APPLICATION OF MODERN TECHNIQUES IN AGRICULTURE PRODUCTION: A COMPREHENSIVE REVIEW

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Abstract

Agriculture production has become increasingly dependent on the application of modern techniques to improve productivity, sustainability, and efficiency. In this mini-review paper, we review the various modern agricultural techniques, including genetic engineering, precision agriculture, and smart farming, and how they can be applied to agriculture. In the introduction, it emphasises the importance of modern techniques to address the challenges faced by agriculture, such as global food demand, limited resources, and environmental concerns. The paper then delves into the specific techniques, starting with genetic engineering. The paper then describes genetic engineering techniques and tools in detail, including transgenic technology and genome editing techniques such as CRISPR-Cas9. The review discusses several applications of genetic engineering in agriculture, including disease control and resistance, crop enhancements, and environmental sustainability. As a next step, the review examines precision agriculture, which utilises remote sensing, GPS, and drones to improve farming practices. Among the key applications of precision agriculture in agriculture production are precision seeding, precise nutrient and water management, and effective weed control. As well, the paper discusses the concept of smart farming, which utilises technologies such as the Internet of Things and data analytics. The article discusses the application of smart farming to agriculture production, including livestock management, crop monitoring, and efficient resource utilization. In addition, the article examines the advantages and challenges associated with the adoption of modern farming techniques. We evaluate the advantages of increased productivity, reduced environmental impact, and optimized resource utilization, along with potential drawbacks and considerations of economic, environmental, and social consequences. The aim of this mini-review paper is to highlight the importance of adopting modern farming techniques to meet the demands of a rapidly changing society.

Keywords: - Modern Techniques, Agriculture Production, IOT, GPS**,** CRISPR-Cas9

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1. Introduction:

Modern techniques in agriculture have indeed revolutionized the industry, offering innovative solutions to address various challenges and improve productivity. Nanotechnology, for instance, has shown promising applications in precision agriculture, aiding in crop protection and enhancing plant growth (Shang et al., 2019). Additionally, the integration of modern technology, such as deep learning and the Internet of Things, has led to the development of intelligent agriculture, promoting efficient resource utilization and overall agricultural development (Li et al., 2021; Sun et al., 2022). Furthermore, the use of modern agricultural techniques, including precision agriculture management systems and the application of unmanned aerial vehicles, has demonstrated effectiveness in enhancing sustainability and productivity in small farms (Loures et al., 2020).

Moreover, the modernization of agriculture has been recognized as a crucial tool for economic transformation and poverty alleviation in rural areas (Курманова et al., 2021). The evolution of agricultural drainage techniques, from ancient practices to modern methods, has significantly contributed to efficient agriculture and the preservation of biodiversity (Yannopoulos et al., 2020; Valipour et al., 2020). Furthermore, the selective integration of modern agricultural techniques with traditional agroecological systems has been shown to enhance soil fertility and agricultural productivity, demonstrating the potential for sustainable agricultural development (Faye, 2020).

It is evident that modern techniques in agriculture have the potential to address various challenges, improve productivity, and contribute to the overall sustainability and development of the agricultural sector. By leveraging advancements in technology and innovative approaches, modern agriculture is poised to meet the demands of a rapidly evolving global landscape while ensuring sustainable and efficient agricultural practices.

2. Overview of Modern Techniques in Agriculture Production

The integration of modern techniques in agriculture, such as genetic engineering, precision agriculture, and smart farming, has significantly transformed the agricultural landscape, offering innovative solutions to address various challenges and enhance productivity. Genetic engineering has revolutionized targeted breeding of crops, leading to increased productivity and adaptation to large-scale farming practices (Pixley et al., 2019). Precision agriculture, on the other hand, has enabled the efficient utilization of resources through the application of advanced technologies such as wireless sensor networks and unmanned aerial vehicles, promoting sustainable and precise farming practices (Panchasara et al., 2021; Al-Khowarizmi et al., 2022). Furthermore, smart farming has emerged as a key enabler of agricultural modernization, leveraging digital technologies and data-driven approaches to optimize production processes and enhance agricultural efficiency (Saad et al., 2021; Islam et al., 2022).

The benefits and potential applications of these modern techniques are extensive and impactful. Genetic engineering has facilitated the development of disease-resistant crops, increased crop yields, and reduced the use of pesticides and insecticides, contributing to sustainable agricultural practices (Pixley et al., 2019; Sharma et al., 2022). Precision agriculture has demonstrated its potential in enhancing crop quality, optimizing irrigation, and minimizing environmental impact through precise resource management (Panchasara et al., 2021; Al-Khowarizmi et al., 2022). Moreover, smart farming technologies have the potential to revolutionize agricultural practices by enabling real-time monitoring, automation of farming processes, and data-driven decision-making, ultimately leading to increased productivity and resource efficiency (Saad et al., 2021; Islam et al., 2022).

The application of modern techniques in agriculture is not only limited to traditional farming practices but also extends to urban environments through concepts such as vertical farming and indoor agriculture. These approaches offer sustainable solutions for food production in urban areas, addressing the challenges of limited space and environmental impact ("Investigating the potential of vertical farming and indoor agriculture for sustainable food production in urban areas", 2023; Langendahl, 2021). Additionally, the adoption of digital skills and IoT-based systems in agriculture has the potential to optimize production processes, accelerate the production cycle, and facilitate market access, contributing to overall agricultural development (Hasan et al., 2023; Park & Park, 2019).

In conclusion, the overview of modern techniques in agriculture production highlights the transformative impact of genetic engineering, precision agriculture, and smart farming on agricultural practices. These techniques offer a wide range of benefits, including increased productivity, resource efficiency, and sustainability, with potential applications in both traditional and urban farming environments. The integration of these modern techniques is essential for meeting the growing demands of a rapidly expanding global population and ensuring the sustainable development of the agricultural sector.

3. Application of Genetic Engineering in Agriculture Production

Genetic engineering has indeed emerged as a pivotal tool in modern agriculture, offering innovative techniques and tools to enhance crop traits, improve productivity, and address various agricultural challenges. Two prominent genetic engineering techniques that have revolutionized agriculture are transgenic technology and genome editing techniques, such as CRISPR-Cas9.

Transgenic technology involves the introduction of foreign genes into the genome of an organism, leading to the expression of desired traits. This technique has been instrumental in developing disease-resistant crops, increasing crop yields, and reducing the use of pesticides and insecticides, thereby contributing to sustainable agricultural practices Esmaeili et al. (2022). Furthermore, transgenic technology has shown potential in improving abiotic stress tolerance in plants, highlighting its role in securing food and fiber supply in the face of a rapidly changing climate and decreasing land and water availability for food production.

On the other hand, genome editing techniques, particularly CRISPR-Cas9, have garnered significant attention for their precision and efficiency in targeted genetic modifications. CRISPR-Cas9 enables the precise modification of specific genes, offering opportunities to improve nutritional quality, post-harvest shelf life, and stress tolerance of fruits, vegetables, and ornamentals (Sharma et al., 2023). Additionally, CRISPR/Cas9 has been discussed in detail for its applications in crop refinement strategies, emphasizing its potential in addressing the limitations and major challenges in grains, vegetables, and fruits (Naik et al., 2022).

The benefits and potential applications of genetic engineering in agriculture are extensive. These techniques have the potential to contribute to disease-resistant crops, enhance nutritional quality, improve post-harvest shelf life, and increase stress tolerance in various agricultural crops (Saravanan et al., 2022). Furthermore, genetic engineering plays a crucial role in accelerating genetic gain related to yield, stress resilience, and nutritional quality, thereby contributing to sustainable agricultural production (Bhowmik et al., 2021). The application of genetic engineering in agriculture is not only limited to crop improvement but also extends to addressing food security challenges, reducing pre- and post-harvest yield losses, and promoting sustainable agricultural practices.

In conclusion, genetic engineering techniques, including transgenic technology and genome editing techniques such as CRISPR-Cas9, have significantly advanced agricultural practices, offering solutions to enhance crop traits, improve productivity, and address agricultural challenges. The potential applications of these techniques in agriculture are vast, ranging from disease resistance and stress tolerance to nutritional quality and post-harvest shelf life, thereby contributing to sustainable agricultural development.

3.1 Applications of genetic engineering

Applications of genetic engineering in agriculture production encompass a wide array of benefits, including disease resistance and control, enhanced crop traits, and environmental sustainability. These applications have been facilitated by various genetic engineering techniques and tools, such as transgenic technology and genome editing techniques like CRISPR-Cas9.

Disease resistance and control have been significantly enhanced through genetic engineering, with the development of disease-resistant crops and the improvement of plant immunity. The use of seed nano-priming, for instance, has been shown to improve the quality of seeds and increase resistance against stress conditions, contributing to disease resistance in agriculture Pereira et al. (2021). Additionally, the development of low-phytate crops through genetic engineering has been a focus, aiming to address the challenge of developing high-yielding, stress-tolerant low-phytate crops, which is crucial for disease resistance and nutritional enhancement (Raboy, 2020).

Furthermore, genetic engineering has played a pivotal role in enhancing crop traits, leading to increased yield, improved nutritional content, and stress tolerance. The application of genetic engineering technology, such as the development of Bt (Bacillus thuringiensis) insect resistance and herbicide resistance, has greatly promoted the development of world agriculture, contributing to enhanced crop traits and increased productivity (Kan et al., 2022). Moreover, the current genetic modification of crops is forecasted to increase productivity and prosperity in sustainable agricultural practices, highlighting the potential for enhanced crop traits through genetic engineering (Aziz et al., 2022).

Environmental sustainability in agriculture has also been a key focus of genetic engineering applications, aiming to address challenges such as

declining biodiversity, poor soil health, and high greenhouse gas emissions. Efforts to integrate ecological principles to achieve optimal management of agroecosystems have been critical in promoting environmental sustainability in agriculture, emphasizing the importance of genetic engineering in sustainable agricultural development (Isaac & Martin, 2019). Additionally, the use of genetically engineered crops that provide protection against insects and diseases, or tolerance to herbicides, has been highlighted as an important tool that complements diversified integrated pest management plans, contributing to environmental sustainability in agriculture (Anderson et al., 2019).
In conclusion, the applications of genetic engineering in agriculture production have demonstrated significant advancements in disease resistance and control, enhanced crop traits, and environmental sustainability. These applications have been facilitated by various genetic engineering techniques and tools, showcasing the potential for genetic engineering to contribute to sustainable and efficient agricultural practices.

4. Application of Precision Agriculture in Agriculture Production

Precision agriculture, also known as precision farming, is a modern approach to agricultural management that utilizes advanced technologies to optimize production efficiency, enhance crop quality, and minimize environmental impact. This approach involves the integration of various precision agriculture techniques, such as remote sensing, GPS, and drones, to enable data-driven decision-making and targeted resource management.
Remote sensing, a key component of precision agriculture, involves the use of satellite imagery and aerial photography to gather information about crop health, soil conditions, and field variability. The improved temporal, spatial, and spectral resolution of satellite platforms, such as the European Space Agency's Sentinel-2, has paved the way for their popularization in precision agriculture Segarra et al. (2020). These remote sensing technologies provide farmers with valuable insights into field conditions, enabling them to make informed decisions regarding irrigation, fertilization, and pest control.

Global Positioning System (GPS) technology plays a crucial role in precision agriculture by enabling accurate field mapping, navigation, and the precise application of inputs. GPS-enabled agricultural equipment allows for the precise placement of seeds, fertilizers, and pesticides, contributing to improved resource utilization and crop yield (Monteiro et al., 2021). Additionally, GPS technology facilitates the collection of spatial data, which is essential for creating detailed field maps and conducting site-specific management practices.
Drones, equipped with advanced sensors and cameras, have become integral to precision agriculture, enabling farmers to monitor crop health, assess field variability, and conduct aerial surveys. The integration of drone technology with artificial intelligence and thermal imaging has facilitated applications such as crop disease detection, soil moisture mapping, and livestock monitoring (Santangeli et al., 2020). Drones provide farmers with real-time, high-resolution imagery, allowing for targeted interventions and precise management practices.
The adoption of precision agriculture techniques has the potential to revolutionize agricultural practices by promoting sustainability, increasing productivity, and reducing input costs. However, challenges such as the initial investment costs, technological literacy, and data security need to be addressed to ensure the successful integration and sustainable adoption of precision agriculture practices.
In conclusion, precision agriculture techniques, including remote sensing, GPS, and drones, have the potential to transform agricultural practices by enabling data-driven decision-making, targeted resource management, and improved productivity. The integration of these advanced technologies is essential for the advancement of modern agriculture and the promotion of sustainable farming practices.

5. Smart Farming in Agriculture Production

Smart farming technologies have indeed revolutionized modern agriculture by integrating advanced tools and techniques such as the Internet of Things (IoT) and data analytics. These technologies have significantly enhanced agricultural practices, leading to improved efficiency, productivity, and sustainability.
The Internet of Things (IoT) has played a pivotal role in smart farming by enabling the connectivity of various devices and sensors to collect real-time data from agricultural fields. This data is then utilized to monitor and manage agricultural processes, such as irrigation, fertilization, and pest control, leading to optimized resource utilization and improved crop yields Farooq et al. (2019). Additionally, IoT-based smart farming solutions have been instrumental in providing farmers with valuable insights into environmental parameters, including temperature, humidity, soil moisture, and pH, thereby facilitating informed decision-making

and precise agricultural management (Madushanki et al., 2019).

Data analytics has emerged as a key component of smart farming, leveraging the vast amount of data collected through IoT devices to derive actionable insights and optimize agricultural operations. By employing machine learning algorithms and big data analytics, smart farming technologies enable predictive modeling, disease detection, and yield forecasting, contributing to enhanced decision-making and improved supply chain performance in agriculture (Sharma et al., 2020). Furthermore, data analytics in smart farming has facilitated the development of precision agriculture, allowing for targeted interventions and resource allocation based on data-driven analysis, ultimately leading to increased efficiency and reduced environmental impact (Alfred et al., 2021).

The application of smart farming technologies has also extended to the development of precision agriculture management systems, integrating IoT-based solutions with machine learning algorithms to optimize agricultural technology and increase the quantity and quality of agricultural products (Al-Khowarizmi et al., 2022). Moreover, the adoption of smart farming technologies, such as unmanned aerial vehicles (UAVs), has provided farmers with advanced tools for assessing, monitoring, and managing their farms, contributing to improved precision agriculture practices and sustainable agricultural development (Delavarpour et al., 2021).

In conclusion, smart farming technologies, including the Internet of Things and data analytics, have significantly transformed agriculture by enabling real-time data collection, informed decision-making, and optimized resource management. These technologies have paved the way for precision agriculture, enhanced supply chain performance, and improved sustainability in agricultural practices, ultimately contributing to the advancement of modern agriculture.

5.1 Applications of smart farming in agriculture production

Smart farming technologies have revolutionized agriculture production by offering innovative solutions for livestock monitoring and management, real-time crop monitoring and decision-making, and efficient resource utilization. These applications have been facilitated by the integration of advanced technologies such as the Internet of Things (IoT) and data analytics, leading to improved efficiency, productivity, and sustainability in agriculture.

Livestock monitoring and management have been significantly enhanced through smart farming technologies, particularly through the implementation of precision livestock farming (PLF) systems. These systems enable real-time and continuous monitoring of livestock using modern sensor technologies, providing farmers with valuable insights into animal productivity, health, and welfare parameters. This real-time monitoring and management of livestock contribute to improved animal welfare, disease control, and optimized production processes Buller et al. (2020)Michel et al., 2022; Abeni et al., 2019).

Real-time crop monitoring and decision-making have been pivotal in smart farming, leveraging IoT-based solutions and data analytics to collect and analyze real-time data from agricultural fields. This data is utilized to monitor crop health, growth, and environmental parameters, enabling farmers to make informed decisions regarding irrigation, fertilization, and pest control. The integration of machine learning algorithms and big data analytics has further facilitated predictive modeling, disease detection, and yield forecasting, contributing to improved decision-making and supply chain performance in agriculture (Farooq et al., 2019; Nanseki et al., 2023; Aliar et al., 2022; Alfred et al., 2021).

Efficient resource utilization has been a key focus of smart farming technologies, aiming to optimize the use of resources such as water, energy, and inputs in agricultural production. IoT-based solutions and data analytics enable farmers to monitor and manage resource utilization in real-time, leading to improved resource efficiency and reduced environmental impact. Additionally, the application of smart farming technologies has extended to the development of precision agriculture management systems, integrating IoT-based solutions with machine learning algorithms to optimize agricultural technology and increase the quantity and quality of agricultural products (Morrone et al., 2022; Mate et al., 2022; Yang et al., 2022; Huang et al., 2021).

In conclusion, smart farming technologies have significantly advanced agriculture production by enabling livestock monitoring and management, real-time crop monitoring and decision-making, and efficient resource utilization. These applications have been pivotal in promoting sustainable and efficient agricultural practices, ultimately contributing to the advancement of modern agriculture.

6. Benefits and Challenges of Modern Techniques in Agriculture Production

The application of modern techniques in agriculture production offers a multitude of benefits, including increased productivity, improved resource utilization, and enhanced sustainability. However, these advancements also present challenges, such as the need for significant investment, potential environmental impact, and social implications. The economic, environmental, and social implications of modern techniques in agriculture production must be carefully considered to ensure their responsible and sustainable implementation.

6.1 Advantages of Modern Techniques in Agriculture Production:

Increased Productivity: Modern techniques, such as precision agriculture and genetic engineering, have the potential to significantly increase crop yields and livestock productivity. Through the use of advanced technologies, farmers can optimize resource use, enhance crop management, and improve overall farm productivity Loures et al. (2020)Bogusz et al., 2021; Li, 2023).

Efficient Resource Utilization: The adoption of modern techniques enables efficient utilization of agricultural resources, such as water, fertilizers, and pesticides. Precision agriculture, IoT-based sensors, and automation technologies contribute to reduced resource wastage, minimized input costs, and improved environmental sustainability (Han & Lu, 2021; Ma, 2022; Li et al., 2022).

Environmental Sustainability: Modern techniques in agriculture production have the potential to promote environmental sustainability by minimizing the use of chemical inputs, reducing greenhouse gas emissions, and enhancing soil and water conservation. Sustainable intensification practices and precision farming technologies contribute to environmentally friendly agricultural practices (Hu et al., 2022; Shahi, 2022; Shrestha et al., 2021).

6.2 Challenges of Modern Techniques in Agriculture Production:

Economic Investment: The adoption of modern techniques often requires significant investment in advanced technologies, equipment, and infrastructure. Small-scale farmers may face challenges in accessing and affording these modern advancements, potentially leading to disparities in agricultural productivity and economic opportunities ("Green Agricultural Products and Soybeans on the Development of Agricultural Economic Modernization", 2022; Huang et al., 2023; He, 2019).

Environmental Impact: While modern techniques aim to enhance sustainability, there are potential environmental implications to consider. The use of certain agricultural technologies and practices may contribute to environmental degradation, such as increased energy consumption, chemical runoff, and habitat disruption ("March 2021", 2021; Manni et al., 2020; Clech & Castejón, 2020).

Social Implications: The transition to modern agriculture practices may have social implications, including changes in labor requirements, rural livelihoods, and traditional farming practices. The adoption of modern techniques may impact local communities, cultural practices, and the well-being of agricultural workers (Doitchinova et al., 2019; Momotaz et al., 2019; He, 2019).

In conclusion, the application of modern techniques in agriculture production offers numerous benefits, including increased productivity, efficient resource utilization, and environmental sustainability. However, these advancements also present challenges, such as economic investment, potential environmental impact, and social implications. It is essential to carefully consider the economic, environmental, and social implications of modern techniques to ensure their responsible and sustainable implementation in agriculture production.

7. Conclusion

The adoption of modern techniques in agriculture production has yielded significant findings and implications, offering a promising pathway to enhance productivity, sustainability, and efficiency in farming practices. The integration of advanced technologies, such as precision agriculture, genetic engineering, and smart farming, has revolutionized traditional farming methods, leading to improved resource utilization, increased crop yields, and enhanced environmental stewardship.

The application of modern techniques, including precision agriculture and genetic engineering, has demonstrated the potential to significantly increase agricultural productivity, optimize resource use, and promote sustainable farming practices. These advancements have the capacity to address global food security challenges, improve crop quality, and mitigate the impact of climate change on agricultural production. Furthermore, the integration of smart farming technologies has the potential to revolutionize livestock monitoring and management, real-time crop monitoring, and efficient resource utilization, contributing to improved animal welfare, enhanced decision-making, and reduced environmental impact .

Further research and widespread adoption of modern techniques in agriculture production are essential to realize their full potential in enhancing productivity, sustainability, and efficiency in farming. Continued research efforts are needed to address the economic, environmental, and social implications of modern techniques, ensuring their responsible and sustainable implementation. Additionally, the adoption of these advanced technologies by farmers, agricultural organizations, and policymakers is crucial to drive the transformation of traditional farming practices and promote the widespread adoption of sustainable and efficient agricultural production methods.

In conclusion, the adoption of modern techniques in agriculture production offers a promising pathway to enhance productivity, sustainability, and efficiency in farming practices. Continued research and widespread adoption of these advanced technologies are essential to realize their full potential and address the challenges and opportunities in modern agriculture.

8. References

[1]. Investigating the potential of vertical farming and indoor agriculture for sustainable food production in urban areas. ejmcm, 06(02). https://doi.org/10.48047/ejmcm/v06/i02/10 (2023).

[2]. Abeni, F., Petrera, F., & Galli, A. (2019). A survey of italian dairy farmers' propensity for precision livestock farming tools. Animals, 9(5), 202. https://doi.org/10.3390/ani9050202

[3]. Al-Khowarizmi, A., Lubis, A., Lubis, M., & Rahmat, R. (2022). Information technology based smart farming model development in agriculture land. Iaes International Journal of Artificial Intelligence (Ij-Ai), 11(2), 564. https://doi.org/10.11591/ijai.v11.i2.pp564-571

[4]. Al-Khowarizmi, A., Lubis, A., Lubis, M., & Rahmat, R. (2022). Information technology based smart farming model development in agriculture land. Iaes International Journal of Artificial Intelligence (Ij-Ai), 11(2), 564. https://doi.org/10.11591/ijai.v11.i2.pp564-571

[5]. Alfred, R., Obit, J., Chin, C., Haviluddin, H., & Lim, Y. (2021). Towards paddy rice smart farming: a review on big data, machine learning, and rice production tasks. Ieee Access, 9, 50358-50380. https://doi.org/10.1109/access.2021.3069449

[6]. Alfred, R., Obit, J., Chin, C., Haviluddin, H., & Lim, Y. (2021). Towards paddy rice smart farming: a review on big data, machine learning, and rice production tasks. Ieee Access, 9, 50358-50380. https://doi.org/10.1109/access.2021.3069449

[7]. Alfred, R., Obit, J., Chin, C., Haviluddin, H., & Lim, Y. (2021). Towards paddy rice smart farming: a review on big data, machine learning, and rice production tasks. Ieee Access, 9, 50358-50380. https://doi.org/10.1109/access.2021.3069449

[8]. Aliar, A., Justindhas, Y., Alagarsamy, M., Karthikeyan, A., Sakkarai, J., & Kannadhasan, S. (2022). A comprehensive analysis on iot based smart farming solutions using machine learning algorithms. Bulletin of Electrical Engineering and Informatics, 11(3), 1550-1557. https://doi.org/10.11591/eei.v11i3.3310

[9]. Anderson, J., Ellsworth, P., Faria, J., Head, G., Owen, M., Pilcher, C., … & Meissle, M. (2019). Genetically engineered crops: importance of diversified integrated pest management for agricultural sustainability. Frontiers in Bioengineering and Biotechnology, 7. https://doi.org/10.3389/fbioe.2019.00024

[10]. Ayundyahrini, M., Susanto, D., Febriansyah, H., Rizanulhaq, F., & Aditya, G. (2023). Smart farming: integrated solar water pumping irrigation system in thailand. Evergreen, 10(1), 553-563. https://doi.org/10.5109/6782161

[11]. Aziz, M., Brini, F., Rouached, H., & Masmoudi, K. (2022). Genetically engineered crops for sustainably enhanced food production systems. Frontiers in Plant Science, 13. https://doi.org/10.3389/fpls.2022.1027828

[12]. Bhakta, I., Phadikar, S., & Majumder, K. (2019). State-of-the-art technologies in precision agriculture: a systematic review. Journal of the Science of Food and Agriculture, 99(11), 4878-4888. https://doi.org/10.1002/jsfa.9693

[13]. Bhowmik, P., Konkin, D., Polowick, P., Hodgins, C., Subedi, M., Xiang, D., … & Kagale, S. (2021). Crispr/cas9 gene editing in legume crops: opportunities and challenges. Legume Science, 3(3). https://doi.org/10.1002/leg3.96

[14]. Boursianis, A., Papadopoulou, M., Diamantoulakis, P., Liopa-Tsakalidi, A., Barouchas, P., Salahas, G., … & Goudos, S. (2022). Internet of things (iot) and agricultural unmanned aerial vehicles (uavs) in smart farming: a comprehensive review. Internet of Things, 18, 100187. https://doi.org/10.1016/j.iot.2020.100187

[15]. Buller, H., Blokhuis, H., Lokhorst, K., Silberberg, M., & Veissier, I. (2020). Animal welfare management in a digital world. Animals, 10(10), 1779. https://doi.org/10.3390/ani10101779

[16]. Delavarpour, N., Koparan, C., Nowatzki, J., Bajwa, S., & Sun, X. (2021). A technical study

on uav characteristics for precision agriculture applications and associated practical challenges. Remote Sensing, 13(6), 1204. https://doi.org/10.3390/rs13061204
[17]. Esmaeili, N., Shen, G., & Zhang, H. (2022). Genetic manipulation for abiotic stress resistance traits in crops. Frontiers in Plant Science, 13. https://doi.org/10.3389/fpls.2022.1011985
[18]. Farooq, M., Riaz, S., Abid, A., Abid, K., & Naeem, M. (2019). A survey on the role of iot in agriculture for the implementation of smart farming. Ieee Access, 7, 156237-156271. https://doi.org/10.1109/access.2019.2949703
[19]. Farooq, M., Riaz, S., Abid, A., Abid, K., & Naeem, M. (2019). A survey on the role of iot in agriculture for the implementation of smart farming. Ieee Access, 7, 156237-156271. https://doi.org/10.1109/access.2019.2949703
[20]. Faye, J. (2020). Indigenous farming transitions, sociocultural hybridity and sustainability in rural senegal. Njas - Wageningen Journal of Life Sciences, 92(1), 1-8. https://doi.org/10.1016/j.njas.2020.100338
[21]. Hasan, K., Masriadi, M., & Husna, A. (2023). Digital farming and smart farming from the perspective of agricultural students at malikussaleh university 2022. Proceedings of Malikussaleh International Conference on Multidisciplinary Studies (Micoms), 3, 00065. https://doi.org/10.29103/micoms.v3i.230
[22]. Hasan, K., Masriadi, M., Aftah, R., & Syakban, M. (2023). Digital skills in the optimization of agricultural technology among milenial 2022 (description study on agricultural students at malikussaleh university). Proceedings of International Conference on Social Science Political Science and Humanities (Icospolhum), 3, 00007. https://doi.org/10.29103/icospolhum.v3i.149
[23]. Hasan, K., Masriadi, M., Aftah, R., & Syakban, M. (2023). Digital skills in the optimization of agricultural technology among milenial 2022 (description study on agricultural students at malikussaleh university). Proceedings of International Conference on Social Science Political Science and Humanities (Icospolhum), 3, 00007. https://doi.org/10.29103/icospolhum.v3i.149
[24]. Huang, Y., Huang, X., Xie, M., Cheng, W., & Shu, Q. (2021). A study on the effects of regional differences on agricultural water resource utilization efficiency using super-efficiency sbm model. Scientific Reports, 11(1). https://doi.org/10.1038/s41598-021-89293-2
[25]. Isaac, M. and Martin, A. (2019). Accumulating crop functional trait data with citizen science. Scientific Reports, 9(1). https://doi.org/10.1038/s41598-019-51927-x
[26]. Islam, M., Islam, M., & Anzum, R. (2022). Smart farming: legal issues and challenges. Journal of Asian and African Social Science and Humanities, 8(2), 31-37. https://doi.org/10.55327/jaash.v8i2.261
[27]. Islam, N., Rashid, M., Pasandideh, F., Ray, B., Moore, S., & Kadel, R. (2021). A review of applications and communication technologies for internet of things (iot) and unmanned aerial vehicle (uav) based sustainable smart farming. Sustainability, 13(4), 1821. https://doi.org/10.3390/su13041821
[28]. Kan, M., Huang, T., & Zhao, P. (2022). Artificial chromosome technology and its potential application in plants. Frontiers in Plant Science, 13. https://doi.org/10.3389/fpls.2022.970943
[29]. Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda. Njas - Wageningen Journal of Life Sciences, 90-91(1), 1-16. https://doi.org/10.1016/j.njas.2019.100315
[30]. Koduru, T. and Koduru, N. (2022). An overview of vulnerabilities in smart farming systems. Journal of Student Research, 11(1). https://doi.org/10.47611/jsrhs.v11i1.2303
[31]. Langendahl, P. (2021). The politics of smart farming expectations in urban environments. Frontiers in Sustainable Cities, 3. https://doi.org/10.3389/frsc.2021.691951
[32]. Li, D., Nanseki, T., Chomei, Y., & Kuang, J. (2022). A review of smart agriculture and production practices in japanese large-scale rice farming. Journal of the Science of Food and Agriculture, 103(4), 1609-1620. https://doi.org/10.1002/jsfa.12204
[33]. Li, J., Yin, J., & Deng, L. (2021). A robot vision navigation method using deep learning in edge computing environment. Eurasip Journal on Advances in Signal Processing, 2021(1). https://doi.org/10.1186/s13634-021-00734-6
[34]. Loures, L., Chamizo, A., Ferreira, P., Loures, A., Castanho, R., & Panagopoulos, T. (2020). Assessing the effectiveness of precision agriculture management systems in mediterranean small farms. Sustainability, 12(9), 3765. https://doi.org/10.3390/su12093765

[35]. Madushanki, A., Halgamuge, M., Wirasagoda, W., & Syed, A. (2019). Adoption of the internet of things (iot) in agriculture and smart farming towards urban greening: a review. International Journal of Advanced Computer Science and Applications, 10(4). https://doi.org/10.14569/ijacsa.2019.0100402

[36]. Mate, S., Somani, V., & Dahiwale, P. (2022). Design and development of iot-based intelligent solutions with blockchain for indian farmers on livestock management.. https://doi.org/10.4108/eai.14-5-2022.2320163

[37]. Michel, V., Berk, J., Bozakova, N., Eijk, J., Estevez, I., Mircheva, T., … & Guinebretière, M. (2022). The relationships between damaging behaviours and health in laying hens. Animals, 12(8), 986. https://doi.org/10.3390/ani12080986

[38]. Morrone, S., Dimauro, C., Gambella, F., & Cappai, M. (2022). Industry 4.0 and precision livestock farming (plf): an up to date overview across animal productions. Sensors, 22(12), 4319. https://doi.org/10.3390/s22124319

[39]. Musa, S., Basir, K., & Luah, E. (2021). The role of smart farming in sustainable development. International Journal of Asian Business and Information Management, 13(2), 1-12. https://doi.org/10.4018/ijabim.20220701.oa5

[40]. NANSEKI, T., LI, D., & CHOMEI, Y. (2022). Impacts and policy implication of smart farming technologies on rice production in japan. Journal of the Faculty of Agriculture Kyushu University, 67(2), 219-225. https://doi.org/10.5109/4797829

[41]. Naik, B., Shimoga, G., Kim, S., Mekapogu, M., Reddy, C., Palem, R., … & Lee, S. (2022). Crispr/cas9 and nanotechnology pertinence in agricultural crop refinement. Frontiers in Plant Science, 13. https://doi.org/10.3389/fpls.2022.843575

[42]. Nanseki, T., Li, D., & Chomei, Y. (2023). Impacts and policy implication of smart farming technologies on rice production in japan., 205-217. https://doi.org/10.1007/978-981-19-9086-1_13

[43]. Nanseki, T., Li, D., & Chomei, Y. (2023). Impacts and policy implication of smart farming technologies on rice production in japan., 205-217. https://doi.org/10.1007/978-981-19-9086-1_13

[44]. Navarro, E., Costa, N., & Pereira, A. (2020). A systematic review of iot solutions for smart farming. Sensors, 20(15), 4231. https://doi.org/10.3390/s20154231

[45]. Okuhle, M. (2021). Innovative climate-smart agriculture (csa) practices in the smallholder farming system of south africa. Sustainability, 13(12), 6848. https://doi.org/10.3390/su13126848

[46]. Panchasara, H., Samrat, N., & Islam, N. (2021). Greenhouse gas emissions trends and mitigation measures in australian agriculture sector—a review. Agriculture, 11(2), 85. https://doi.org/10.3390/agriculture11020085

[47]. Park, H. and Park, J. (2019). Design and implementation of iot-based smart-farm management system. International Journal of Innovative Technology and Exploring Engineering, 8(9), 396-399. https://doi.org/10.35940/ijitee.h7252.078919

[48]. Pereira, A., Oliveira, H., Fraceto, L., & Santaella, C. (2021). Nanotechnology potential in seed priming for sustainable agriculture. Nanomaterials, 11(2), 267. https://doi.org/10.3390/nano11020267

[49]. Pixley, K., Falck-Zepeda, J., Giller, K., Glenna, L., Gould, F., Mallory-Smith, C., … & Stewart, C. (2019). Genome editing, gene drives, and synthetic biology: will they contribute to disease-resistant crops, and who will benefit?. Annual Review of Phytopathology, 57(1), 165-188. https://doi.org/10.1146/annurev-phyto-080417-045954

[50]. Raboy, V. (2020). Low phytic acid crops: observations based on four decades of research. Plants, 9(2), 140. https://doi.org/10.3390/plants9020140

[51]. Rowe, E., Dawkins, M., & Gebhardt-Henrich, S. (2019). A systematic review of precision livestock farming in the poultry sector: is technology focussed on improving bird welfare?. Animals, 9(9), 614. https://doi.org/10.3390/ani9090614

[52]. Saad, M., Hamdan, N., & Sarker, M. (2021). State of the art of urban smart vertical farming automation system: advanced topologies, issues and recommendations. Electronics, 10(12), 1422. https://doi.org/10.3390/electronics10121422

[53]. Saravanan, K., Praveenkumar, K., Vidya, N., Gowtham, K., & Saravanan, M. (2022). Enhancement of agricultural crops: a crispr/cas9-based approach.. https://doi.org/10.5772/intechopen.100641

[54]. Shang, Y., Hasan, K., Ahammed, G., Li, M., Yin, H., & Zhou, J. (2019). Applications of nanotechnology in plant growth and crop protection: a review. Molecules, 24(14), 2558. https://doi.org/10.3390/molecules24142558

[55]. Sharma, P., Pandey, A., Malviya, R., Dey, S., Karmakar, S., & Gayen, D. (2023). Genome editing for improving nutritional quality, post-harvest shelf life and stress tolerance of fruits, vegetables, and ornamentals. Frontiers in Genome Editing, 5. https://doi.org/10.3389/fgeed.2023.1094965
[56]. Sharma, P., Singh, S., Iqbal, H., Parra-Saldívar, R., Varjani, S., & Tong, Y. (2022). Genetic modifications associated with sustainability aspects for sustainable developments. Bioengineered, 13(4), 9509-9521. https://doi.org/10.1080/21655979.2022.2061146
[57]. Sharma, R., Kamble, S., Gunasekaran, A., Kumar, V., & Kumar, A. (2020). A systematic literature review on machine learning applications for sustainable agriculture supply chain performance. Computers & Operations Research, 119, 104926. https://doi.org/10.1016/j.cor.2020.104926
[58]. Sharma, R., Kamble, S., Gunasekaran, A., Kumar, V., & Kumar, A. (2020). A systematic literature review on machine learning applications for sustainable agriculture supply chain performance. Computers & Operations Research, 119, 104926. https://doi.org/10.1016/j.cor.2020.104926
[59]. Sun, L., Sun, H., Cao, N., Xiao, H., Cao, G., Huo, W., … & Higgs, R. (2022). Intelligent agriculture technology based on internet of things. Intelligent Automation & Soft Computing, 32(1), 429-439. https://doi.org/10.32604/iasc.2022.021526
[60]. Valipour, M., Krasilnikof, J., Yannopoulos, S., Kumar, R., Deng, J., Roccaro, P., … & Angelakis, A. (2020). The evolution of agricultural drainage from the earliest times to the present. Sustainability, 12(1), 416. https://doi.org/10.3390/su12010416
[61]. Yang, Y., Deng, Z., Xian-ming, L., & Gao, X. (2022). Study on the environmental efficiency of agricultural water resources about typical cropping patterns around the dongting lake area. Journal of Water and Climate Change, 13(10), 3716-3728. https://doi.org/10.2166/wcc.2022.225
[62]. Yannopoulos, S., Grismer, M., Bali, K., & Angelakis, A. (2020). Evolution of the materials and methods used for subsurface drainage of agricultural lands from antiquity to the present. Water, 12(6), 1767. https://doi.org/10.3390/w12061767
[63]. Zaman, N., Raof, W., Saili, A., Aziz, N., Fatah, F., & Vaiappuri, S. (2023). Adoption of smart farming technology among rice farmers. Journal of Advanced Research in Applied Sciences and Engineering Technology, 29(2), 268-275. https://doi.org/10.37934/araset.29.2.268275
[64]. Курманова, Г., Суханбердина, Б., & Уразова, Б. (2021). Modernization of agrarian economy in the republic of kazakhstan. The Economy Strategy and Practice, 16(3), 35-50. https://doi.org/10.51176/1997-9967-2021-3-35-50