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Advancing Sustainable Agriculture: A Critical Review of Innovative Strategies to Decrease Chemical Dependency for Environmental Health

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A B S T R A C T

Sustainable agriculture is a fast-growing field that attempts to provide energy and food for both present and future generations. Given that the concept of sustainability differs across disciplines, each region and country employs various alternative methods. The three primary facets of sustainable agriculture are social, environmental, and economic. For the past 25 years, experts have concentrated on sustainable agriculture, which has garnered a lot of attention. The SALSA (Search, Appraisal, Synthesis, and Analysis) and PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocols are followed in this work. The literature search was conducted using Research Gate, Semantic Scholar, and Google Scholar. We thoroughly explored eight different strategies from earlier research. The eight (eight) primary sustainable practices: agroforestry, agrobiodiversity, cover crops, crop rotation, conservation tillage, soil conservation, water management, and smart farming-are based on the thematic analysis of this systematic study. The results provide a foundational understanding of incorporating these alternative methods with scientific findings into sustainable farming techniques. Government assistance is essential to achieving sustainable agriculture because it allows businesses to lower costs and facilitate the purchase of recyclable goods by consumers. Furthermore, through education on the land and farms, the government may help farmers advance their abilities.

1. Introduction

With the world's population predicted to reach 9–10 billion people by 2050, an intensified agricultural sector is now required to meet the world's expanding food needs [1]. Owing to the global scarcity of cultivable land, creative approaches and methods have been devised to increase yields per unit area.

Enhancing and preserving soil fertility and maintaining crop productivity are global priorities. Maintaining biodiversity and ensuring sustainable agricultural output require managing soil health [2]. The terms "soil health" and "soil quality" are sometimes used interchangeably and are both encompassed in environmental health, but in this context, "soil health" refers to the complex and integrated range of functions that soils provide, including carbon sequestration, nutrient cycling, water filtration and regulation, and biological variety. Being a wide concept, soil health is difficult to quantify and understand. A deeper comprehension of the different indicators of soil health can be achieved by looking at soil from an ecological standpoint, considering its physical, chemical, and biological characteristics [3].

Most inputs used in modern agriculture include pesticides, chemical fertilizers, guaranteed irrigation, better seeds, and herbicides. Their employment in agriculture boosts output, but it's concerning that their inappropriate use negatively influences soil productivity and environmental quality [3].

In the 1950s, many chemical and pharmaceutical firms began producing pesticides and fertilizers utilizing chemicals like phosphate, sulfate, and nitrate, which were used in explosives that grew more widespread following World War II. The production of chemical fertilizers and pesticides rapidly expanded after that [1].

According to Sharma *et al.* [4], this strategy has wreaked havoc on the environment and reduced life expectancy. These days, many chemical compounds are constantly being utilized to get rid of undesired weeds and insects; pesticides are the one that are most employed. Pesticides are a unique family of chemical compounds that are used to eradicate a variety of pests, such as rodents, weeds, and insects [5]. These substances are utilized to improve both the yield and quality of crops [6].

The persistent invasion of pests like insect larvae, which destroy crops and cause enormous financial losses to farmer communities, is the primary cause of the many-fold growth in the demand for pesticides worldwide [7]. According to Larsen et al. [8], there is a strong correlation between the rise in pesticide use and detrimental impacts on the environment and public health. Pesticide use has been connected in some reports to the global extinction of insect species [9] or the collapse of insect populations [10-12]. But there are other elements at play as well, like habitat degradation brought on by intensifying agriculture, which is the primary cause of this occurrence [9].

The three primary dimensions of sustainable agriculture are social, environmental, and economic. Agriculture needs to establish equilibrium to be sustainable [13, 14]. In the context of agriculture, "sustainability" refers to the requirement to feed the world's expanding population while minimizing negative effects on the environment, human health, and farmer profitability [15]. There is agreement that agricultural sustainability should address environmental, economic, and social challenges related to its practice, even though estimating sustainability in an agricultural system is still difficult and ambiguous [16]. Any agricultural system must continue to be sustainable over the long term for the soil to continue being productive and for the inputs needed to continue being available. Nonetheless, in many agricultural environments, soil loss happens more quickly than soil creation [17].

Solutions for producing food and other agricultural products at a low environmental cost that do not jeopardize food availability and accessibility or the general well-being of future generations can be found in sustainable agricultural systems and practices [18]. A comprehensive system of plant and animal production practices with a site-specific application that, in the long run, will meet the needs of humankind for food and fiber, improve the environment and the natural resource base that supports the agricultural economy, maximize the use of non-renewable resources and on-farm resources, integrate natural biological cycles and controls where appropriate, maintain the viability of farm operations economically, and improve the standard of living for farmers and society at large is known as sustainable agriculture [19].

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The deliberate mixing of trees and shrubs with crops or livestock is known as agroforestry, and it is one multipurpose strategy for our food system. For almost fifty years, agroforestry, cover crops and conservation tillage, have been acknowledged as a sustainable method of farming, and the idea of incorporating trees into the agricultural landscape has been around for as long as land cultivation. Reduced runoff of fertilizer and pesticides, carbon absorption, higher soil quality, erosion management, enhanced wildlife habitat, less reliance on fossil fuels, and heightened resilience in the face of an uncertain agricultural future are among the advantages of agroforestry, cover crops, crop rotation and conservation tillage [20]. While efficient water management minimizes runoff carrying harmful chemicals and promotes sustainable irrigation practices. Agrobiodiversity, involving crop cultivation, creates resilient ecosystems, reducing dependence on specific chemical treatments. Soil conservation practices, like contour plowing, maintain soil fertility, lessening the need for chemical supplements. Smart farming utilizing technology for precise input application minimizes wastage and environmental impact. Collectively, these practices offer a comprehensive approach to sustainable agriculture, aligning to reduce chemical use for a more environmentally conscious and resilient farming system [21].

The main objective of this systematic review is to systematically analyze and synthesize existing literature published over the past decade on reducing chemical use in agricultural sustainable alternatives for a healthier environment. This comprehensive review aims to evaluate and consolidate evidence on sustainable alternatives and practices that can effectively reduce the reliance on conventional chemical inputs. The overarching goal is to promote a transition towards environmentally friendly and ecologically sustainable agriculture systems. This includes examining diverse approaches such as agroforestry, cover crops, crop rotation, conservation tillage, water management, agrobiodiversity, soil conservation and smart or precision farming. Fig. 1 shows three dimensions of sustainable agriculture.

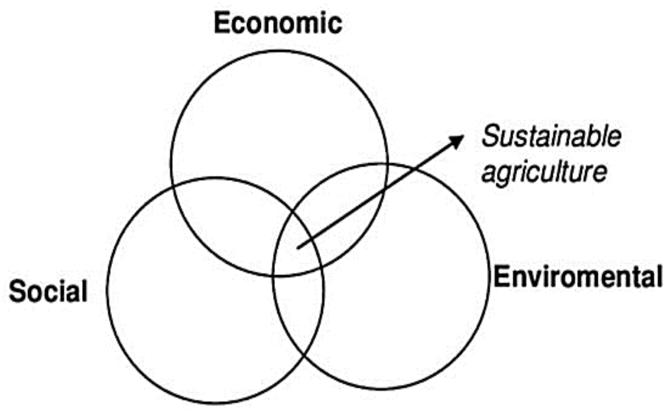

Fig. 1 Three dimensions in sustainable agriculture [14]

2. Experimental Methods

The SALSA framework was used for conducting a systematic literature search and analysis to reduce subjective biases. The SALSA technique is widely regarded in the scientific community as a very effective instrument for discovering, analyzing, and systemizing literature. It guarantees methodological accuracy and completeness, as highlighted by Siksnelyte-Butkiene et al. [22]. In addition, the study procedure adhered to the PRISMA declaration to ensure uniformity and comprehensiveness. PRISMA also guarantees the accuracy and comprehensiveness of the study.

2.1 Systematic Searching Strategies

The systematic searching approaches include three primary strategies: identification, screening, and eligibility, as well as four SALSA stages (Fig. 2).

2.2 Identification

Identification is the systematic search for appropriate keywords that align with study topics. The first stage of the SALSA approach involves searching. The keywords were "Chemical use in Agriculture", Reducing Chemical use in Agriculture", "Sustainable Agriculture", "Sustainable Alternatives used in Agriculture", "Agroforestry", "Cover crops", "Conservation tillage", "Crop rotation", "Water management", "Agrobiodiversity", Soil conservation" and "Smart or Precision Farming". The keywords were constructed by the research question, as proposed by Okoli [23]. The identification techniques were based on internet thesauruses, keywords used in previous research, keywords recommended by search engines, and input from specialists. The scope of our search included the period from 2015 to 2024, and it included papers in the disciplines of agriculture, economics, social sciences, and physical sciences written in English. We choose to pursue this topic of research due to our focus on the social scientific, environmental, agronomic, and economic aspects of sustainable agriculture. We were intrigued by publications that critically analyze the concept of chemical use in agriculture and sustainable agriculture.

2.3 Screening

This is the subsequent phase of SALSA. The following papers are selected using the PRISMA methodology. If the publication met the criteria for inclusion, it was included for further study. For a paper to be included, it had to fulfill the following criteria: it needed to have a combination of specific keywords in its title, keywords section, or abstract; it had to be published in a scientific journal that undergoes peer review; and it had to fall within the categories related to energy fuels, economics, environment, agriculture, and social sciences as defined by the search engine database. The decision was made to set the maximum year for searching as 2024. Hence, the period spanning from 2015 to 2024 was also chosen as one of the criteria for admission. In addition, we made care to include only review papers that included empirical data and were published in a journal to confirm their quality. The exclusion criteria included publications authored in languages other than English, editorial letters, conference proceedings papers, and any other forms of grey literature.

2.4 Eligibility

During the third stage, known as eligibility, the authors conducted a manual assessment of the collected articles to ensure that, after the screening procedure, each article fully satisfied the specified criteria. The first stage in this strategy was perusing the titles and abstracts of the articles. A total of 67 manuscripts were removed due to the absence of empirical data, lack of clarity in the methods section, or being published as book chapters. The third stage involves the extraction and classification of data. The study's overarching concepts and subordinate concepts were developed by using the method of thematic analysis.

The retrieved data underwent clustering, counting, and thematic analysis to identify patterns and themes, and to establish parallels and linkages. This study was used to define the main themes and sub-themes. Following a thorough analysis, all relevant and similar extracted data was grouped together, resulting in the creation of eight (8) themes. These themes are based on current strategies for achieving sustainable agriculture that benefits both producers and consumers. The themes include soil conservation, agrobiodiversity, agroforestry, water management, cover crops, crop rotation, conservation tillage, and smart and precision farming.

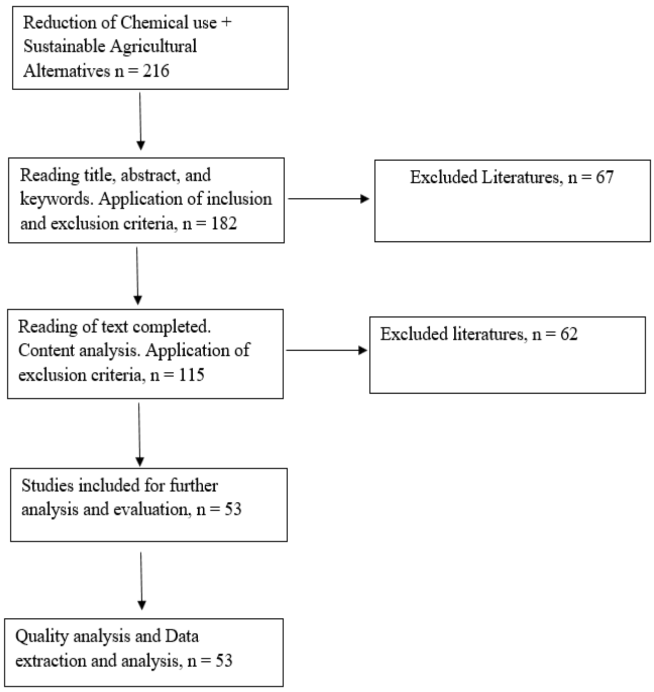

Fig. 2 Flow chart indicating the PRISMA steps for the appraisal phase

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3. Results and Discussion

Fig. 3 shows the papers' topic area, collected from 53 reviewed papers, 11 of which were published in the sustainable agriculture section. In this section, the literature was related to sustainable agriculture dimensions: economic, environmental, and social. Twelve (12) published in the use of Chemicals section 7 for pesticides and 5 for fertilizers, these being related to landing, farming, and soil. Alternative approaches to sustainable agriculture consisted of 30 papers and journals in total with agroforestry (5), cover crop (4), crop rotation (3), agrobiodiversity (4), soil conservation (4), conservation tillage (3), smart farming (4), water management (3).

The identified indicator and theme sets were found in journal articles and reports published from 2015 to September 2024. Out of the 53 publications analyzed, 33 were published before 2019 and 20 after 2019. Fig. 4 shows the number of published papers from 2015–2024.

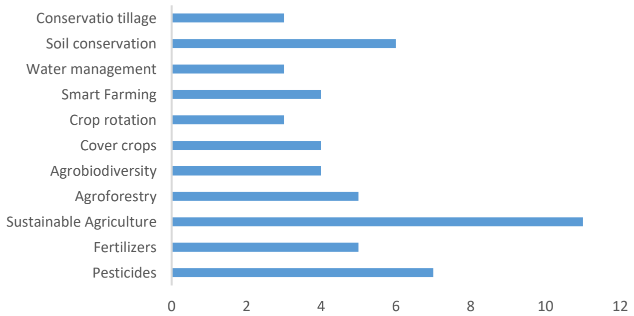

Fig. 3 Literature topic area

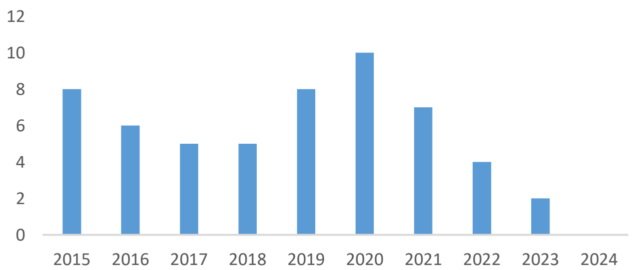

Fig. 4 Year of published papers

3.1 Agroforestry

The idea of including trees in the agricultural landscape is as old as the act of cultivating land, and agroforestry has been acknowledged for almost fifty years as a sustainable agricultural technique [21]. Reductions in fertilizer and pesticide runoff, carbon sequestration, enhanced soil quality, erosion management, better wildlife habitat, decreased reliance on fossil fuels, and higher resilience in the face of an uncertain agricultural future are just a few of the advantages of agroforestry [24]. To put it briefly, many of the negative consequences of agriculture can be lessened by including trees and other perennials in a landscape. Agroforestry has a lot of potential as a land use plan in both the developed and developing worlds since it may concurrently deliver economic, ecological, and cultural benefits [25].

Agroforestry is done in various forms worldwide. Historically, tropical agroforestry has attracted more attention and has been implemented more extensively than temperate agroforestry. Certain tropical agroforestry approaches are more feasible than in regions where machine harvesting is more prevalent due to the well-developed systems, such as shade-grown coffee and tea, and the availability of hand labour [26]. Agroforestry has historically been significant to cultures in both native tropical regions and temperate regions like Europe; however, in northern regions, land abandonment and agricultural intensification have resulted in a reduction in traditional agroforestry techniques [27].

The temperate zone, particularly in North America, promotes five widely accepted agroforestry practices: alley cropping, silvopasture, riparian buffers, windbreaks, and forest farming [21]. These methods work in a range of climate zones, topographies, and cropping systems. Growing field crops in between rows of trees is known as alley cropping. While the alley crops can include a range of grains, vegetables, or forages, the trees can be planted for their timber, fruits, or nuts. Livestock is incorporated into a purposeful blend of pasture and trees in silvopasture. Compared to just "grazing the woods," silvopasture involves carefully planning the tree spacing to provide enough sunshine for the forages below and prevent animal damage to the trees. Planting areas near streams that are vulnerable to erosion, nutrient leaching, or habitat loss are known as riparian buffers [27].

Shelterbelts, another name for windbreaks, were first identified as an effective agroforestry technique. Due to reduced evapotranspiration and the benefits of trapping snow, windbreaks reduce wind erosion, offer shelter for wildlife, and can enhance the amount of water available to surrounding crops. Growing mushrooms, gathering medicinal herbs like goldenseal and ginseng, and selling woody decorative materials are examples of forest agricultural activities [21].

3.2 Cover Crops

The term "cover crops" refers to crops that are planted to cover the ground. These crops are carefully cultivated to stop surface runoff and leaching by removing nutrients from deep layers of the soil [28]. To increase agricultural production and productivity, cover crops are sown in between primary crops. Legumes are the main component of cover crops; they are grown to cover the soil's surface and contribute to the improvement of the physical, chemical, and biological qualities of the soil. The best cover crops are those that sprout and emerge rapidly, can withstand harsh weather, fix atmospheric nitrogen from the air, take nutrients from the soil through the development of deep roots, yield more biomass in a shorter length of time, and are simple to work with and nurture [29].

In no-till farming systems, pre-plant, pre-emergence, and early post-emergence herbicide applications are common early-season weed control strategies. In tilled systems, mechanical cultivation is an option. Herbicides boost crop vigor and output by giving farmers an easy and affordable option to control weeds in their crops [30]. On the other hand, they could potentially pose a risk to the environment (such as pesticide residues in surface and/or groundwater), and in certain places, the emergence of resistant weed biotypes has made herbicides less effective. Research has shown that cover crops can reduce environmental degradation, enhance soil quality, and partially limit weed growth in crops [31]. Cover crops can potentially provide an alternative tactic for control of herbicide-resistant weeds [32]. For many years, the advantages of cover crops for the farming community and environment have been widely recognized [29].

3.3 Crop Rotation

Unlike monoculture, crop rotation refers to the shifting of crops throughout time and space. This would imply that a crop shouldn't be planted on the same plot more than once in succession [33, 34]. Crop rotation has well-established advantages, including the removal of certain weeds, diseases, and insects, increased yields, optimal plant utilization of soil nutrients, and an increase in the amount of readily available soil nitrogen when certain crops, like those in the Fabaceae family, are grown [35]. The utilization of crop rotations, which involve the successive planting of specific crops over time to enhance crop diversity, results in a change in soil chemistry and quality over time as well as nutrient competition. Nevertheless, there are benefits of rotational diversity below ground, such as higher stocks of soil organic matter (SOM). The benefits of plant diversity below ground have been associated with sustainable agriculture and alterations in microbial communities in natural systems. This is also true in agroecosystems, although maybe at different temporal and spatial scales [33].Furthermore, numerous studies have proposed that applying agrobiodiversity to a certain piece of land by cultivating a variety of crops can be advantageous. Crop diversity and varied crop residues have an impact on the microbial communities in the soil and plants, which in turn impacts weeds, pests, and plant diseases. Crop rotation is an efficient way to manage a wide range of pests and diseases [36].

3.4 Agrobiodiversity

Managing soil and water as resources differ greatly, yet agrobiodiversity is characterized as the result of interactions among genetic resources, the environment, and various human behaviors [37]. As a result, agrobiodiversity encompasses a vast variety of plants, animals, and microbes that are necessary for agroecosystems to be sustained. In addition to many years of deliberate unintentional selection of beneficial and healthy plants and animals by farmers and ranchers, natural selection is the primary cause of agrobiodiversity [37].

In addition to serving as a primary supply of raw materials for the textile, pharmaceutical, and leather industries, agriculture provides a fundamental source of sustenance for both humans and animals. Without biodiversity, our nutrition would not be able to be so diverse. The result of ongoing plant and animal evolution is biodiversity [38]. Agriculture is

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based on biodiversity. Its existence is essential to the production of food and other agricultural products, which are beneficial to human health, nutrition, and food. Additionally, all plant and animal species, as well as their variations, depend on biodiversity for their continued existence.

Without the use of pesticides to aid farmers in the battle against illnesses and pests, modern agricultural output is essentially unthinkable. However, nature uses its own processes to get rid of the most prevalent infections [39].

3.5 Conservation Tillage

An inventive and environmentally friendly agricultural production method that offers more benefits to the economy and environment is conservation tillage [40]. The financial benefits include more cropping diversity and intensity, as well as lower labour, fuel, and machinery operating costs and time savings. Increased soil organic matter and soil organism activity, improved soil health and resilience, improved physical, chemical, and biological properties, improved wildlife habitat restoration and enhancement, decreased soil erosion, nitrate leaching, fuel use, and agricultural greenhouse gas (GHG) emissions are just a few of the environmental benefits [41]. Conservation tillage farming refers to the practice of reducing the amount of soil that is tilled in cropping systems to preserve residue cover on the soil surface [41].

All weed seeds are left on the soil's surface beneath the crop residue when conservation tillage is used. Large-seeded weeds stay in the soil, but small-seeded weeds sprout and flourish in these more favorable environmental circumstances [42]. Herbicide treatment time is crucial in reduced tillage to achieve the ideal balance between treating weeds while they are still little and treating after the greatest number of weeds have germinated. To attain comprehensive weed control, it might be necessary to apply one or more postemergence herbicide treatments in addition to an early mixture of burndown and soil-active herbicides [43]. The effective application rate of herbicides is a crucial factor in the control of weeds in reduced tillage systems. The amount of soil organic matter, crop residue level, timing, and size or density of weeds affect the rate of herbicide application. The factors can affect herbicide activity under reduced tillage. According to Busari *et al*. [40]. there is relatively little risk of surface water contamination under ZT due to the drastic decrease in erosion (runoff) and the speed at which soil organisms, which are often abundant under ZT, break down herbicides into innocuous molecules. Compared to land that has not been plowed, these agrochemicals can go farther than the vadose zone when applied to heavily plowed soil [40].

3.6 Soil Conservation

Soil, which is essential for farming, can become contaminated by a variety of heavy metals that build up through industry emissions, mining operations, the disposal of high metal wastes, petrol, fertilizer application, sewage sludge, pesticides, wastewater irrigation, residues from coal combustion, etc. In the past, a significant quantity of chemicals was regularly sprayed to agricultural soils as insecticides and fertilizers. The number of heavy metals in the soil, especially Cd, Pb, and As, may rise as a result of such applications [44]. Most pesticides that are currently in use are synthetic organic or inorganic chemicals. Pesticides can be categorized according to several factors, including their chemical composition, target pests, soil persistency (half-life), the spectrum of activity, mode of entry in the pest, mode of formulation, toxicity of the active molecule, and volatilization behavior. Pesticides can also be categorized according to the chemical composition of the active constituent, which indicates the properties and behavior of the pesticide. The ideal pesticide should have the following qualities: (1) not affect nontarget soil organisms; (2) have low persistence in soil; (3) be cost-effective; and (4) be biodegradable. But the majority of pesticides are both acutely and chronically harmful, and they function as biocides—that is, they can destroy any other live forms in addition to the pests they are intended to kill [44]. Numerous investigations have revealed that most pesticides enter the cell walls of unintended microorganisms in the soil, interfering with their regular metabolism and ultimately causing cell death. Pesticides have been found to pose a serious risk to the health of the soil microbiota and to the natural habitats that exist there. Additionally, pesticides have well-documented detrimental consequences due to contamination of soil and water, which enters the food chain and ultimately affects human health as well as the health of other species and develops resistant pest varieties [44].

3.7 Water Management

The Sustainable Development Goals (SDGs) aim to protect the environment and significantly enhance everyone's standard of living. One of the current "crisis resources" is water, particularly in areas where water is becoming more and more scarce [45]. Applications for reusing water include irrigation for agriculture and landscaping, industrial reuse, and recharging groundwater. The most popular use of recovered water is in agriculture, which holds a 30% market share [46]. Seventy percent of freshwater withdrawals worldwide are typically related to agriculture. Lack of water in agriculture can have a significant impact on livelihoods, food security, nutrition, and other socioeconomic factors, but these stresses and uncertainties can be lessened with a steady supply of water [45]. When pesticides contaminate surface and groundwater, the damage is higher. Significant alterations in the water quality are linked to the contamination of groundwater. Studies have shown that the fish in the River Ganga have accumulated a sizable amount of DDT and HCH. It has been discovered that the amount of organochlorine residues in surface water in coastal river basins is higher than what is allowed [47]. DDT residues in commercial beverages were examined by the National Occupational Health Institute in Ahmadabad. Research on soft drinks and water in Delhi has revealed that 20% of the beverages had pesticides in them, which is seen as a 2% rise in the MRL globally [47].

Rivers and lakes are examples of surface waterways. Surface waterways are exposed to pesticides by flushing, discharging, spilling, and air waste disposal. Pesticides that reach the atmosphere by the previously indicated pathway will travel over great distances, influencing the local flora and animals. During dry deposition, pesticides are absorbed by wind-eroded soil particles, causing fast leaching and soil erosion [45].

Concern among the general population regarding pesticide residues has improved recently. Even at trace amounts, pesticides are present in drinking water over the allowed limits of concentration. Pesticide exposure in humans may occur by drinking water. Furthermore, overuse and improper disposal of pesticides harm fish and the environment: empty chemical container disposal and equipment cleaning. The main uses of river water are irrigation, drinking by livestock, and swimming on rare occasions [45]. Water that has been poisoned by pesticides poses a serious hazard to aquatic life. This will have a significant impact on aquatic life. Plants that have lower DO levels in the water experience physiologic alterations [48, 49].

3.8 Smart Farming

The latest phrase in agriculture, "smart farming," promises to revolutionize the production and management of food. One could argue that the phrase Precision Agriculture evolved into Smart Farming [50]. Furthermore, "smart agriculture" is the literary counterpart of "smart farming." The phrase "smart farming" will be used in this document. The new buzzword in the agriculture industry is "smart farming," which refers to the innovative use of information and communication technologies (ICT) to replace conventional methods. Specific technologies that are anticipated to bring about major changes are Unmanned Aerial Vehicles (UAVs), Unmanned Ground Vehicles (UGVs), Image Processing, Machine Learning, Big Data, Cloud Computing, and Wireless Sensor Networks (WSNs) [50].

4. Discussion

This study aimed to reduce chemical use in agricultural sustainable alternatives for a healthier environment by methodically analyzing and synthesizing existing literature produced over the previous ten years. Sustainable development encompasses social, economic, and environmental elements. There are several indicators accessible today that have a lot in common, even though there are some differences in details. We may accomplish sustainable development in agriculture by paying attention to and putting alternative approaches like agroforestry, cover crops, crop rotation, soil conservation, conservation tillage, agrobiodiversity, water management, and smart or precision farming into practice. Many researchers have written papers on this topic; however, as Figure indicates, these publications are from diverse domains, thus further research is necessary to compile all the parameters in one piece. Researchers published in the sustainable agriculture and ecosystem fields more than other fields.

An essential component of sustainable agriculture practices is agroforestry. The main adverse effect it has in most agricultural contexts is the destruction of natural rainforests to make way for farming. For this reason, farmers must find and implement novel approaches, such as developing only lands that have been well-investigated for farming [51, 52]. Cambien et al. [53] state that the use of pesticides and fertilizers in the agriculture industry is responsible for 67% of global contamination of soil and water. It is therefore essential to find an alternative to the synthetic insecticides and biochemical fertilizers that are now in use. It is possible to commercialize the use of household waste as organic fertilizer and bio-pesticides, such as microorganisms or herbs, to provide new approaches to sustainable practices in agriculture [54]. Additionally, during the replanting stage of farming, the method of crop rotation can be performed and implemented to ensure that the usage of fertilizers and pesticides is maintained to a minimum. By preserving the soil's moisture content and texture, crops like potatoes, tomatoes, herbs, and other vegetables help maintain the fertility of the soil. Environmental compensation has been implemented in several countries, including Cameroon [55], India [56], Thailand [57], and Columbia. This has involved setting aside 10–30% of the overall plantation area as a conservation area. United States wheat-growing regions have been using this technique [58]. Greater soil conservation zones will help maintain environmental attributes including humidity, temperature, and soil fertility in addition to lessening the environmental impact of plants [59]. In agroecosystems, biodiversity maximizes the fight against pests, illnesses, and weeds. Some beneficial insects feed on other insects; ladybirds, for example, eat aphids. Among the most prevalent and varied creatures in the environment are insects. Approximately 10,000 new insect species are described each, bringing the total number of known insect species to over a million. Less than 1% of all known insect species are regarded as pests; the great majority of insects are helpful or neutral to crop production [60].

In contrast to conventional farming methods, organic agroecosystems are limited in the amount of non-synthetic or synthetic elements they can employ and can only use pesticides as a last resort. Practices that "maintain or enforce natural resources of work, including soil and water quality" must be adjusted by organic farmers. To successfully build an organic farm, it is imperative to consider the environmental aspects of insects, particularly their biology and interactions with plants, other species, and the surrounding environment [37].

Cover crops are also an alternative approach to enhance soil structure, increase organic matter, promote biodiversity, and improve overall soil health. Healthier soils require fewer inputs, including chemicals, as they retain nutrients better, have improved water-holding capacity, and are more resistant to erosion and compaction. Certain cover crops, such as legumes (e.g., clover, vetch), form symbiotic relationships with nitrogen-fixing bacteria in their root nodules. These bacteria convert atmospheric nitrogen into a usable form for plants, reducing the need for external nitrogen sources like synthetic fertilizers [61, 30]. A dense cover crop canopy helps prevent weed growth by limiting growing season sunlight penetration and creating competition for resources. As a result, there may be less need for herbicides or manual weeding. Some cover crops attract beneficial insects and organisms that prey upon harmful pests, reducing the need for chemical pesticides. Additionally, certain cover crops can break pest cycles, making them less likely to establish themselves [29, 43].

Water management is an important aspect of sustainable agriculture that can serve as an alternative approach to reducing chemical use by improving irrigation methods, such as using drip irrigation or precision application technologies, which can ensure that water is delivered directly to plant roots, thereby reducing evaporation losses and deep percolation below the root zone [48]. Efficient water usage lowers the need for excessive applications of soluble fertilizers, which might otherwise be required to compensate for water-related nutrient losses. Water reuse and recapture methods by implementing strategies like rainwater harvesting, stormwater, retention basins, or treated wastewater reuse can provide supplemented water supplies for irrigation purposes. Utilizing these alternate water sources reduces the demand for freshwater diversions, conserves energy related to pumping and potentially reduces the necessity for intensive chemically assisted production techniques [45].

Precision agriculture focuses on optimizing spatial management practices to increase crop production while avoiding the misuse of pesticides and fertilizers [62]. Smart agriculture is a technology that depends on its implementation of the use of AI and IoT in cyber-physical farm management [63]. Reduction of runoff, which typically carries leftover agrochemicals and soil sediments with it, is one of the main advantages of conservation tillage [40]. For example, the decrease in runoff that comes with zero-till plots presents a wonderful chance to lessen pollution of surface and even groundwater. Practices such as no-till or minimum tillage can improve soil structure and porosity, enhancing its ability to store water and reduce runoff. Well-structured soils allow for more efficient utilization of applied water and nutrients, subsequently decreasing the dependency on chemicals to achieve desired yields.

5. Conclusion

This systematic review's main objective is to systematically analyze and synthesize existing literature on reducing the use of chemicals as a sustainable agricultural alternative that has been published in the last ten years to create a healthier environment. The study makes several important additions to the body of knowledge and to practice. Through the evaluation, stakeholders with an interest in best-practice agriculture, including policymakers, the general public, researchers, and environmentalists, can develop both short- and long-term plans and alternatives that will strengthen the current certifications. The approaches discussed in this study may not all address sustainable agriculture in the same way because they may approach the topic from different perspectives. However, the many approaches to sustainable agriculture may be more similar than they are to conventional farming strategies or practices. This study has proposed eight (8) areas of best practice (agroforestry, agrobiodiversity, cover crops, crop rotation, soil conservation, conservation tillage, water management, and smart farming) based on the 53 selected studies. Sustainable agriculture is a commitment to meeting people’s present and long-term food and fiber needs while simultaneously improving the living standard of farmers and society at large. To do this, sustainability should be followed by every aspect of agriculture. Still, it is difficult to identify clues in this field. Government assistance is essential to achieving sustainable agriculture because it allows businesses to lower costs and facilitate the purchase of recyclable goods by consumers. Furthermore, through education on the land and on farms, the government may help farmers advance their abilities.

Author Contributions

KFD: Writing - review & editing; YEM and KDF: Project administration, Funding acquisition; YEM and KFD: Investigation, Data curation; YEM: Sampling & investigation; KDF: Project Supervision.

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Conflicts of Interest

The authors declare no conflict of interest.

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