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The Role of Information Technology in Improving Resource Management Efficiency in Sustainable Agriculture

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ABSTRACT

Agriculture is one of the key sectors in the global economy that plays a key role in feeding the world's growing population. However, the agricultural sector is also faced with serious challenges, including climate change, environmental degradation, increasing demand for food, and pressure on natural resources. This research aims to analyse the role of IT in improving resource management efficiency in sustainable agriculture. This research is a literature review that adopts a qualitative method approach, which means it will analyse and interpret data by relying on information and text from various sources. The study results show that the role of information technology in improving resource management efficiency in sustainable agriculture cannot be ignored. Information technology enables farmers to better manage natural resources, optimise agricultural production, reduce negative impacts on the environment, and face challenges associated with climate change and global markets.

Keyword: Information Technology, Efficiency, Resource Management, Sustainable Agriculture

INTRODUCTION

Agriculture is one of the key sectors in the global economy that plays a key role in feeding the world's growing population (Pawlak & Kołodziejczak, 2020). As the main engine of food fulfilment, the agricultural sector serves not only as a food provider, but also as a vital foundation for economic stability and global food security. However, in fulfilling its important role, the agricultural sector is not immune to serious challenges that are increasingly complex and profound (Rozaki, 2021). These challenges include continued climate change, which affects weather patterns and agricultural productivity, and potentially threatens global food security. In addition, environmental damage caused by unsustainable agricultural practices is also a critical issue, such as deforestation, soil erosion and water pollution. Not only that, with the world's population continuing to grow, the demand for food is increasing significantly (van Dijk et al., 2021). This increased demand brings additional pressure on the agricultural sector to increase production sustainably without compromising environmental quality. This creates demands for innovations in farming practices, the use of more advanced technologies, and policy changes that favour sustainable agriculture. In addition, there is growing pressure on the natural resources used in agriculture, such as land, water and energy. The utilisation of these resources must be carefully considered so as not to over-stretch them, so that agriculture can continue to be sustainable in the long term.

To address these challenges and ensure the viability of the agricultural sector, there needs to be a serious effort to develop a more sustainable agriculture. This means that food production must be able to meet the needs of future generations without damaging limited natural resources. Investments in research and innovation are needed to improve the efficiency of agricultural

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production, reduce environmental impacts, and promote sustainable agricultural practices (Blakeney, 2022). As such, agriculture should be a leading example in realising sustainable development that not only ensures the sustainability of natural resources, but also safeguards global food security and the well-being of the world's growing population.

Efficiency in resource management in the agricultural sector plays an undeniably central role in achieving the vision and mission of sustainable agriculture (Bobitan et al., 2023), which is a goal that is highly sought after. This process of resource management involves the optimal utilisation of various crucial elements, such as water, soil, energy and other inputs, which together comprise the basic framework of efficient and sustainable agricultural production. The importance of efficiency in resource management cannot be overlooked, as it has a major impact on agricultural productivity, food security and the environment (Steenkamp et al., 2021). In an increasingly complex and rapidly changing era, ensuring that available resources are utilised appropriately is an indispensable strategic move.

One of the key instruments that has proven to be an important proponent of improving the efficiency of resource management in agriculture is the use of Information Technology (IT), which is undergoing rapid development. The integration of IT in farming operations provides a highly effective tool to monitor, manage and optimise the use of these diverse resources (Subeesh & Mehta, 2021). The application of IT in agriculture enables smarter and more accurate decision-making through in-depth data analysis and real-time monitoring. With the help of this technology, farmers and agricultural businesses can more precisely determine the amount of water required by crops, manage nutrients and fertilisers more efficiently, and plan for optimal energy use (Dhanaraju et al., 2022). In addition, IT also facilitates inventory management, weather monitoring, as well as crop growth monitoring, all of which contribute to the overall improvement of farm operational efficiency. Therefore, in order to achieve sustainable agriculture that meets the needs of the future without compromising on natural resources, the adoption of Information Technology (IT) is a very important and impactful step in formulating effective solutions for better management of agricultural resources. These technologies bring hope for increased efficiency, productivity and sustainability, taking agriculture towards a brighter future.

In the ongoing transformation tactics in the agriculture sector, Information Technology (IT) has emerged as one of the major forces exerting profound influence. The rapid development in the world of technology has led IT to become an essential element in achieving significant evolution in the agricultural sector. The critical role of IT in various aspects of agricultural resource management cannot be underestimated, as it opens up tremendous opportunities to improve efficiency, productivity and sustainability (Xie et al., 2019). Firstly, IT acts as a reliable partner in weather monitoring and prediction. With advanced software and connected sensors, farmers now have the ability to monitor weather conditions in real-time and access accurate weather predictions (Huang et al., 2020). This is an important foundation for smarter agricultural decision-making, such as organising irrigation based on weather forecasts, scheduling planting more precisely, and determining effective measures to maintain agricultural productivity that is highly linked to weather fluctuations.

Furthermore, IT enables the implementation of smart and automated irrigation systems (Obaideen et al., 2022). These systems can be connected with various sensors that monitor soil moisture levels and respond by regulating irrigation according to crop needs. In this way, water use can be significantly optimised, creating a more efficient and sustainable farming environment. Efficient fertiliser use is also enhanced by IT. Through in-depth soil data analysis, TI can provide highly precise recommendations on the type and amount of fertiliser that should be used for each crop (Bijay-Singh & Craswell, 2021). This not only reduces wastage of resources, but also reduces the impact of environmental pollution as fertilisers are applied according to the needs of the crop.

Not only that, technological advancements have introduced drone-based agricultural monitoring and other aerial monitoring technologies (Shah et al., 2023). This provides a more comprehensive view of farm conditions, helps in detecting crop problems or pest threats earlier, and assists in optimising overall farm planning. Besides being effective in the operational aspects of farming, IT is also becoming an invaluable tool in production and distribution management. IT

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systems can assist farmers in production planning, inventory management, and access to a wider market through e-commerce platforms or applications that facilitate direct links between producers and consumers (Glaros et al., 2023). Last, but not least, IT paves the way for more accurate resource tracking and farm carbon footprint monitoring. With the help of these technologies, farms can measure their environmental impact more effectively, which then becomes the basis for developing and implementing more sustainable farming practices. Thus, it can be concluded that the role of IT in the transformation of the agricultural sector is a key element that strengthens the vision of sustainable agriculture. IT is not just a tool, but a driving force that helps move forward towards more efficient, productive and sustainable agriculture (Altieri et al., 2017).

In this context, research on "The Role of Information Technology in Improving Resource Management Efficiency in Sustainable Agriculture" is highly relevant. This research will discuss how IT can be used to improve efficiency in agricultural resource management, increase agricultural productivity, and overall support sustainable agriculture. Through this research, we can identify the potential and challenges in the application of IT in agriculture, as well as develop recommendations and guidelines for farmers and other stakeholders to maximise the benefits of IT in supporting sustainable agriculture.

LITERATURE REVIEW

Information Technology

Information Technology (IT) refers to the various technologies used to collect, store, process, transmit, and manage information (Harahap, Kraugusteeliana, et al., 2023; Prastyaningtyas et al., 2023; Sutrisno, Ausat, et al., 2023; Wahyoedi et al., 2023). It includes hardware and software along with the infrastructure, networks, and systems used to facilitate data processing and exchange (Harahap, Ausat, et al., 2023; Harahap, Sutrisno, et al., 2023; Sutrisno, Kuraesin, et al., 2023; Touriano et al., 2023). Information Technology is one of the very important aspects of the modern world and plays a major role in various areas of life, including business, education, health, entertainment, and more (Azzaakiyyah et al., 2023; Diawati, Gadzali, Abd Aziz, et al., 2023; Kraugusteeliana et al., 2022; Mahardhani, 2023; Ohara, 2023; Said Ahmad et al., 2023). Here are some of the main components of Information Technology:

1. Hardware: This includes all physical devices such as computers, servers, laptops, smartphones, tablets, printers, computer networks, storage devices (such as hard disks and SSDs), communication devices (routers, modems), and other hardware used to process and store information (Ausat, 2023; Suherlan, 2023; Wanof, 2023).
2. Software: Software are computer programmes that perform a variety of tasks, ranging from word processors and spreadsheets to operating systems, graphic design software, banking applications, security software and more. Software enables hardware to perform certain functions and process data.
3. Computer Network: This includes the infrastructure and technologies that allow computer devices to communicate and share data with each other. Computer networks include the internet, corporate intranets, and local networks (LANs), all of which connect computer devices of various scales.
4. Information System: This is a combination of hardware, software, and procedures designed to collect, manage, store, and retrieve information. Information systems can include databases used to store data, as well as applications used to manipulate that data.
5. Information Security: This is an important aspect of IT that involves protecting data and information from threats, theft, or unauthorised access. Information security involves practices such as data encryption, firewalls, and antivirus software.
6. IT Project Management: This is the discipline concerned with the planning, execution, and supervision of IT projects. IT project management ensures that these projects are successful in line with set objectives and timelines.
7. Cloud Technology: Cloud computing services allow organisations and individuals to store data and run applications on servers located in external data centres, allowing access from anywhere with an internet connection.

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Information Technology plays a key role in changing the way we work, communicate, and live on a daily basis. It has transformed business, education, healthcare, entertainment, and more, providing the ability to access and utilise information more efficiently and effectively.

Efficiency

Efficiency is a concept that refers to the optimal level of productivity, performance, or use of resources in achieving a particular goal (Ausat, Rachman, et al., 2023; Sudirjo et al., 2023). In general, efficiency measures the extent to which a system, process, or organisation can achieve its desired results using a minimal amount of resources (Muhamad et al., 2023; Satriadi et al., 2022; Sutrisno, Sitinjak, et al., 2023). In a broader context, efficiency is about doing more with less. There are several ways to explain efficiency, including:

1. Resource Utilisation: Efficiency is often measured in terms of the use of resources such as time, labour, money, or raw materials. If a process or system can achieve the same or better results using fewer resources, it is considered a more efficient process.
2. Time: Efficiency can mean completing tasks in less time. For example, in a production environment, if a factory can produce more products in the same time or even less time, it is considered a more efficient factory.
3. Cost: Efficiency is also often measured in terms of cost. Organisations or individuals that can achieve the same results at a lower cost are considered more efficient. This can include reduced operating costs, savings in the use of raw materials, or reduced labour costs.
4. Quality: Efficiency does not necessarily mean achieving results at a lower cost or time; it can also mean achieving better results. For example, if a product or service can improve its quality without significantly increasing production costs, it is considered an efficiency improvement.
5. Output: Efficiency can be measured by observing the output or result of a process or system. If a greater amount of output can be obtained from the same input, it indicates an increase in efficiency.

Efficiency is one of the important goals in various contexts, including business, industrial production, government, and even in daily life. By improving efficiency, organisations or individuals can save resources, reduce waste, improve competitiveness, and achieve better results overall. Therefore, efficiency is often the focus of process improvement and management efforts.

Resource Management

Resource Management is the process of planning, organising, managing, and supervising all types of resources available in an organisation or system to achieve predetermined goals (Diawati, Gadzali, Mahardhani, et al., 2023; Gadzali et al., 2023; Rustiawan et al., 2023). These resources can be human resources (manpower), financial, physical, technological, time, and various other elements used to support the operations and activities of the organisation (Ausat, Risdwiyanto, et al., 2023; Diawati, Gadzali, Abd Aziz, et al., 2023; Kamar et al., 2022). Resource management is an integral part of overall management and is critical in optimising organisational performance and efficiency (Purnomo, 2023; Rijal, 2023; Salamah, 2023; Sari, 2023; Sudirjo, 2023; Sukenti, 2023). Here are some key aspects of resource management:

1. Human Resource (HR) Management: This involves recruiting, training, developing, motivating, and managing an organisation's workforce. HR management seeks to ensure that the organisation has competent and high-performing staff to achieve its strategic goals.
2. Financial Management: This covers the management of an organisation's financial assets, including budget planning, accounting, financial reporting, debt and investment management, and financial risk management.
3. Physical Resource Management: This involves managing the organisation's physical assets, such as facilities, equipment, and property. The aim is to ensure that these physical resources are used efficiently and contribute to the organisation's productivity.
4. Information and Technology Management: This covers the management of information systems and technology within the organisation, including IT infrastructure, software, and data. The goal is to utilise technology to improve the efficiency and effectiveness of operations.

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5. Time Management: Time management is about planning and optimal allocation of time for specific activities. It includes scheduling, prioritising, and setting timeframes to achieve the organisation's tasks and projects.
6. Natural Resource Management: In the context of agriculture and the environment, natural resource management involves managing land, water, energy, and other natural resources in a sustainable and environmentally friendly manner.
7. Inventory Management: This involves managing stocks of goods or raw materials used in the production or operations of an organisation. The aim is to avoid stock shortages or wastage.
8. Project Management: In projects, resource management involves the allocation of resources such as labour, time, and budget to achieve the project objectives within the set time limit and budget.

Resource management is one of the key components in achieving organisational success. It involves wise decision-making, efficient resource allocation, sound planning, and careful supervision to ensure that resources are used to the best of their ability to achieve organisational goals effectively and efficiently.

Sustainable Agriculture

Sustainable Agriculture is an agricultural system that is designed and operated with attention to its long-term environmental, social, and economic impacts (Velten et al., 2015). The main goal of sustainable agriculture is to fulfil food, raw materials, and economic needs while maintaining and improving ecosystem health, social welfare, and agricultural productivity in the long term (Çakmakçı et al., 2023). The concept attempts to address challenges such as climate change, soil and water degradation, and the economic sustainability of agriculture (Gomiero, 2016). Some of the key characteristics of sustainable agriculture include:

1. Environmental Balance: Sustainable agriculture strives to maintain the balance of natural ecosystems. This includes good soil preservation, wise use of water, and reduction of pollution and environmental damage.
2. Conservation of Natural Resources: Sustainable agriculture focuses on the conservation of natural resources such as soil, water, and biodiversity. This involves practices such as restoration of degraded soils, planting of cover crops, and efficient use of irrigation.
3. Judicious Use of Inputs: Sustainable agriculture seeks to reduce the use of chemical inputs such as pesticides and artificial fertilisers by using organic or environmentally friendly techniques.
4. Agricultural Diversification: Agricultural diversification is the practice of growing different types of crops or animals in a field. This can increase the farm's resilience to changes in weather and disease and reduce the risk of yield loss.
5. Local Community Empowerment: Sustainable agriculture seeks to improve the social and economic well-being of farming communities. This can include agricultural education, access to markets, and local economic empowerment.
6. Technological Innovation: Modern technology also plays a role in sustainable agriculture, such as the use of sensors to manage water and fertiliser more efficiently, or the use of data and analytics to improve productivity.
7. Resilience to Climate Change: Sustainable agriculture tries to address the challenges of climate change by developing practices that are more resilient to a changing climate, such as selecting crop varieties that are resistant to heat and drought.

Sustainable agriculture aims to maintain and increase agricultural productivity over the long term without damaging natural resources or compromising social welfare. It is an important approach in dealing with global challenges such as food security, climate change and environmental conservation.

RESEARCH METHOD

This research is a literature review that adopts a qualitative approach, which means it will analyse and interpret data by relying on information and texts from various sources. The main focus of a qualitative literature review is to collate, evaluate and integrate existing knowledge on the topic

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under study, namely the role of IT in improving resource management efficiency in sustainable agriculture. In this research, data will be collected from various sources relevant to the topic under study, such as scientific journals, books, research reports, and other articles. The data period covers the time from 2014 to 2023, which allows the researcher to see developments, trends, and changes that have occurred during this period.

The qualitative approach in the literature review allows researchers to describe and characterise complex and multidimensional issues in greater depth (Elo et al., 2014). In addition, this method makes it possible to involve multiple sources of information and cover a range of different viewpoints, thus enriching the analysis and strengthening the validity of the findings. The data collection process will involve meticulous text analysis, searching for information, and categorising relevant data for the research topic. Subsequently, the author will collate this information in a structured format, compare and synthesise findings from multiple sources, and identify patterns, themes and trends that emerge from the collected data.

One of the advantages of a qualitative literature review is its flexibility in understanding and explaining complex phenomena, as it is not limited by numerical or statistical constraints (Rahman, 2016). This method also allows researchers to gain deep insights into how the topic under study has evolved over time, as well as how concepts and understandings of the topic have changed over the years. In this research, it is important to scrutinise the reliability and credibility of the sources used, as well as critically analyse the information collected. With a qualitative approach, the researcher must be able to present findings objectively and reflectively, provide clear and accurate interpretations, and recognise the limitations of the methods and data used (Bradshaw et al., 2017). The conclusion of this research will hopefully provide a comprehensive picture of the development of the topic under study over the 2014 to 2023 time period, and may also provide recommendations for further research that can broaden the understanding of issues related to the topic.

RESULTS AND DISCUSSION

The rapid development of information technology in recent decades has brought about inevitable changes in a large number of sectors of the economy, and it is no surprise that the agricultural sector has also participated in these changes. Information technology is not just a complement, but has actually become the foundation that supports substantial evolution in the agricultural landscape (Roztocki et al., 2019). The role of information technology in improving the efficiency of resource management in the context of sustainable agriculture is no longer something that can be ignored, but has developed into one of the key factors that are integral in driving the progress of the agricultural sector towards a more sustainable, productive and competitive future (Siebrecht, 2020). With its widespread and mature implementation, information technology is not just a tool, but a key pillar that enables agriculture to better respond to global challenges and provide innovative solutions that lead to a more sustainable and efficient agriculture in meeting the evolving needs of the world community.

Agriculture, as one of the key pillars supporting the continued existence of humans on this planet, plays a central role in fulfilling the basic human need of food. Agriculture is a productive machine that plays a major role in creating the inevitable food supply for human survival around the world (Giller et al., 2021). However, in line with this pivotal role, agriculture is also faced with the unenviable challenge of maintaining its productivity while trying to minimise negative impacts on an increasingly deep and complex environment. These challenges range from ongoing climate change to environmental degradation issues, and from increasing food demand to intensifying pressure on the natural resources used in agriculture. All of these challenges are at the centre of ensuring that agriculture continues as a key driver of meeting the world's food needs without compromising the balance of ecosystems and natural resources.

In the face of these challenges, Information Technology (IT) has taken centre stage as an essential tool in helping to address the diverse complexities facing the agricultural sector (Khan et al., 2021). IT is no longer just a tool, it has become an integral part of modern sustainable agriculture

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strategies. With the help of these technologies, farms can more intelligently manage resources, monitor and predict weather changes, optimise water and energy use, and reduce environmental impacts with more efficient and accurate management. As the integration of IT deepens in agricultural operations, the sector is increasingly able to address challenges, adopt more sustainable practices and develop innovative solutions that lead to a more productive, sustainable and competitive future for agriculture. Thus, the role of IT in the context of agriculture is not just to assist, but also to become a central element that drives agriculture towards a more sustainable direction, so as to maintain the world's food supply without compromising the environment that we inherited from previous generations (Borsellino et al., 2020).

One aspect that stands out in the concept of sustainable agriculture is the wise management of natural resources, which is a major milestone in maintaining a balance between agricultural productivity and environmental preservation. Amidst the complexity of challenges facing the agricultural sector, information technology has emerged as a key element that opens up tremendous opportunities in the pursuit of sustainable agriculture. The use of information technology enables farmers and stakeholders in the agricultural sector to collect and analyse highly detailed data on various aspects that affect agriculture, such as soil conditions, climate change and adjacent environmental factors (Balafoutis et al., 2020). With the help of advanced sensors, high-flying drones and Internet of Things (IoT)-based devices, real-time information can be collected continuously, providing a clearer and more in-depth view of such factors. For example, data collected through soil sensors enables constant monitoring of soil moisture, and water quality data can be analysed to understand the impact of agriculture on the local water environment. In addition, information on air temperature and other parameters relevant to agricultural production can also be accessed easily through available information technology infrastructure (Wang et al., 2021). All this information is invaluable in informing farmers' decisions. With a better understanding of these conditions, farmers can take smarter and more targeted decisions in the use of resources such as water, fertilisers and pesticides. This helps to reduce waste of valuable resources, improve efficiency in farming operations, and ultimately, strengthen the foundation of sustainable agriculture. In other words, information technology has become a transformational tool in supporting sustainable agriculture by providing farmers and stakeholders in agriculture with deeper insights, accurate information, and the ability to take smarter actions (Dayioglu & Turker, 2021). Thus, through the widespread application of information technology, the agricultural sector has taken an important step in addressing global challenges while maintaining the increasingly important balance of nature.

In addition to the benefits already mentioned, it is worth emphasising that information technology also paves the way for the adoption of highly sophisticated and indispensable precision farming practices. Precision farming practices pursue a remarkable level of accuracy in every action taken on the farm, thereby delivering optimal results (Lencsés et al., 2014). For example, by utilising highly advanced GPS devices and specialised software, farmers have the ability to map their farmlands to an incredible level of detail. This allows them to pinpoint the exact locations that require specific pesticide spraying or fertiliser application. As a result, there is no more wastage of valuable resources such as fertilisers or pesticides, as only the areas that truly require treatment receive such treatment. These precision farming practices result in very high efficiency in the use of resources, which in addition to reducing production costs also has a very significant positive impact on the environment. In other words, precision farming practices driven by information technology are not only economically beneficial for farmers, but are also an important step in maintaining environmental sustainability (Lindblom et al., 2017). In the context of sustainable agriculture, the role of information technology as a catalyst for precision farming practices is becoming increasingly vital in ensuring that our agriculture not only continues, but also thrives in a more efficient and environmentally friendly manner.

If we look deeper, it needs to be recognised that information technology has not only had a significant impact in the management of natural resources on farms, but has also played a key role in changing the overall agricultural supply chain management paradigm. The sophisticated information systems available today allow farmers to run their operations with a level of precision

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and efficiency that was previously difficult to imagine (Saiz-Rubio & Rovira-Más, 2020). In the context of agricultural supply chain management, information technology enables farmers to take highly informed strategic steps. They can monitor their stocks with great accuracy, identify ongoing market trends, and better plan their production, taking into account factors such as weather, market demand, and seasonal changes. With these advanced information systems in place, wastage of resources can be avoided, as agricultural production can be tailored to actual market demand. This means that agricultural products reach the market at the right time and under optimal conditions, resulting in greater economic benefits for farmers, consumers and the entire supply chain. In addition, through information technology, it is possible to track products from the farm to the consumer with great accuracy (Gabriel & Gandorfer, 2023). This opens up opportunities for increased transparency and food safety, as consumers can better trace the origin of products, which also provides additional benefits in terms of consumer confidence in the agricultural products they purchase. In other words, information technology has brought about a revolution in agricultural supply chain management, helping actors in the sector to operate more efficiently, reduce wastage and improve overall sustainability. Therefore, the role of information technology in agriculture is not just about increasing productivity, but also about strengthening the bond between farmers and markets, which in turn provides significant benefits to sustainable agriculture (Mwangi & Kariuki, 2015).

The application of information technology has not only had a positive impact on previous aspects of the agricultural sector, but also opened new doors in agricultural risk management (Patel & Sayyed I.U, 2014). In this context, information technology provides farmers with a very powerful tool to deal with the uncertainties inherent in agriculture. With better access to real-time weather data, farmers have the ability to monitor current weather conditions and future forecasts more accurately (Hachimi et al., 2022). This allows them to take more proactive measures in protecting their crops from potential natural disasters such as floods, droughts, or pest attacks. For example, they can adjust irrigation systems based on weather forecasts, or apply crop protection if needed. In addition, information technology also gives farmers the tools to better keep up with market developments. With access to continuously updated market information in real-time, they can monitor price fluctuations and demand trends. With this information, they can make smarter decisions in terms of sales and marketing strategies, which in turn can help them optimise their profits. Thus, the application of information technology not only provides benefits in terms of operational efficiency and farm sustainability, but also enhances farmers' ability to manage risks and deal with uncertainties inherent in agriculture (Monteiro et al., 2021). This is an important step in maintaining the stability and long-term viability of the agricultural sector.

The proven benefits in terms of efficiency that information technology brings to the agricultural sector are a clear first step in steering agriculture towards a more sustainable business model (Vrchota et al., 2022). However, it is important to note that information technology also opens up wider and more fundamental opportunities in the transformation of the sector. With advances in information technology, agriculture now has the ability to develop more sustainable business models across the board. One particularly relevant example is farmers' access to e-commerce platforms and wider distribution networks. This allows them to sell their products directly to end consumers, reducing dependence on middlemen in the supply chain. This move not only results in economic efficiency, but also opens the door to increased farmer income. Furthermore, reducing dependence on middlemen also has a positive impact on sustainable agriculture (Sudrajat et al., 2021). Farmers are more incentivised to keep investing in environmentally-friendly and sustainable farming practices. This is because they have greater control over their products and the prices they receive. In other words, it creates a positive cycle where sustainable farming practices not only benefit the environment, but also result in better profits for farmers, who in turn maintain and improve the practices. Thus, information technology is not just about efficiency, but also about fundamentally changing the way the agricultural sector operates (Berti & Mulligan, 2016). This opens up huge opportunities to achieve a more sustainable, productive and competitive agriculture, which will ultimately deliver greater benefits to all stakeholders, from farmers to consumers and the environment.

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In the quest to continuously improve the efficiency of resource management in sustainable agriculture, we must understand that innovations in information technology have an irreplaceable role to play. As we look towards a smarter and more sustainable future for agriculture, one of the most important steps is to expand the use of intelligent systems based on artificial intelligence (AI) and apply increasingly sophisticated data analytics. The development of AI-based intelligent systems provides great potential to support farmers in making smarter and more informed decisions (Karunathilake et al., 2023). With the ability to analyse data in greater depth and generate more accurate insights, these systems can provide invaluable guidance in various aspects of farming, from water management to the selection of optimal crop varieties. This will help farmers optimise productivity without damaging important natural resources. In addition to technological innovation, investment in training and providing access to information technology for farmers around the world also plays a very important role. Especially in developing countries, where agriculture is often the main livelihood, providing appropriate training and providing access to information technology will have tremendous benefits. This will help farmers at all levels of society to adopt more sustainable and efficient agricultural practices (Azzaakiyyah, 2023; Sutrisno, 2023). With this comprehensive approach, we can create an ecosystem that supports sustainable agriculture, harness the limitless potential of information technology, and ensure that the benefits can be enjoyed by farmers around the world, supporting the vision of smarter and more sustainable agriculture for the future.

In conclusion, it is undeniable that information technology plays a very important and multidimensional role in accelerating the improvement of resource management efficiency in the context of sustainable agriculture. With the various possibilities it offers, information technology is able to have a profound positive impact on various aspects of the agricultural sector. First of all, information technology enables better management of natural resources by providing a deeper understanding of the factors that affect agricultural ecosystems. This includes real-time weather monitoring, sophisticated soil data analysis and relevant environmental information. All these provide a stronger foundation for sustainable decisions in the use of water, energy and other inputs in agriculture. Furthermore, in terms of supply chain management, information technology creates opportunities for more efficient management. With access to more accurate market information, farmers can better plan their production, avoid wasting resources, and ensure that agricultural products reach the market at the right time and under optimal conditions. Not only that, information technology also supports better risk management. With accurate weather information and other risk data monitoring, farmers can take more informed actions to protect their crops from natural disasters and other threats. This helps reduce uncertainty in farmers' income. Last, but not least, information technology enables the shift to more sustainable business models in agriculture. Farmers' access to e-commerce platforms and wider distribution networks allows them to sell their products directly to consumers, reducing dependence on middlemen and increasing their profits. This creates a strong incentive to keep investing in sustainable agricultural practices. Overall, the role of information technology in sustainable agriculture is diverse and highly significant. By enabling better natural resource management, more efficient supply chain management, better risk management and more sustainable business models, information technology serves as a catalyst to move agriculture forward in a more sustainable, productive and competitive direction. It is the key to meeting the world's growing food demands while maintaining a balance with nature that is increasingly important.

CONCLUSION

The role of information technology in improving resource management efficiency in sustainable agriculture cannot be overlooked. Information technology enables farmers to better manage natural resources, optimise agricultural production, reduce negative impacts on the environment, and face challenges associated with climate change and global markets. In addition, information technology also opens up new opportunities in the agricultural business that are more sustainable and competitive. Therefore, suggestions that can be given for the results of this research include:

a) Invest in Technology Infrastructure: Governments, non-profit organisations, and the private sector need to collaborate to ensure farmers have adequate access to information technology infrastructure, including internet connectivity, hardware, and necessary software. This will help farmers in different regions to better adopt information technology.
b) Training and Education: Training and education programmes need to be improved to ensure farmers have sufficient understanding on how to use information technology effectively. This could include training in the use of sensors, IoT devices, data analytics, and AI-based smart systems.
c) Financial Support: Providing financial support to farmers to invest in information technology can be an important step. This could be assistance in purchasing the necessary hardware or software or even incentive programmes for technology adoption.
d) Inter-Farmer Collaboration: Encouraging collaboration between farmers, both locally and internationally, can help in sharing knowledge and experience in using information technology. This can accelerate technology adoption and allow farmers to learn from each other.
e) Continuous Innovation: Information technology is constantly evolving, and it is important to continue to encourage innovation in this regard. Investment in research and development of information technology for sustainable agriculture should be increased.
f) Supervision and Regulation: The government also needs to play a role in regulating the use of information technology in agriculture to ensure data security and safeguard the environment. Proper regulation can ensure that information technology is used ethically and sustainably.

By implementing these suggestions, we can ensure that information technology continues to provide great benefits in improving the efficiency of resource management in sustainable agriculture. This will help fulfil the world's growing need for food while maintaining environmental sustainability and generating economic benefits for farmers.

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