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Systematic Review

A Systematic Review of Agricultural Sustainability Indicators

Ahmad Bathaei * and Dalia Štreimikienė

Lithuanian Centre for Social Sciences, Institute of Economics and Rural Development, A. Vivulskio g. 4A-13, LT-03220 Vilnius, Lithuania

* Correspondence: Bathaei.ahmad@graduate.utm.my; Tel.: +370-6462-1197

Abstract: A rapidly expanding field, sustainable agriculture aims to produce food and energy for people today and future generations. The sustainability concept is different in every field; thus, the indicators are unique in any area and country. Sustainable agriculture contains three main dimensions: economic, environmental, and social. Sustainable agriculture has been the focus of researchers for the past twenty-five years and has attracted much attention. Many researchers tried to identify these dimensions, but there is a lack of new research concerned with grouping all indicators together. Moreover, the indicators will change every year, so the indicators list needs to be frequently updated. This study follows the protocol for SALSA (Search, Appraisal, Synthesis, and Analysis) and PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Web of Science (WoS) was used for the literature search. A total of 101 indicators were found from previous studies for the three dimensions: social, environment, economic. In order to measure the most important indicators for sustainable agriculture, the paper proposes an appropriate set of indicators, as well as providing the previous papers analyzed by year of publication, continent, and topic.

Keywords: sustainable agriculture; PRISMA; SALSA; indicators; Systematic Literature Review

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1. Introduction

Agricultural production is essential to human and civilizational survival. Agricultural income and employment are supported along the entire food supply chain. A growing and affluent population has led to increased agricultural productivity. However, this has come at a cost to the environment and social systems worldwide. Agriculture plays a crucial role in the international economy; 1.3 billion people, or 16% of the global population, are employed by it, contributing 24% to global output [1]. Agriculture development programs have focused on increasing agricultural production in many developing countries [2].

In many developing countries, agricultural productivity has been emphasized at the expense of sustainability. Therefore, essential and natural resources were not preserved while production increased. Soils are degrading, water is causing erosion, groundwater is polluted, and natural resources are depleted in large parts of the world. Poor and developing countries are more likely to suffer from this condition because they rely heavily on agriculture and natural resources [3].

Agricultural practices contribute to society's current and long-term food, fiber, and other needs by conserving resources while maintaining other ecosystem functions and long-term human development [4]. Technical fixes and expertise are not the keys to agricultural sustainability. Changes in policy, institutions, and behavior are necessary to integrate ecological and societal knowledge [5].

The definition of sustainable agriculture varies considerably across countries, and few quantitative assessments of agricultural sustainability are available. Sustainability is defined by some scholars and practitioners as a set of management strategies, while others describe it as an ideology or a group of goals [6]. Nonetheless, sustainable agriculture is increasingly framed regarding its impact on sustainability's environmental, economic, and social pillars. There are several frameworks and indicators for assessing the sustainability of

food systems at the national and global levels and for determining sustainable agricultural intensification at the farm level [7].

There is a strong connection between sustainable agriculture and the multi-functional role assigned to the primary sector [8]. There are three dimensions to this sustainability approach: social, environmental, and economical. Agricultural practices are examined based on local ecosystem services, consumer needs, and the impact on the global environment [9]. Multifunctionality ensures environmental protection, healthy farming, and rural community health and can also be considered a 'moral' system [10].

Most studies have focused on assessing various environmental, economic, and social sustainability dimensions at the national level, setting thresholds or targets, and analyzing synergies and exchanges between them [11]. Sustainable agriculture is now a broader concept that encompasses both economical and more general social dimensions, having begun by focusing on ecological factors. Ecological conservation, enhancing and using local ecosystem resources [12], and reducing adverse environmental and health externalities are the core concerns of sustainable agriculture [9,13,14]. A growing awareness of ecological sustainability in agricultural activities has included topography, slopes, and soil quality. An economic perspective on sustainable agriculture tries to assign value to environmental parameters, such as the area under cultivation, agricultural productivity, and income earned. Sustainable agriculture often relates to farmer satisfaction, technical knowledge, skills, and social capital from a social standpoint [15,16].

Sustainability indicators cover many aspects of sustainability, but not all. There may be differences between the indicators used in one country and the indicators used in another country. There is much subjectivity in the indicator systems for different countries, regions, and development stages. There are many indicators in sustainable agriculture system that can have an effect on this system. The indicators for sustainable agriculture are scattered in many articles. It is therefore hard for researchers to group them together. Moreover, the indicator list needs to be updated because every year the indicators will be changed. The article tries to gather all the indicators in one article, so systematic review used to this article.

2. Research Background

2.1. Sustainable Agriculture

Sustainable agriculture has three main dimensions; economics, environment, and social. Agriculture must achieve sustainability by creating a balance [17]. Sustainable agriculture focuses on reducing negative externalities on the environment and health, enhancing and utilizing local ecosystem resources, and preserving biodiversity. Environmental sustainability in agricultural activities includes topography, slope, and soil quality [18]. Agricultural productivity and income are considered economic indicators of sustainable agriculture, in addition to ecological parameters. As far as sustainability is concerned, farmers' participation, satisfaction, and technical knowledge are often associated with sustainable agriculture [19]. There are three dimensions to sustainability agriculture, as shown in Figure 1.

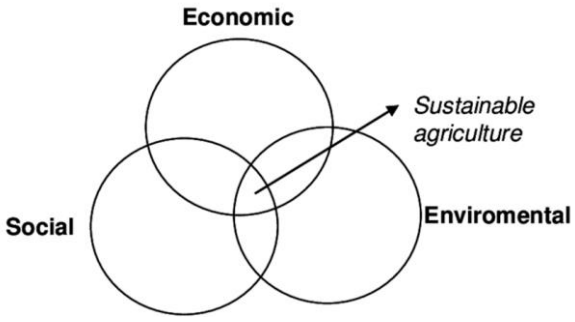

Figure 1. Three dimensions to sustainability agriculture.

It is important to understand what sustainable agriculture means, or how the salient attributes of agriculture are interpreted. There are many attributes to consider, ranging from soil–plant relations at the farm field level to global trading arrangements and distribution mechanisms for agricultural commodities [20]. Agricultural growth is influenced by soil fertility, climate, and pests, from a biophysical perspective [21]. Various management practices and environmental conditions are examined in order to determine how they affect yield. Biophysical productivity has been the subject of much research on agricultural sustainability [22]. In economic terms, agriculture is a farm business and a regional or national economic sector. Despite changing environmental, social, and economic conditions, economic sustainability is measured by the cost of production and the prospects for continued viability [23].

Agriculture is viewed from a macro perspective as a producer capable of satisfying food and fiber requirements. Sustainability concerns the potential for meeting national and global food and fiber needs, as well as the quality and security of food supplies, transferring technology, and improving the food distribution systems' efficiency and fairness [24].

There are different perspectives depending on the scale at which one is looking. A farm's main concerns are soil conditions, nutrient levels, water availability, and plant growth [25]. A farm operation refers to the production of crops and livestock, management practices, and the structure and viability of the operation. A key element of land use patterns and natural resource use at the regional level is agriculture. Globally and nationally, agriculture involves trade, equity, and food security [26]. Table 1 shows the three level of sustainability agriculture based on the micro, meso, and macro level.

Table 1. Micro, meso, and macro level of sustainable agriculture.

Dimension	Scale		
	Micro	**Meso**	**Macro**
Natural resource base	Field level soil fertility	Agroecosystems	Continental water and land resources
	Moisture	Regional land capability	Global climate
Crop production	Field yield	Regional production, Land use patterns	Global food and fiber supplies
Economic return	Management farm level production costs	Regional economy,	Trade marketing
	Viability Capital outlay	Value of production,	Policies Politics
Rural community	Farm level tenure	Rural community size and function	Global poverty
	Family involvement Communication	Access to food Facilities	Hunger Equity

2.2. Social Dimension

Since the 1960s, the public's environmental concerns have led to the development of the idea of sustainability. The most commonly used definition of "sustainable development" is "humanity has the power to create a development that meets the needs of the present without impairing the ability of future generations to meet their own needs" [27].

The social dimension of sustainability is now being studied at many levels, across several sectors, and using a variety of conceptual frameworks. Among the topics are development studies, political studies [28,29], and project development [30–32]; in food-related studies, several scholars address participatory approaches [33,34] and social learning among farmers and rural communities [35] or consumers [36]. Some studies take a theoretical stance when addressing the social dimension of sustainability, defining the concept and analyzing the state of the field [37,38].

People play a role in social sustainability, and two major groups can be identified [39]. The first aspect of sustainability that affects the farming community is social. This has

to do with the happiness of the farmers and their households. The indicators from the literature were divided into three categories by Lebacq et al. (2013): education; working circumstances (measured by working hours, workload including pain, and workforce); and quality of life (measured by isolation and social involvement) [40]. Van Cauwenbergh et al. (2007) divided quality of life into physical (indicators related to labor conditions and health) and psychological (indicators related to education, gender equality, family access to infrastructure and services, and the farmer's sense of independence) well-being [41]. They only took into account quality of life as a social theme. Employee physical health can also be considered an aspect of well-being (e.g., van Calker et al., 2007), albeit this can be seen as a result of working conditions [42].

There is social sustainability that matters at the level of society. This is "related to society's demands, depending on its values and concerns". Lebacq et al. (2013) divided the literature's indicators into three categories: multifunctionality (such as rural areas' quality, employment contribution, and ecosystem services), acceptable agricultural practices (which have environmental impacts and animal welfare), and food safety and quality (including food safety) [40]. Van Calker et al. (2007) evaluated the impact of sustainability measures on the rural economy, which is less strict than the impact of such measures on employment, but can still be included in Lebacq et al.'s (2013) quality of rural life report [40,42]. In addition to equity and heritage, cultural, spiritual, and aesthetic values were included by Van Cauwenbergh et al. (2007). Social sustainability sometimes includes succession as one of its dimensions [41].

"Economic and social elements are only relevant in this approach insofar as the greening of social development needs to be economically and socially compatible as well" [43]. According to some researchers, the historically ingrained dualism between social and natural science and the use of disparate terminologies and methodologies are to blame for social science's lack of participation in conceptualizations of sustainability [33]. During the past twenty years, social scientific notions have gradually eroded this duality [35,44].

2.3. Economic Dimension

Agriculture should, in the words of van Cauwenbergh et al. (2007), "bring prosperity to the farming community." Economic viability, or the ability of a farming system to endure over the long term in a changing economic environment, is commonly understood to be the same as economic sustainability in this context. Variability in production and input prices, yields, output outlets, and public backing and regulation can influence economic environment changes. Long-term can be interpreted as occurring throughout a farmer's career or across several generations. The latter is connected to durability, or a farm's ability to be passed on to a successor. Profitability, liquidity, stability, and productivity are the primary indicators of economic viability [42].

Profitability is determined by comparing revenue and cost, either as a difference or as a ratio, or by income variables such as farm income. The ability to pay for immediate and short-term obligations is known as liquidity, and equity capital share and growth are typically used to gauge stability [45]. The ability of the factors of production to produce output is measured by productivity. It is generally quantified using a partial productivity indicator, a ratio of the production to one input. Still, it may also be conducted using metrics such as total factor productivity (T.F.P.) and technical efficiency that consider the possibility of information or output replacement. Indicators of profitability and productivity are mostly quantitative indicators that are stated in terms of money or as ratios, i.e., reference scales are only occasionally utilized [46].

A more extensive range of indicators has been proposed to capture additional economic characteristics of farming systems related to sustainability, even if measuring economic sustainability often does not go beyond such indicators [47].

2.4. Environment Dimension

Due to the rising concern for sustainability and environmental challenges over the past 20 years, many projects have been put forth with various indicators [48]. Lebacq et al. (2013) categorized ecological indicators from the literature into eleven environmental themes/topics that either concentrate on observable physical features of the environment or human activities with significant environmental impact [40,49]. These topics include soil quality, biodiversity, nutrients, pesticides, non-renewable resources (such as energy and water), land management, emissions of greenhouse gases (GHG), and compounds that cause acidification. Three categories of environmental topics can be distinguished more broadly:

- Themes related to local or global impacts, which have consequences on the functional units used to express the indicators [50];
- Themes according to the action chain, namely the ultimate goal (e.g., human health), the process to achieve the goal (e.g., balance of environmental function), and the means (e.g., protecting environmental compartment) [51];
- Themes based on goal-oriented frameworks (where themes are goals to be achieved) and frameworks oriented towards system properties (where themes are system properties) [52].

Despite the variety of ways sustainable agriculture is conceptualized, one factor frequently highlighted is its numerous dimensions, including economic, environmental, and social concerns [53]. Pramanik (2016) used a suitability study for agricultural land use in the Darjeeling district using A.H.P. and G.I.S. methodologies [54]. For Cihanbeyli (Turkey) County, Bozdag et al. (2016) conducted a land suitability analysis based on A.H.P. and G.I.S [55].

Performance must be measured and benchmarked to assess how well an agricultural system operates and how sustainable it might be. Numerous indicators have been developed due to widespread interest in sustainability and are frequently included in sustainability frameworks. Furthermore, rather than supporting stakeholder learning and guiding their activities during the sustainability transition, many indicators created for sustainability studies have been designed and used for evaluation and assessment purposes [56]. The ability and interest of the stakeholders to embrace technologies and practices in agriculture and related sectors are enhanced by the stakeholder-driven and inclusive prioritization of adaptation alternatives [57,58].

3. Methods

The SALSA framework was used for literature search and analysis in order to minimize subjectivity. The scientific literature points to the SALSA methodology as one of the best tools for identifying, evaluating, and systematizing literature, which ensures methodological precision and completeness [59]. Furthermore, the PRISMA statement was followed in order to guarantee the consistency and completeness of the research process. PRISMA also ensures that the research is accurate and complete. Figure 2 shows the framework for systematic literature search and review.

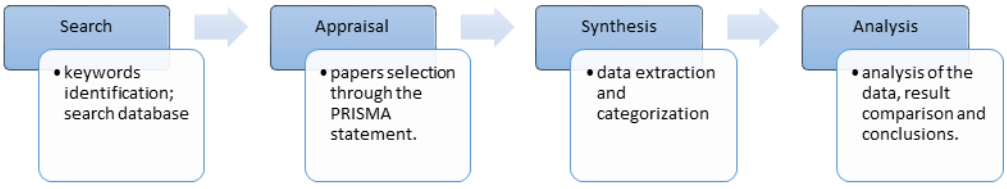

Figure 2. Framework for systematic literature search and review.

The first phase of the SALSA technique is the search; the literature search was carried out in the Web of Science (WoS) collection database with combinations of topics: "sustainability agriculture" and "economic indicators"; "sustainability agriculture" and

"environment indicators"; "sustainability agriculture"; and "social indicators. The search covered the period 2010–2022. The second phase of SALSA is appraisal. The PRISMA technique is used for selection of papers that followed. The publication was included for further analysis if it met the inclusion criteria. The inclusion criteria were as follows: a combination of keywords was in the title, keywords section, or abstract of the paper; the assessment was oriented at the farm and food industry; the paper was published in a scientific peer-reviewed journal; and the paper was published in the economics or energy fuels WoS database category. Exclusion criteria were as follows: review articles; editorial letters; conference proceedings papers; papers that were not written in English; papers were not primary research papers.

The search divided to three parts: the first related to economic part, second part related to environment and the last one related to social. Table 1 shows the number of papers that were obtained from the search for each dimension. Figure 3 shows the PRISMA steps for the appraisal phase.

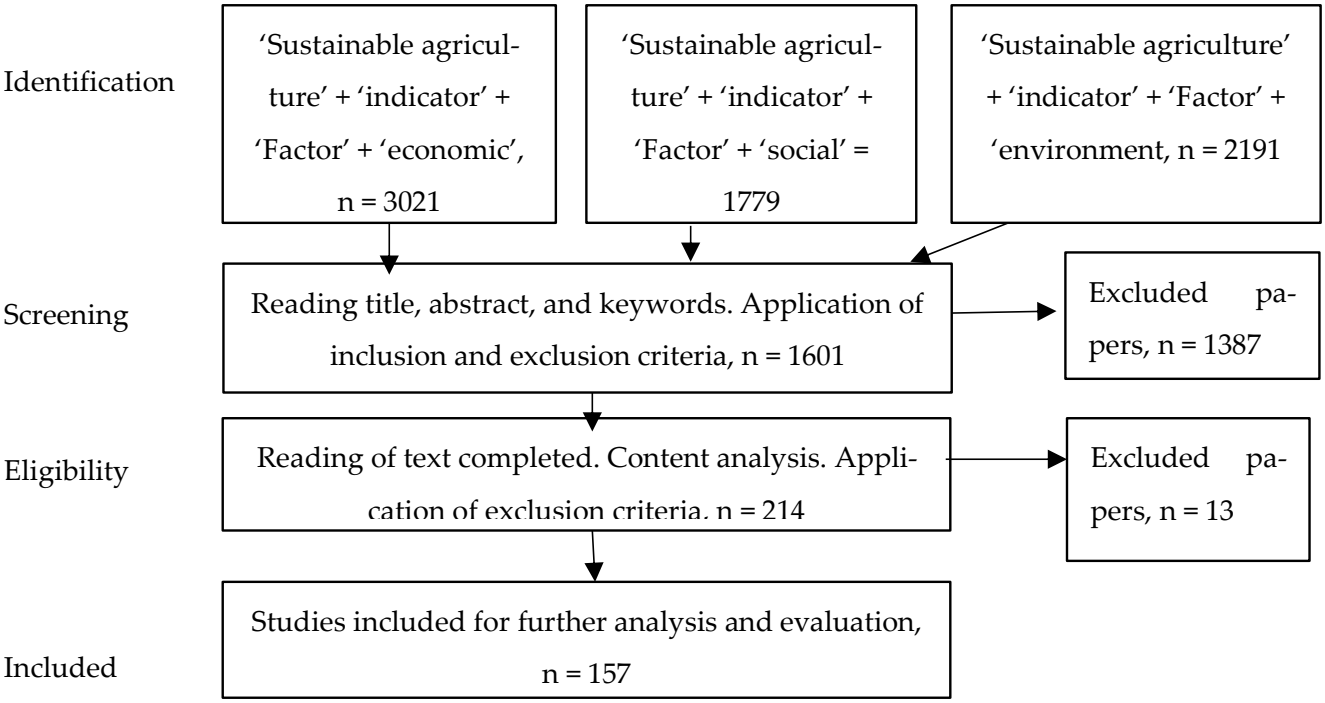

Figure 3. PRISMA steps for the appraisal phase.

Figure 4 shows the papers' topic area, collected from 157 reviewed papers, 71 of which were published in the sustainable agriculture section. In this section, the papers were related to sustainable agriculture dimensions: economic, environment and social. forty-nine papers were published in the ecosystem section, these being related to landing, farming, and soil. Employees and farmers play a key role in the sustainability; 19 papers were published in this area.

The identified indicator sets were found in journal articles and reports published from 2010 to September 2022. Out of the 157 publications analyzed, 82 were published before 2019 and 75 after 2019. Figure 5 shows the number of published papers from 2010–2022.

Based on the Figure 6, 38% of the authors of the articles were from Europe, which equals 59 authors. Moreover, in Asia, 53 authors published articles in this field and introduced indicators, amounting to 34%. The United stated of America has 25 articles, India has 19 articles, China has 13 articles, and England has published 7 articles in the period of 2010–2022 in the field of introducing indicators.

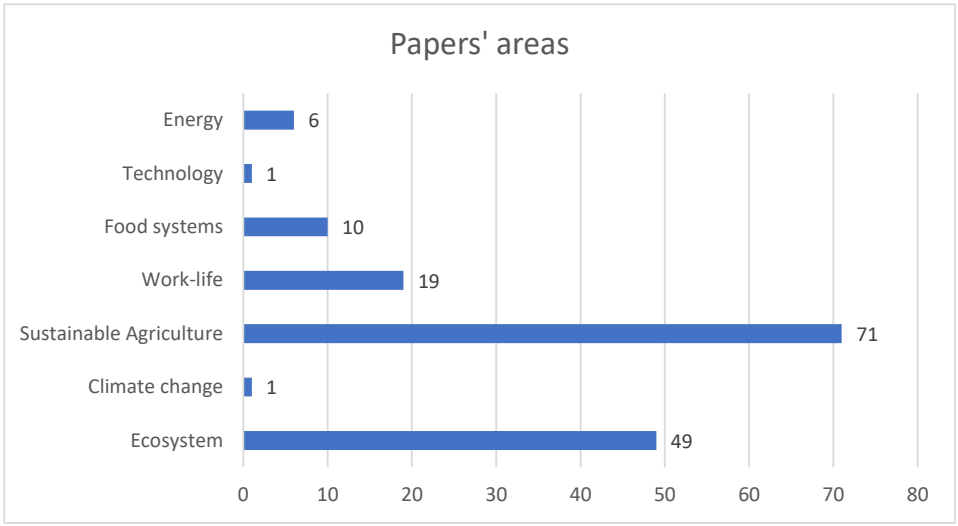

Figure 4. Papers' topic area.

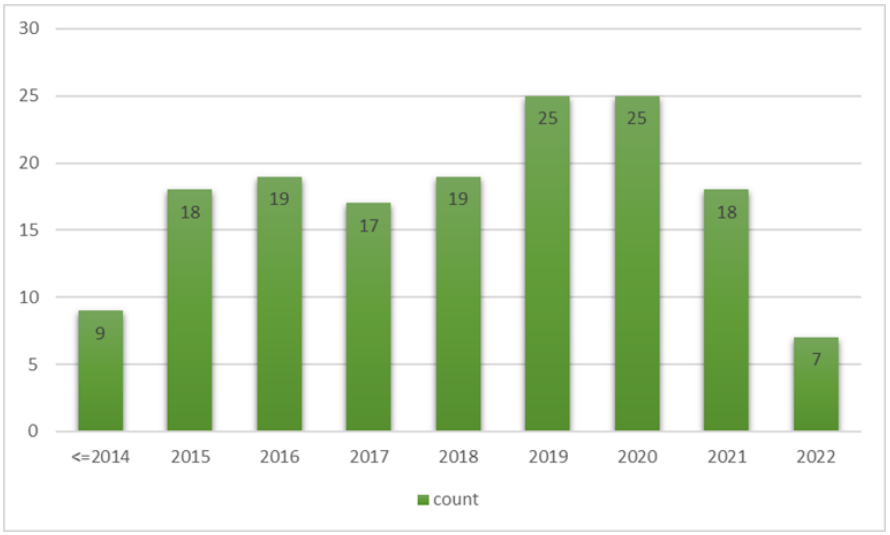

Figure 5. Year of published papers.

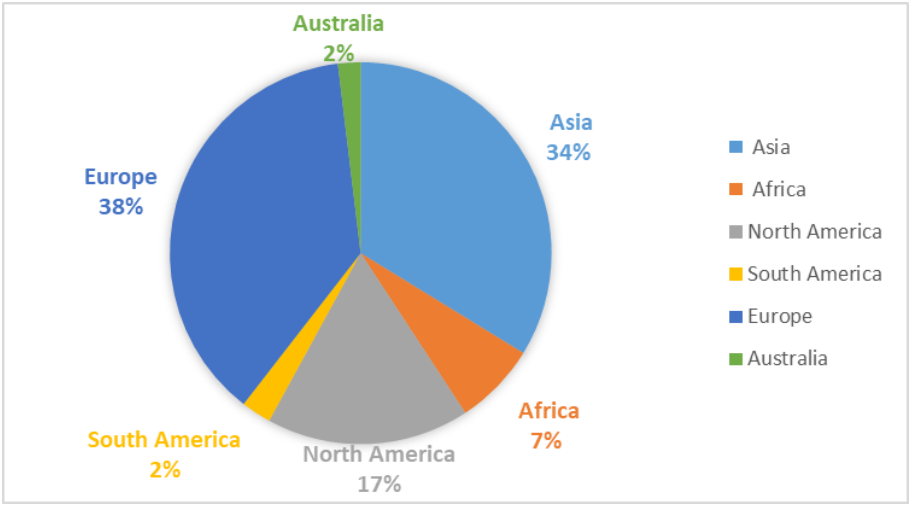

Figure 6. Published papers by continent.

The analysis shows a total of 157 papers were found for this study for extracting the indicators. Table 2 shows the indicators that are extracted from these papers. For the social dimension, 30 indicators were found from 49 papers; from 78 papers that related to the economic dimension, 31 indicators were found; for the environment, 40 indicators were found from 77 papers. Table 2 shows the obtained indicators from previous studies. These indicators grouped by the three dimensions.

Table 2. Indicators of sustainable agriculture.

Dimension	Indicators	References
Social	Acceptable agricultural practices	[40,60]
	Compatibility	[61,62]
	Contribution to employment	[40,63,64]
	Demographic structure	[65–67]
	Ecosystem services	[40,68,69]
	Education	[40,70,71]
	Employment	[40,72]
	Equality	[73,74]
	Farmers' rights	[6,75,76]
	Farmers' well-being	[6,73,77]
	Food	[61,78]
	Food safety	[61,79,80]
	Health and nutrition	[6,81]
	Health and Safety	[61,82,83]
	Isolation	[40,84]
	Knowledge	[61,85]
	Life quality—consumers	[61]
	Life quality—workers	[61]
	Multifunctionality	[40,86,87]
	Quality of life	[40,88]
	Quality of product	[40,89–91]
	Quality of rural areas	[40,92]
	Quality of process	[40,93,94]
	Relative wages	[95,96]
	Resilience	[6,97,98]
	Share of the family labor force	[99–101]
	Social implication	[40]
	Technology	[61,102,103]
	Women empowerment	[104,105]
	Working condition	[40,106]
Economic	Accessibility	[61,107–109]
	Agricultural activities	[40,60]
	Agricultural labor productivity	[6,110,111]
	Agricultural support	[6]
	Animal feeding	[40,112,113]

Table 2. *Cont.*

Dimension	Indicators	References
Economic	Capital productivity	[114–117]
	Cost	[61,118,119]
	Credit availability	[6]
	Diversification of activities	[120,121]
	Diversification of income	[122,123]
	Efficiency	[40,119,124]
	External financing	[40,125]
	External income	[40,126,127]
	External inputs	[40,128–130]
	Farm's profitability	[40,131]
	Farmer's risks	[6]
	Food loss	[6,132–134]
	Income	[40,61]
	Investment intensity	[135–137]
	Labor productivity	[116,138,139]
	Land productivity	[140–142]
	Liquidity	[143–145]
	Market access	[6,146–148]
	Marketability	[40,61]
	Mineral fertilizers	[40,149]
	Non-agriculture activities	[40,150,151]
	Price	[61,152,153]
	Production	[40,154–156]
	Profitability	[157–159]
	Subsidies	[40,160,161]
	Working capital level	[40,162]
Environment	Agriculture practices	[40,163,164]
	Biodiversity	[165–167]
	Biological soil quality	[40,168]
	Chemical soil quality	[40,169]
	Climate change	[6,170]
	Compaction measurements	[40,171,172]
	Complex model	[40,173]
	Crop protection intensity	[98]
	Crop rotation	[40,174,175]
	Culture reside management	[40]
	Domestic biodiversity	[40,176]
	Ecosystem	[61,68,177]
	Emission of acidifying gasses	[40]
	Emission of greenhouse gasses	[40,178–180]

Table 2. *Cont.*

Dimension	Indicators	References
Environment	Energy intensity	[181–184]
	Environment measure	[40,185,186]
	Farm structure	[40,187,188]
	Fertilizer use intensity	[119,135,189,190]
	Greenhouse gas emission intensity	[191,192]
	Importance of grasslands	[40,193]
	Land use and loss of biodiversity	[6,194,195]
	Livestock density	[196,197]
	Machine use	[40,198,199]
	Nitrogen farm-gate balance	[40,200,201]
	Non-renewable	[61,202,203]
	Operational model	[40,68]
	Organic carbon indicator	[40,204]
	Organic fertilization	[40,149,205]
	Permanent grasslands	[206,207]
	Physical soil quality	[40]
	Pollution	[6,208]
	Renewable resources	[61,209]
	Resources	[40,85]
	Soil analysis	[40,210]
	Soil cover	[40,199]
	Soil health	[6]
	Soil type	[40]
	Soil fertility	[107]
	Specific positive	[40,211]
	Water availability	[6,212,213]

4. Discussion

This study aimed to find the indicators that improve sustainability in agriculture systems based on previous studies. Ecological, economic, and social aspects are all part of sustainable development. Despite some differences in detail, there are a number of indicators available today that share a lot in common. By paying attention to our location, land, products, etc., we can achieve sustainable development in agriculture.

Many researchers published papers in this area; however, based on Figure 4, which shows that these articles have been conducted in different fields, research is needed to collect all the parameters in one article. Researchers published in the sustainable agriculture and ecosystem fields more than other fields. Indicators in these fields are more related to pollution, soil condition, water condition, material of products, etc. Based on the results of Figure 5, researchers pay attention to this topic after 2014. Moreover, the results show that modern countries research agriculture sustainability more than other countries. These countries investigate this field to improve sustainability; they care about environment and acknowledge their responsibility to keep it clean and green. They work on indicators to introduce a new paradigm then, in using this new paradigm, they can decrease their cost and improve the profit. Figure 7 shows the most recommended indicators for sustainability in agriculture.

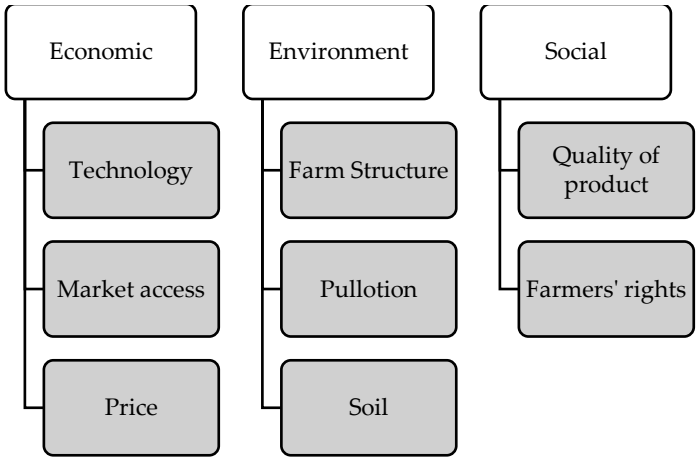

Figure 7. Most recommended indicators for sustainability in agriculture.

One of the most introduced indicators in this field is farmers' right; improving farmers living quality can have an effect on agriculture systems and then, with cooperation with governments, they can improve sustainability in the country [214]. Employees also important because if they cannot help you to apply the new methodology, the money and time will be gone. So it is important to improve their skills in order to improve sustainability [215]. It is possible to improve the product quality over its life cycle, resulting in a decrease in product waste which, in turn, helps the customer to refrain from buying the same product again, as well as saving raw materials from the farm and factory [216]. In the economic dimension, the market is very important, as are customers. The market can lead people to use green or organic products to make the society sustainable [217]. For example, using recycle plastic bags for shopping and also returning plastic, cans, and glass is a good way to recycle product. In addition, the technology is also very important, as we should use technology to produce these recyclable products [218]. Furthermore, price can affect customers' behavior while shopping. The government can support the companies to lower the final price in order that the customers can buy the recyclable products and save raw materials and the environment [219]. A key indicator in the environment is farm structure and soil material. Using the farm in a sustainable way is the beginning of sustainability in the whole cycle of agriculture system. Soil fertilizer can affect human health, so farmers must follow the government rules to use the permitted limit of fertilizer [220].

5. Conclusions and Future Research Areas

Researchers introduced many indicators during these years, and these indicators can be grouped into three dimensions: economics, environment, and social. Different indicators are used in different countries and regions, so it is difficult to collect all of them in one study, and every year a new indicator is added to the sustainable agriculture field. In this study, the leading indicators were found based on previous studies; in future research, these indicators can be ranked and chosen for any parts of the agricultural process such as finding stakeholders, the market, employment etc. Agriculture that can consistently produce food and other resources for a population that is expanding worldwide is essential to human existence and, by extension, to any human activity. The ability of agriculture to meet human needs now and in the future, however, is threatened by a wide range of issues, such as climate change, a high rate of biodiversity loss, land degradation due to soil erosion, compaction, salinization, depletion and pollution of water resources, rising production costs, a steadily declining number of farms, and, associated with this, poverty and a decline in the rural population. Sustainable agriculture is a commitment to meeting peoples' present and long-term food and fiber needs while simultaneously improving the living standards of farmers and wider society. All components of agriculture should adhere to sustainability in order to achieve this. However, it is challenging to pinpoint indications in this area. One of the keys to achieving sustainable agriculture is government support, as

governments can help companies reduce their prices and make it easier for customers to buy recyclable products. In addition, the government can assist farmers in improving their skills through education on the farm and on the land.

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