted by all stakeholders to further measure local farming activities. Practically, the higher the degree of acceptability, the greater the chances of success in implementing the indicators.

Table 3. The assessment of each indicator, by stakeholder group, considering all criteria.

Agri-Environmental Indicators	Scores Assigned by Stakeholders *		
	Farmers	Policymakers	Agri-environmental Researchers
Agri-environmental commitments	2.9	1.55	6.4
Agricultural areas under Natura 2000	2.75	2.65	6.95
Farmers' training level and use of environmental farm advisory services	2.9	1.95	7.3
Area under organic farming	5.05	2.55	8.05
Mineral fertiliser consumption	6.6	2.35	8.65
Consumption of pesticides	6.6	2.25	8.25
Irrigation	7.15	2.45	8.4
Energy use	4.7	1.8	6.7
Land use change	4.1	2.45	6.85
Cropping patterns	5.85	2.55	8.6
Livestock patterns	5.65	2.55	8.65
Soil cover	5.55	1.8	7.4
Tillage practices	6.05	2	7.8
Manure storage	6.35	2.05	7.95
Intensification/extensification	3.65	1.7	6.7
Specialisation	4.4	2.4	7.65
Risk of land abandonment	3.15	1.9	6.15
Gross nitrogen balance	2.8	2.35	8.55
Risk of pollution by phosphorus	3.35	2.1	8.1
Pesticide risk	3.65	2.3	8.4
Ammonia emissions	3.25	2.45	8.7
Greenhouse gas emissions	3.35	1.8	8.35
Water abstraction	3.85	2.1	8.6
Soil erosion	4.3	2.35	8.7
Genetic diversity	3	2.5	8.95
High Nature Value farmland	2.15	2.65	8.8
Production of renewable energy	3.2	2.3	8.55
Population trends of farmland birds	3.6	2.35	8.95
Soil quality	5.8	2.7	9.5
Water Quality-Nitrate pollution	5	2.7	9.6
Water Quality-Pesticide pollution	5	2.7	9.6
Landscape-state and diversity	2.5	2.3	7.95

* These scores were calculated by summing the evaluations for each indicator given by the members of one group considering all criteria and dividing the sum by 20 (the number of participants in a group × the number of criteria).

4. Discussion

Although agricultural performance has been evaluated during the last 30 years using mainly one criterion, namely "Productivity" [156], a broader perspective is needed to better reflect the environmental concerns and human needs. The transition to sustainable agriculture implies a shift from farm-level solutions to a focus on interactions within the entire value chain, from production to consumption [213]. The demand of the European welfare society, which targets higher agricultural productivity, must meet consumers' expectations of more environmentally friendly farming products and their concerns for a balanced environment. To understand these new societal needs, researchers have looked beyond that single criterion—productivity—and turned their attention to natural resources, which, together with financial resources, labor force, and technology, are at the basis of agricultural productivity. Consequently, tools such as AEIs have been developed to successfully assess the sustainability of farming systems [214].

Although the present study may be the first review that mirrors the indicators of the most relevant international organizations in the field, it must be underlined that a fit for all sets of indicators is almost impossible due to the specificity of each geographical area. For example, the agri-environmental indicator "Agricultural areas under Natura 2000" (included by EUROSTAT) cannot be used in any other places outside the European Union since "Natura 2000" is a network of core breeding and resting sites for rare and threatened species and rare natural habitats [215] that are protected under the EU legislation. Despite this, similar indicators are present in different strategic documents. An example is the case of the "Irrigation" indicator proposed by EUROSTAT, which has its equivalent in the "Irrigation and water management" indicator from OECD and the indicator of the same name, "Irrigation", elaborated by FAO. In the case of mineral fertilizers, all three organizations have developed different approaches. EUROSTAT cites the "Mineral fertilizer consumption" indicator, OECD calls it the "Nutrient use" indicator, and the FAO proposed a "Total fertilizer consumption" indicator. Although the indicators are different and the methodology used differs between organizations, each indicator's scope and main objective is to provide state-of-the-art data within the geographical area where it is used. A clear example of the diversity of methodology and data sources used, and the assessment of indicators (how and from where to collect the raw data and analyze them), is the EUROSTAT indicator of "Consumption of pesticides". In this case, the methodology considers the sales of pesticides within the EU. On the contrary, the OECD and FAO methodology for "Pesticide use" indicators is based on data obtained from farm surveys and face-to-face interviews. At the farm scale, the culture of pesticide use can be captured by investigating knowledge, attitudes, and practices to inform intervention strategies [216]. In a study investigating the willingness of Romanian farmers to replace conventional pesticides with biochemicals and to pay a higher price for the latter, 81.7% of the interviewees considered that conventional pesticides were efficient, a perception valued as a hindering factor for the transition to bio-pesticides [217].

Overall, several commonalities of views regarding the AEIs can be drawn from the literature review. One central idea is that there is still considerable room for improvement in the indicator selection process [71,218,219]. Additionally, the lack of robust and coherent "procedures for selecting indicators makes it difficult to validate the information provided by those indicators" [220]. Other referenced studies stressed that a transparent indicator selection process would increase the scientific credibility of environmental assessment [218,221,222], underlying the need for indicators that can link ecological dimensions with environmental, social, and economic dimensions. Additionally, the AEIs literature review highlighted that AEIs are not yet universal tools for global monitoring of farm sustainability. As many referenced authors argued in the scientific literature, new indicators and indicator-based methods [e.g., DPSIR (drivers, pressures, state, impact, and response model of intervention)] should be developed to address local or regional agri-environmental particularities.

By exploring different sources for AEIs (EUROSTAT, FAO, OECD), a clearer picture of AEIs can be provided by highlighting their strengths and weaknesses. However, further research can be undertaken to obtain more in-depth information about how an agri-environmental indicator can be developed to better respond to sustainability goals of a farm system from a specific area. Based on the original indicators from EUROSTAT, OECD, and FAO, researchers around the world have tried over time to elaborate on indicators, develop new methodological approaches, or create new indicators [107] to meet the needs of local communities for sustainable agricultural systems. Therefore, mirroring the AEIs can help us understand the differences, similarities, equivalence, and development dynamics of indicators used at the global level. However, for this research, the authors considered that the review of the AEI literature is not sufficient *per se* to make a conclusive statement about the relevance of these indicators. Therefore, another variable had to be added to this equation: the investigation of those involved in the elaboration and implementation of these indicators. Consequently, it was assumed that since much of human behavior is influenced by perceptions [223,224], the next step was to reveal the stakeholders' assessment of a set of indicators based on several sustainability criteria. In the same direction, and in line with the assumption of Gómez-Limón and Sanchez-Fernandez [48] that sustainability is also a "social construction" that considers society's preferences for assigning different importance to each indicator, an evaluation matrix was constructed.

Figure 3 shows that the key stakeholders (farmers, policymakers, and researchers) set the highest scores for indicators directly related to farm productivity, such as "Irrigations" and the environmental indicator "Soil quality". This is probably because they connect these indicators with productivity, with each indicator scoring 6 points in the evaluation matrix. Next, the stakeholders scored the "Risk of land abandonment" indicator at 3.73 and the "Agri-environmental commitments" indicator at 3.62, which may reflect two things: first, Romanian stakeholders do not perceive the risk of land abandonment as significant, and second, agri-environmental commitments may be underrated. Based on the evaluation matrix, it can be inferred that the selected stakeholders are more focused on farm productivity indicators than environmental protection indicators. Similar to the findings of the present study, the scientific literature often reports that farmers tend to prioritize indicators measuring farm productivity [225,226]. The stakeholders' overall evaluations of the 28 AEIs range between 3.6 and 6 (Table 2). One reason for not having higher values may be that the investigated stakeholders did not consider indicators, in general, to be a tool with high performance. To extend the understanding of AEI evaluation beyond the context of these 28 AEIs, additional information on the stakeholders' preferred indicators should be collected in future studies. However, given the extended use of the 28 AEIs, revealing the stakeholders' opinions about the indicators' main characteristics (i.e., Availability, Relevance, Target-oriented, and Operational simplicity) may be considered an intervention point to improve the understanding and acceptance of the indicators, or to consider their replacement. In addition, the results facilitate a comparison between the tested 28 AEIs and allow us to understand where stakeholders place them compared to the extreme points of the scale.

From a practical perspective, the present study provides policymakers and researchers with a broader view of AEIs since it encompasses all relevant organizations (EUROSTAT, FAO, OECD) and mirrors the indicators from each organization to those found in the scientific literature. Moreover, the present paper may be valued as an updated inventory list of the AEIs, offering the readership information from various documentation sources. Finally, the perceptions of rural stakeholders of the selected indicators provide valuable information for future elaboration and implementation of bottom-up policy initiatives (strategies, action programs) in the field of agri-environmental sustainability.

The present study is not without limitations. First, the study design focused only on the environmental dimension of farming sustainability without incorporating the social and economic dimensions, which were beyond the scope of the paper. Second, relevant studies may have been omitted using a manual search of papers. Third, the stakeholders involved in the analysis are from a specific area of Romania, meaning the analysis of their perceptions was regional. Therefore, even if the evaluation matrix is one of the best approaches to weigh the opinions of stakeholders, the results of the analysis cannot be extrapolated to other stakeholders since the assignment of weights and scores could be subjective. Fourth, it does not provide a ready-made solution that is valid in any circumstances because the selection of criteria depends on multiple variables whose importance may vary depending on the geographical area under study, and the environmental, social, economic, or political determinants.

Therefore, future research can be developed more robustly, covering all three sustainability dimensions. The present study can also serve as a reporting model for sustainable agriculture indicators worldwide, focusing on the environment. It can also help assess the perception of proposed indicators from a given area, considering the specificity (climate conditions, economy, community needs) of that geographical area.

5. Conclusions

The present contribution offered a comparative view of the EU, OECD, and FAO agri-environmental indicators, additionally revealing how the 28 EU AEIs are reflected in the scientific literature. Based on a comprehensive literature review of AEIs, the study explored the theoretical and practical utility of AEIs as tools to provide information on the sustainability of agricultural systems. One main conclusion is that AEIs must be developed within a transdisciplinary context that brings together agricultural and environmental dimensions to provide the best and most sustainable solutions to the current challenges facing the agricultural system. Furthermore, once the indicators are developed according to local specificity and tested by agri-environmental specialists, they must be integrated into national, regional, and local agricultural policies and strategies.

Furthermore, to bridge the gap between practitioners and researchers seeking sustainability in agriculture, this study revealed the stakeholders' assessment of the 28 AEIs based on several sustainability criteria. Practically, this step reflected stakeholders' perceptions and values about the quality of the tools (AEIs) used to measure agri-environmental sustainability. Following the discussions with the selected farmers (in the context of matrix evaluation), a critical aspect must be underlined: the possible reluctance of farmers to accept and implement AEIs. Tripartite cooperation between stakeholders—agri-environmental researchers, policymakers, and farmers—is necessary to ensure this approach is successful.

Another aspect that must be acknowledged is that most AEIs refer to only one dimension of sustainable development—the environment. Therefore, to have a broader picture of a sustainable farming system, one must combine different indicators or develop sets of interrelated indicators that approach all three dimensions of sustainability.

Finally, the AEIs play a critical role in highlighting the current and future trends in the state of the environment within the agricultural system (e.g., soil erosion, and pesticide load from soil or water). Consequently, the AEIs can help monitor a farming system and set the priorities for future policy actions.

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Appendix A

Table A1. EUROSTAT set of AEIs.

No.	Indicator	Definition
1	Agri-environmental commitments	This indicator refers to the share (%) of the area under agri-environmental commitments in Priority 4 on the total Utilised Agricultural Area (UAA).
2	Agricultural areas under Natura 2000	The indicator includes the share (%) of UAA under Natura 2000.
3	Farmers' training level and use of environmental farm advisory services	This indicator refers to the share (%) of farm managers with agricultural training (basic training, full training or farm managers with practical experience only).
4	Area under organic farming	This indicator represents the share (%) of organic farming from the total UAA.
5	Mineral fertilizer consumption	Mineral fertilizer consumption is indicated by the evolution of the consumption of nitrogen (N) and phosphorus (P) in mineral fertilizers by agriculture over time.

Table A1. *Cont.*

No.	Indicator	Definition
6	Consumption of pesticides	The consumption of pesticides refers to the use of pesticides per area of cropland. These data are, however, not available today.
7	Irrigation	The indicator assesses the trend of the irrigable and irrigated areas and their share of the total UAA (the irrigable area is the area that is equipped for irrigation).
8	Energy use	The indicator relates to the direct use of energy (solid fuels, petroleum products, gas, electricity, renewables, heat) in the agricultural sector, per hectare (ha) of utilized agricultural area (UAA). It assesses the trend of energy consumption per ha and fuel type.
9	Land-use change	The indicator assesses the changes in agricultural land use.
10.1	Cropping patterns	Cropping patterns are defined as trends in the share of the UAA occupied by the main agricultural land cover types (arable land, permanent grassland, and land under permanent crops).
10.2	Livestock patterns	Livestock patterns are defined as trends in the share of major livestock types (cattle, sheep, goats, pigs, and poultry) and density of livestock units (LSUs) on agricultural land.
11.1	Soil cover	Share of the year when plants or plant residues cover the arable area.
11.2	Tillage practices	Tillage practices refer to the soil treatment of arable land carried out between the harvest and following sowing/cultivation operation. Three tillage methods can be distinguished: conventional tillage, conservation tillage, and zero tillage.
11.3	Manure storage	The indicator assesses the number of holdings with manure storage facilities.
12	Farming intensity	The indicator assesses the degree of intensification/extensification of EU agriculture.
13	Specialization	Farm specialization describes the dominant activity in farm income: an agricultural holding is specialized when a particular activity provides at least two-thirds of the production or the business size of an agricultural holding.
14	Risk of land abandonment	Farmland abandonment is a cessation of agricultural activities on a given land surface, leading to undesirable changes in biodiversity and ecosystem services.
15	Gross nitrogen balance	The indicator assesses the potential surplus of nitrogen on agricultural land (kg N per ha per year).
16	Risk of pollution by phosphorus	The indicator assesses the potential surplus of phosphorus on agricultural land (kg P per ha per year).
17	Pesticide risk	The pesticide risk indicator is a based on modeling or actual data from monitoring studies or surveys, predicting the risk of damage from pesticide toxicity and exposure for a target organism.
18	Ammonia emissions	This indicator shows the annual atmospheric emissions of ammonia in the EU-28 for 1990–2015.
19	Greenhouse gas emissions	This indicator tracks trends in greenhouse gas (GHG) emissions by agriculture, estimated and reported under UN Convention on Climate Change, the Kyoto Protocol, and the Decision 525/2013/EC.
20	Water abstraction	This indicator assesses the amount of water abstraction for agriculture expressed in million m^3.
21	Soil erosion	The indicator soil erosion estimates the agricultural areas and natural grassland affected by a certain rate of soil erosion by water.
22	Genetic diversity	Genetic diversity is the total number of genetic characteristics in the genome of a species.
23	High Nature Value farmland	The concept of high nature value farmland refers to the causality between certain types of farming activity and corresponding environmental outcomes, including high levels of biodiversity and the presence of environmentally valuable habitats and species.

Table A1. *Cont.*

No.	Indicator	Definition
24	Production of renewable energy	This indicator assesses the share (%) of renewable energy production from agriculture and forestry.
25	Population trends of farmland birds	The indicator shows the trends in farmland birds' population.
26	Soil quality	The indicator provides an account of the ability of soil to deliver agri-environmental services through its capacities to perform its functions and respond to external influences.
27.1	Water Quality—Nitrate pollution	Nitrate pollution is indicated by current values and trends in nitrate concentrations in groundwater and rivers expressed in mg NO3/l for groundwater and mg N/l for rivers.
27.2	Water Quality—Pesticide pollution	Pesticides in water are indicated by current values, exceedances, and trends in the concentrations (μg/l) of selected pesticides in rivers and groundwater.
28	Landscape—State and diversity	The landscape state and diversity indicator describes the main characteristics of the agrarian landscape in terms of landscape structure, cultural influence on potential natural vegetation due to human activities, and societal awareness of the rural landscape.

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