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Review

Digital Tools and Decision Support Systems in Agroecology: Benefits, Challenges, and Practical Implementations

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Abstract: Farmers are increasingly faced with challenges such as climate change, population growth, and the need for sustainable food production, while simultaneously having to address the environmental impacts of conventional agriculture. Agroecology has emerged as a holistic and sustainable approach to agriculture, integrating environmental, social, and economic principles. This study investigates the role of digital tools, including decision support systems (DSSs), in supporting agroecological transitions. Through a literature review and analysis of case studies, this paper examines the benefits and challenges associated with the adoption of digital tools in agroecology, highlighting their potential to promote sustainable practices such as soil and water management, pest control, and efficient resource use. The findings indicate that while digital solutions offer significant potential to enhance productivity and improve environmental outcomes, their adoption remains limited due to barriers such as low digital literacy, lack of infrastructure, and concerns about effectiveness in real-world farming conditions. Despite these challenges, digital solutions offer significant potential to enhance productivity, improve environmental outcomes, and support farmers' decision-making. To comprehensively understand their benefits, a holistic approach is necessary, combining digital tools with hands-on training, policy support, and ongoing research. This paper highlights the role of digital tools in agroecology, explores their benefits and challenges, and discusses the need for continued research to assess their long-term potential in terms of the agroecological transition.

Keywords: agroecology; decision-making; decision support system; digital tools; agroecological transition

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1. Introduction

In recent years, farmers have faced challenges due to climate change, population growth, and the growing need to ensure food security. At the same time, they must address the negative environmental impacts of conventional agriculture, such as soil degradation, biodiversity loss, and water pollution. In response, agroecology has emerged as a promising, environmentally friendly approach. Agroecology is a holistic and integrated method that applies principles to develop sustainable agroecosystems [1].

Agroecology is an approach to agriculture that integrates ecological, social, and economic principles to create sustainable and resilient agricultural systems. Rooted in the practices of indigenous and peasant agriculture, agroecology emphasizes the importance of traditional knowledge and local practices while incorporating modern agricultural science [2]. Agroecology is based on key principles that promote sustainable productivity and long-term stability, reduced inputs, and improved efficiency [3]. Most importantly, farmers are placed at the forefront, with their role being reinforced and their knowledge, skills, and active participation recognized as vital to the success of agroecology [4]. Socially equitable decision-making also stands at its core, promoting an inclusive approach to agricultural development [3].

Various digital tools have been developed to put these principles into practice (Figure 1). Digital tools are individual software applications, platforms, or technological instruments that assist with data collection, analysis, management, or communication in various fields, including agriculture. These tools can range from mobile applications and software programs to hardware devices such as sensors and drones. In the context of agriculture, digital tools are used to monitor crop health, manage resources, optimize irrigation, track weather patterns, and improve decision-making processes [5]. Tools are considered agroecological if they incorporate principles like productivity, stability, and input reduction [3]. Today, digital technology has begun to play an increasingly supportive role in the agroecological transition [6,7]. Given the rapid expansion of digital technology across industries, agriculture will likely need to accelerate its adoption to keep pace [7].

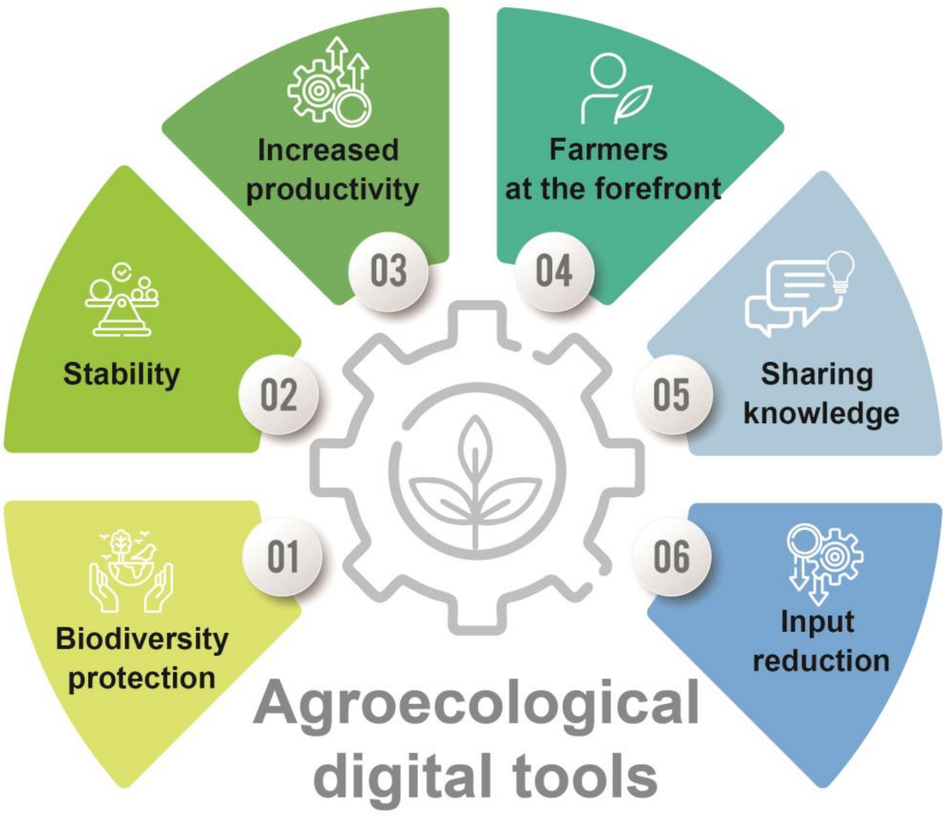

Figure 1. Key principles of agroecological digital tools.

Until recently, digital technologies in agriculture were mainly dedicated to precision agriculture more suited to conventional large-scale systems [8]. Precision agriculture primarily aims to boost production, while digital tools are increasingly applied across the entire agricultural value chain, enhancing sustainable management of soil, water, and other natural resources [7]. However, there has been a growing shift toward using these technologies to support more sustainable and agroecological practices. More than 240 digital tools, including programs and applications, are available to assist users in making informed decisions and sharing knowledge [3]. These tools take various forms, such as websites, apps, and podcasts, and allow users to connect with experts through messaging, phone calls, or consultations with remote agronomists.

A digital solution is a broader term that encompasses a wide range of technologies or platforms, including DSSs, mobile applications, and cloud-based platforms, which exemplify the practical application of agroecological principles. These solutions may or may not involve decision-making components. For example, CONECT-e enables public participation in documenting traditional agroecological knowledge, preserving and making this knowledge accessible for future use [9]. Other tools focus on farmer-to-farmer training, providing expert recommendations for farm management, live chat support, and communication channels like messaging or hotlines, all of which enhance practical implementation of agroecological principles [3]. For instance, the Macho Sauti platform offers the opportunity to small-scale farmers to connect with researchers to share knowledge about simple agroecological practices [4]. The recommendations are not only for crops but also for livestock and agroforestry systems. Also, they can provide information about weather, soil health and diseases. Although some digital tools may not be dynamic, acting more as passive information sources, they still play a crucial role in building the foundation for the agroecological transition within the agricultural community.

On the other hand, digital applications have been developed that help farmers communicate with the end users of their products, as well as to facilitate communication between companies and their customers [4]. Another category of digital tools, such as the Agricultural Land Information System (ALIS), focuses on supporting policy decisions, particularly in terms of the prioritization of farm preservation [10].

Decision support systems (DSSs) are computer-based support systems designed to provide recommendations based on collected data under different circumstances and help farmers' decision-making [11]. By integrating data from multiple sources, such as weather stations, soil sensors, statistical models, and geographic information systems, DSSs help farmers make timely and informed decisions [12]. DSSs come in a variety of formats, ranging from advanced, user-focused crop models to more accessible options such as software with graphical user interfaces or even simple spreadsheets. Over the years, these systems have been developed and refined worldwide, with their evolution beginning in the 1980s. For example, SIRATAC, a cotton pest management system, was used in Australia between 1980 and 1993 [13]. This early example demonstrated the effectiveness of DSSs in improving agricultural practices, setting the stage for the continued evolution and widespread use of these systems. Today, DSSs continue to play a vital role in agricultural practice, providing farmers with valuable data for sustainable agriculture. They also assist policymakers, planners, and local stakeholders during planning processes [10]. Recent technological advancements have created increasingly conducive conditions for the successful application of DSSs. While significant advancements have been made in the development and adoption of digital tools in agriculture, there is a notable lack of research exploring their integration into agroecological practices. Existing studies often focus on the technical aspects of these tools without adequately examining their real-world applicability, particularly in diverse agroecological contexts. Addressing these gaps is critical to unlocking the full potential of digital tools to support the agroecological transition and contribute to sustainable farming systems. The aim of this review paper is to explore the role of digital tools in agroecological farming systems and highlight their limitations. This analysis seeks to provide a comprehensive understanding of how digital innovations can support the principles of agroecology while identifying gaps and opportunities for future research and practical implementation.

2. Application of Decision Support Systems in Agroecology

In this section, it is not intended to make an exhaustive review of the developed DSSs, but rather, to provide an overview of their application in agroecology. The selected DSS tools, as summarized in Table 1, were chosen to represent a broad spectrum of functionalities, geographical applications, and agroecological principles. These tools illustrate how digital innovations are being harnessed to promote sustainable farming practices, optimize resource use, and address region-specific challenges. Moreover, they exemplify the diverse range of applications in agriculture and agroecology, encompassing critical aspects such as soil health, pest management, irrigation efficiency, and resource optimization.

The MicroLEIS decision support system (DSS) is a tool designed to assist with sustainable land use and management, particularly focusing on soil quality evaluation. By integrating multiple technological tools, such as databases, statistical models, expert systems, and geographic information systems (GISs), it supports decision-making processes for agroecological systems [14]. The biophysical and environmental characteristics of specific regions are also taken into account. Similarly, another DSS, named "RASKAZ", also contributes to sustainable land management by analyzing soil data to provide customized recommendations for agricultural land use and management, addressing nutrient deficiencies and soil structure issues [15]. In the realm of irrigation management, Navarro-Hellin et al. [12], introduced the Smart Irrigation Decision Support System, which uses continuous soil measurements from soil sensors, combined with climatic data, to precisely predict crop irrigation needs for the upcoming week. This tool offers significant benefits to agricultural producers by helping them optimize water usage and reduce water waste in agricultural lands. A similar study in Greece compared traditional irrigation practices with a DSS for irrigation management in vineyards, finding that the DSS accurately estimated the soil moisture, without requiring specific in-field monitoring hardware, validating its effectiveness for enhancing irrigation practices in vineyards [16]. Another DSS is vite.net, focusing specifically on vineyards, helping farmers to optimize the use of both natural resources and technical inputs and promoting more efficient and sustainable practices. The specific tool can provide farmers with up-to-date information for managing the vineyard in the form of notifications and decision supports [17].

IPMwise is a DSS tool dedicated to integrated weed management in cereal crops, designed to reduce reliance on chemical herbicides while maintaining effective weed control [18]. IPMwise leverages data on crop types, weed populations, climate, and soil conditions to deliver tailored recommendations, enabling farmers to make strategic decisions about the timing and rate of herbicide applications. Through a focus on sustainable practices, including selective herbicide use and alternative non-chemical methods, IPMwise has demonstrated the ability to reduce chemical herbicide use in cereals by up to 30% [18]. While many DSSs for weed management have been developed, they typically focus on a single technique or weed species. To date, no DSS has assessed the long-term impacts of combining multiple cultural practices on various weed species at the cropping-system scale, nor has any DSS considered the multifaceted impacts of weeds on both crop production and biodiversity [19]. According to Kanatas et al. [20], effective communication between farmers and agronomists is crucial for the successful development of a DSS. This collaboration ensures that the system meets the practical needs of farmers while integrating expert knowledge, ultimately leading to more relevant and usable tools.

X-farm is a model designed to optimize farm management by balancing energy efficiency, economic profitability, and ecological sustainability [21]. Similarly, the Daisy model, a decision support tool, helps secure high potato yields while minimizing water use and nitrogen input in potato crops [22]. Another valuable tool is AZODYN, which predicts the impact of nitrogen fertilization strategies on the crop yield, grain protein content and soil mineral nitrogen at harvest. This model considers the soil characteristics, weather conditions, cultivar traits, and fertilizer types, and was developed to assist farmers in determining the optimal timing and quantity of nitrogen fertilizer application, aiming to reduce nitrogen deficiency and prevent excessive environmental losses throughout the crop cycle [23].

As shown in Table 1, many decision support systems, despite their significant differences, are united by the common goal of achieving more sustainable agricultural practices [24,25]. Among these, LandCaRe-DSS is a model-based tool designed to develop cost-effective climate adaptation strategies in agriculture, integrating information and climate impact assessment models. It allows users, including agricultural advisors, planners, and insurers, to evaluate climate change effects at different spatial levels [24]. Another valuable tool is the Integrated Decision Support System for Intercropping (IDSS-I), which addresses the challenges of intercropping, particularly in Africa, where crop production is hindered by inadequate expertise, poor planning, and ineffective management. The IDSS-I enhances the efficiency and productivity of intercropping systems by providing farmers with tools and information for better decision-making. It focuses on optimizing crop combinations, managing resources effectively, and improving soil fertility to improve farm yields [25].

Table 1. Summary of the decision support systems for the agroecological transition.

Acronym	Purpose	Modeling Method Used	Primary Users	Region of Application	References
MicroLEIS	Promotes sustainable agricultural land use.	Utilizes databases, statistical models, expert systems, and GISs.	Policymakers, farmers	Mediterranean region	[14]
RASKAZ	Automated agroecological assessment of soils, focusing on optimizing nutrient levels and managing soil structure.	Agroecological classification, soil data analysis, GIS applications, digital mapping.	Agronomists, scientists	Russia	[15]
SIDSS	Predicts weekly crop irrigation needs.	Integrates soil sensor measurements and climatic data.	Farmers	-	[12]
DSS for irrigation management	Aims to improve irrigation management, estimates soil moisture.	Uses weather time series from seven automatic agro-meteorological stations.	Farmers	Europe	[16]
vite.net	Aims to optimize natural resource use and technical inputs in crop management.	Integrated system for real-time monitoring of the vineyard components (air, soil, plants, pests, and diseases) and analyzes data.	Farmers	Europe	[17]
IPMwise	Aims to assist in making precise pest management decisions, focusing on optimizing pesticide use.	Collects detailed input from farmers about their specific field conditions.	Farmers	Northern and Western Europe	[18]

Table 1. *Cont.*

Acronym	Purpose	Modeling Method Used	Primary Users	Region of Application	References
X-farm	Optimizes farm management by balancing energy efficiency, economic profitability, and ecological sustainability.	Collects detailed input from farmers and literature information.	Farmers	Europe	[21]
Daisy model	Secures high yields while saving water and nitrogen inputs for potato crops.	Uses data from a two-years experiment.	Farmers	Europe	[22]
AZODYN	Assists farmers in determining the optimal timing and quantity of nitrogen fertilizer application.	Uses data from national weather network with input directly provided by farmers.	Farmers	Europe	[23,26]
LandCaRe-DSS	Aims to solve various issues related to climate change in agricultural landscapes.	Uses information and a model-based simulation system.	Agricultural consultants, agronomists, decision makers for public regional and landscape planning bodies, water management boards and agricultural insurance companies	Europe	[24]
IDSS-I	Aims to improve the efficiency and productivity of intercropping practices.	Uses data provided by farmers.	Farmers	Africa	[25]

Researchers have also proposed a DSS capable of predicting rice crop yields under various climatic scenarios [27]. The system allows users to insert the climatic conditions of their region, uses historical data, and finally, predicts the rice yield to support farmers in decision-making [27]. Furthermore, another DSS based on expert knowledge has been developed for managing rice, coffee, and cocoa crops. This system combines user-provided inputs with external data to offer guidance on crop selection, monitoring, pest control, fertilizer application, and more, with the goal of reducing costs, improving productivity, and optimizing harvest timing [28]. In Figure 2, the interaction between inputs and outputs to help farmers taking the right decisions is shown.

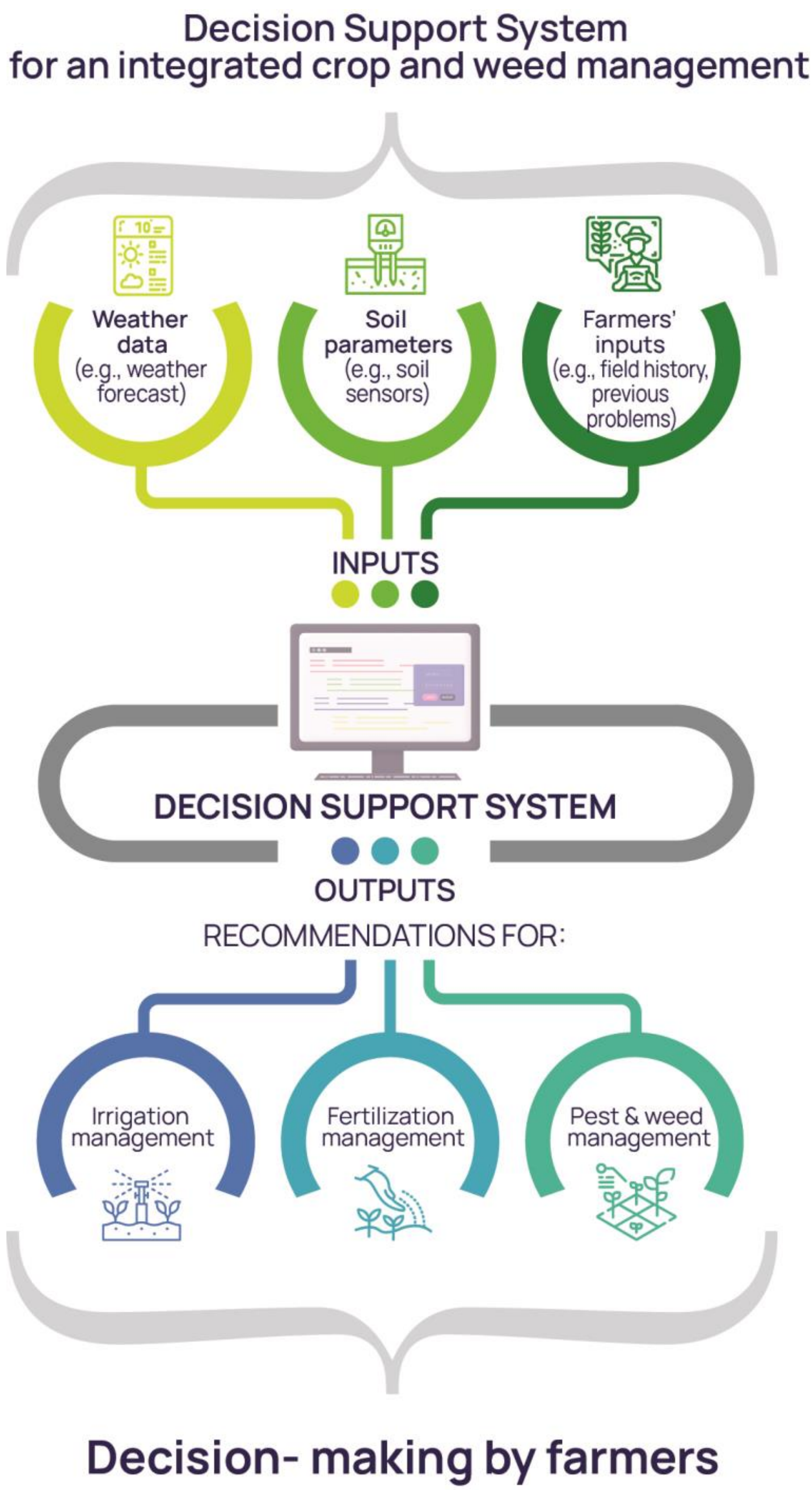

Figure 2. Visual example demonstrating the interaction between inputs and outputs to guide farmers in making informed decisions.

3. Benefits of Digital Solutions in Agroecology

Digital solutions have the potential to enhance farmers' capacity to respond to four major challenges essential to support the agroecological transition [8]. First of all, digital tools can support agroecological principles by creating valuable knowledge for the agroecological transition, aiding farmers in adapting to external factors, such as climate change [8]. These technologies contribute to improving production not only by helping farmers manage and optimize farm operations but also by integrating agroecological practices that reduce environmental impacts [7]. Second, digital solutions assist farmers in efficiently running their farms by providing real-time data, automation options, and analytics. These features enable them to make well-informed decisions that align with sustainable agroecological practices [15].

Additionally, they offer real-time reporting, cost reduction, time saving and better resource allocation, while also increasing yields, improving product quality, and enhancing labor productivity [15,29]. The use of digital technologies can improve crop diversification, enhance biodiversity, and promote ecosystem services [30]. DSSs that deliver recommendations address challenges in interpreting specific indicator values, such as soil nutrient levels, pest population densities, or crop health metrics, and help identify priority areas for interventions like targeted fertilization or pest control [31]. DSSs also help users determine the optimal timing and location for pesticide applications. The use of DSSs often leads to a reduction in pesticides or offers recommendations for alternative control strategies, thereby reducing negative environmental and health impacts [32]. Other DSSs evaluate the environmental conditions that support the target pest populations at a specific location and use these data to assess the risk of pest outbreaks, guiding decisions on whether to apply a treatment [32]. Agroecological decision-making tools prioritize alternative non-chemical pest management practices, with pesticides considered the last option [33].

Furthermore, digital tools help embed farmers more firmly within the agricultural ecosystem, strengthening their roles in regional ecosystems and value chains [8]. By facilitating connections between local producers, suppliers, and consumers, these technologies support economic resilience and foster collaborative practices essential for sustainable agriculture [4]. Finally, digital platforms facilitate the sharing, learning, and understanding necessary for a successful agroecological transition. Through data sharing, open knowledge, and collective learning opportunities, digital tools empower farmers and stakeholders to access and contribute to a growing knowledge base [5]. Thus, a collaborative environment is created that promotes continuous learning and ensures improvement in terms of sustainable agricultural practices.

Farmers may integrate multiple tools in their decision-making process, and when these tools are used on a shared basis, they can serve as effective mediators for skill development concerning agroecological practices [3,5]. Also, digital platforms for learning and AI-based recommendations tailored to agroecology can support young farmers, helping them gain experience and make informed decisions as they begin in agriculture [34].

4. Challenges of Digital Solutions in Agroecology

Despite the rapid growth of digital agriculture and the existence of numerous applications, the level of use remains low [7]. One reason for this is that producers are often hesitant to adopt digital solutions because their expectations of the potential benefits of these tools may not align with the actual capabilities of the technologies offered [35]. This lack of confidence in DSSs may be a consequence of the recommendations that are often not applicable in real agricultural conditions. Many farmers, particularly smallholders, may lack digital literacy, technical skills, or access to the necessary digital infrastructure to effectively use these tools [3,29]. Also, implementing a new DSS may face resistance from users who are accustomed to traditional decision-making methods, such as manual, experience-based approaches or reliance on expert advice. Additionally, effective use of these systems often requires training, which can be time-consuming and costly [35,36].

Furthermore, DSSs often require regular maintenance and updating but do not receive the necessary attention, leading to outdated or less effective recommendations [17]. Another obstacle is the availability of DSSs, which are often developed in specific regions and may be tied to subscription fees, limiting their accessibility for many farmers [33]. Some DSSs are even pushed into service before being sufficiently refined and validated, further diminishing their utility [17]. Additionally, many DSSs require specific crop monitoring data to operate, which farmers may be unwilling or unable to provide, further limiting their adoption [33].

Additionally, the gap in adoption can be attributed to the overly generic or excessively complex nature of some DSSs [10,17]. Although the use of digital solutions is increasingly important, the market for software and algorithms that support these systems is not sufficiently developed worldwide, further limiting their adoption and effectiveness [15]. Many DSSs focus on addressing only specific issues, which may not align with the interconnected challenges farmers face throughout the production process, further limiting their effectiveness and uptake [17]. These tools often lack technical guidance tailored specifically to agroecology, which makes it challenging for users to fully integrate these tools into their farming practices [3]. Additionally, many of these tools fail to incorporate considerations regarding climate change adaptation and mitigation, leaving a gap in their ability to address the broader environmental challenges faced by farmers [3]. Furthermore, there is also concern that these tools may inadvertently reinforce reliance on conventional, large-scale farming practices, potentially restricting farmers' flexibility in exploring alternative approaches [31]. In many regions, despite the growing need for digital solutions, adoption remains low, and the interaction between digital technologies and agroecological transitions is not well understood [8]. Finally, an exclusive focus on technological solutions, without addressing the broader dimensions of agriculture, risks slowing the transition toward effective agroecological practices [30].

DSSs that attempt to prescribe optimal solutions and replace farmers in decision-making are often rejected, as farmers prefer systems that assist rather than replace them [17]. Such systems should be designed to empower farmers without diminishing their decision-making role, respecting their expertise and fostering sustainable agricultural practices [30,34].

5. Adoption of Digital Tools in Agriculture

In a series of case studies exploring the impact of decision support systems (DSSs) on agricultural efficiency, various tools were assessed for their ability to optimize resource use and improve crop yields. Bonfante et al. [37] examined three DSSs—W-Tens, IRRISTAT, and W-Mod—focused on water use efficiency in maize cultivation. The results showed that W-Mod, with its six recommended irrigation events and relatively lower total water input, achieved the highest maize yield of 60.2 t ha^{-1}. In another study, researchers employed two algorithms to forecast the optimal fungicide treatment periods for controlling *Phytophthora infestans* in potatoes. Using the negative prognosis model and the Fry model, they achieved a high accuracy rate of 96% in predicting the timing of treatments, thus enhancing crop protection while minimizing chemical use [38,39].

The integration of AgroDSS with TrapView for pest monitoring in European vineyards and orchards demonstrated the potential of DSSs to improve farm management. Over two years on three farms, this combination enabled targeted interventions, increasing crop prices by 6.7% to 13.8% and reducing insecticide costs by 20.2% to 42.9% [40]. These findings highlight how DSSs enhance pest management, optimize inputs, and improve crop quality and economic outcomes. According to Chen et al. [41], the use of the Decision Support System for Irrigation Scheduling (DSSIS) in a cotton crop increased the seed cotton yield and water productivity by 32 and 20%, respectively, compared to relying solely on soil moisture sensors.

A DSS developed in India focused on optimizing fertilizer use for crops such as maize and chili. This system provided tailored fertilizer recommendations based on comprehensive soil tests, enabling farmers to reduce excess fertilizer application significantly. As a result, farmers reported substantial savings by avoiding unnecessary expenditures on fertilizers, which also contributed to maintaining soil health. Additionally, they observed an increased mean yield of approximately 6% in the maize and chili crops compared to conventional fertilizer practices, highlighting the effectiveness of the DSS in promoting sustainable agricultural practices [42]. A recent study developed a decision support system (DSS) specifically aimed at reducing food loss among lettuce growers. By enabling growers to conduct scenario analyses, the DSS facilitated the simulation of various management strategies, helping them make informed decisions that minimize waste while maintaining productivity. The results indicated that the food loss was the lowest at 8.5% when the agricultural inputs were reduced minimally, demonstrating the importance of balanced resource management in optimizing crop yields and minimizing waste [43]. Trials conducted in commercial vegetable fields in the Salinas Valley from 2012 to 2019 evaluated the effectiveness of CropManage in improving irrigation and nutrient use. In lettuce production, the amount of nitrogen fertilizer applied following CropManage's recommendations was reduced by 31% on average compared to typical grower practices, while the yields achieved were slightly higher than the one obtained through conventional methods [44]. Similarly, the GesCoN DSS was developed to enhance fertigation management in open-field vegetable crops. In trials conducted across various vegetable types, the GesCoN DSS demonstrated a significant reduction in water and fertilizer use while maintaining or increasing yields. In particular, it was found that implementing the GesCoN system led to an average reduction of 24% in seasonal irrigation water and a 7% decrease in nitrogen fertilizer application compared to conventional practices [45].

6. Future Directions

The future of DSSs in agriculture is increasingly focused on enhancing sustainability, usability, and effectiveness in decision-making processes for farmers [42,46]. As agriculture faces challenges such as climate change, resource scarcity, and the need for increased productivity, the development of advanced DSSs will be crucial. Despite their potential, DSSs' adoption remains low, highlighting the need for targeted efforts to address barriers to their implementation. Future research should investigate the return on investment for farmers adopting DSSs, considering both set-up and operational costs, alongside financial and environmental benefits. Additionally, aligning DSSs' capabilities with government agricultural policies and subsidy programs could boost adoption rates and amplify their adoption. Many case studies focus on specific crops, but further exploration is needed to determine whether these findings can be generalized to other crops or geographical regions, especially those with different climatic or economic conditions.

One major challenge is the lack of standardization in data inputs across diverse platforms, which limits the integration and interoperability of DSS tools. Furthermore, many existing DSSs lack robust evaluation frameworks to assess user experience, usability, and trustworthiness. Research indicates that usability evaluations, which are user-centric in nature, remain underdeveloped in agricultural contexts, further hindering widespread adoption [35]. The development of future DSSs should aim to consolidate all the available systems under a common platform, facilitating proactive and reactive management strategies, such as for the control of herbicide resistance weed populations. Also, it is necessary to expand the scope to include a wider range of crops, countries, ecosystem services and agroecologically based recommendations, which will enhance the relevance and effectiveness of these tools [35,47]. To ensure usability, future DSSs should prioritize user-friendly interfaces, multilingual support, and robust offline functionality, making them usable even in remote areas with limited digital literacy [48].

Future research must address these gaps while engaging directly with farmers to familiarize them with how to use DSSs and optimize their decision-making processes. Extended research and experimentation are also essential for developing effective DSSs tailored to weed management under varying soil and climatic conditions, meeting the specific needs of individual farmers. By addressing these challenges and advancing DSSs' capabilities, such as enhanced data analysis, real-time decision support, integration with climate models, and precision agriculture technologies, agriculture can move toward a more sustainable and efficient future. Further research and extended experimentation are needed to develop effective DSSs for weed management under different soil and climatic conditions, balancing the need for a broadly applicable system with the ability to adapt to the specific conditions and requirements of individual farmers. In parallel, the development and validation of DSSs more focused to agronomic practices and with an agroecological direction (like the one currently created for the ONE GREEN project) are also crucial for further adoption by the farmers and agronomists and the transition of our farming systems.

7. Conclusions

The considerable potential of digital tools, such as DSSs, in agroecology remains largely underexploited and is sometimes seen as controversial. Notably, there is a scarcity of studies in the literature that examine the practical use and real-world application of DSSs and digital tools in agroecology, highlighting the need for more in-depth, action-oriented research to better understand their effectiveness and limitations in the field. Many existing tools are tailored to specific regions or agricultural systems, and there has been limited research to assess whether these tools can be effectively applied in other contexts or geographical areas. Farmers and stakeholders may, in some cases, have access to information and knowledge through digital tools that provide them with support, but they are still unlikely to have a comprehensive understanding of agroecological applications or complete confidence in all the potential outcomes. In the long term, the successful integration of digital tools into agroecology could lead to more sustainable farming practices, greater resilience against climate change, and improved food security, benefiting both farmers and ecosystems. Digital tools and decision support systems are undeniably means for the agroecological transition, but they cannot be the only means. Demonstration events for agroecological practices, educational workshops and even financial assistance are equally important to encourage the widespread adoption of agroecological practices. The present review offers insights into the intersection between digital agriculture and agroecological principles, underscoring the need for more research to explore the synergies and tensions between technological innovation and sustainability. By identifying the barriers to adoption and offering actionable recommendations for further development, this study aims to guide future research and inform policy and practice, ensuring that digital tools can more effectively support the agroecological transition.

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