

Review

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Posted Date: 17 April 2023

doi: 10.20944/preprints202304.0409.v1

Keywords: Animal welfare; Virtual environments; Metaverse; Augmented reality; Precision Livestock Farming; Ethical farming; Sustainability; Livestock; Environmental impact; Digital agriculture



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Review

The Ethical Frontier: Navigating the Metaverse in Modern Animal Farming

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Abstract: The metaverse is a virtual world, consisting of a collective virtual shared space where users can interact with one another through avatars and computer-generated objects. Its goal is to mimic our real world as closely as possible, integrating elements of various trends like AI, immersive reality, advanced connectivity, and Web3. While there is currently no universally accepted definition of the metaverse, the emergence of metaverse technologies across multiple sectors, including animal farming, is rapidly gaining momentum. The potential value of the metaverse, particularly in relation to its capacity for solving complex problems (e.g., climate change and sustainability) in precision food production systems makes it an exciting endeavor. However, it is crucial to consider ethical implications during the development of metaverse technologies for modern animal farming, given the sensitive and controversial nature of animal welfare. Failure to address these ethical considerations could lead to a lack of credibility and insensitivity towards the adoption of metaverse technologies in the animal farming sector. It is therefore important to ensure that the development of metaverse technologies does not prioritize technology over animal welfare, ethics, and socio-economic implications. Additionally, addressing the topic of diversity and equity in the context of animal farming and the metaverse is crucial to avoid perpetuating existing inequalities during the implementation of metaverse technologies. The purpose of this critical review is to stimulate dialogue among stakeholders such as farmers, animal scientists, bioengineers, veterinarians, policymakers, consumers, and business-to-business clients. It aims to help them better understand the potential and power of the metaverse, identify ethical implications and strategic imperatives, and act as a force for its positive evolution.

Keywords: animal welfare; virtual environments; metaverse; augmented reality; precision livestock farming; ethical farming; sustainability; livestock; environmental impact; digital agriculture

1. Modern Animal Farming and Metaverse

Animal farming has been an integral part of human society for thousands of years, providing essential resources such as food and clothing. The domestication of animals' dates back approximately 10,000 years, with dogs being the first domesticated species, followed by cattle, chickens, pigs, and sheep (Collarini et al., 2022; Van der Horst & Maree, 2022). As animal farming practices have evolved, technology has played an increasingly significant role in enhancing efficiency and productivity.

Modern animal farming is characterized by the use of advanced technologies such as Artificial Intelligence (AI), robotics, and automation, which have improved the industry's efficiency (Liu et al., 2020). However, these technological advancements have also raised ethical concerns regarding animal welfare. Key concerns include overcrowding, limited access to food and water, inhumane treatment, and the use of antibiotics and hormones to promote growth (Kirchhelle, 2018). Furthermore, the spread of disease in animal farming can have detrimental consequences for ecosystems and human health.

Environmental implications of animal farming are also significant, as it requires substantial amounts of land, water, and other resources. Animal waste contributes to pollution and other environmental issues, while carbon emissions from animal farming contribute to climate change (Rojas-Downing et al., 2017).

In recent years, virtual environments have emerged as a potential solution to address some of the ethical and environmental concerns associated with animal farming. Virtual environments offer numerous benefits, such as improved animal welfare, reduced costs, and increased efficiency. Many experts believe that these technologies can help mitigate some of the challenges (Neethirajan, 2023) inherent in modern farming practices.

However, the implementation of virtual environments in animal farming raises crucial ethical considerations that require careful examination. To ensure the responsible development and application of virtual environments in animal farming, it is essential to assess their impact on animal welfare, environmental sustainability, and human-animal interactions. By addressing these ethical concerns and leveraging the potential of emerging technologies, the future of animal farming in the metaverse can contribute to the development of more humane, environmentally responsible, and efficient practices.

2. Definition of the metaverse, virtual reality and augmented reality

The metaverse is a collective, immersive, hyper spatio-temporal virtual shared space that exists online, enabling users to interact using avatars and computer-generated objects (Wang et al., 2022). It aims to create a virtual world that closely mimics reality by integrating cutting-edge trends such as AI, immersive reality, advanced connectivity, and Web3.

Virtual reality (VR) is a technology that generates a simulated environment, either resembling or diverging from the real world (Liagkou et al., 2019). VR employs computer-generated imagery, sound, and other sensory experiences to create an immersive environment, typically necessitating the use of a headset or similar device to fully engage users in the virtual setting.

In contrast, augmented reality (AR) overlays digital information onto the real world, enhancing user experiences primarily through mobile applications (Farshid et al., 2018). Unlike VR, which generates a fully simulated environment, AR enriches real-world experiences with digital content.

Virtual environments in animal farming are computer-based systems that emulate real-world settings. These systems leverage sensors, cameras, and other technologies to oversee and manage various aspects of animal farming. In recent years, the application of virtual environments in animal farming has gained traction as a method for improving animal welfare, reducing costs, and increasing efficiency (Jukan et al., 2017).

By integrating the metaverse, virtual reality, and augmented reality in animal farming, researchers and industry professionals can potentially revolutionize current practices. The combination of these technologies can create immersive and interactive experiences, providing novel insights and opportunities for optimizing animal welfare and farm management. As the metaverse continues to expand, exploring its applications in animal farming will be essential for driving innovation, enhancing sustainability, and addressing ethical concerns in the industry.

2.1. Evolution of Animal Farming and Ethics

Throughout thousands of years, human-animal interactions have significantly influenced the evolution of animal farming practices. However, the modern industrialization of animal farming has raised ethical concerns surrounding animal welfare. Critics argue that contemporary farming systems are cruel, inhumane, and unsustainable, fueling a rising interest in alternative animal farming methods that prioritize animal welfare and ethical treatment (Hampton et al., 2021).

2.1.1. The Evolution of Animal Farming and its Impact on Animal Welfare

Animal welfare legislation has evolved over time in response to concerns about inhumane treatment of animals within farming industries. The British Cruelty to Animals Act of 1822, for example, prohibited mistreatment of domestic animals like horses and dogs, while the United States enacted a law in 1828 prohibiting cruel treatment of animals during transportation by ship (DeMello, 2021). The 1866 ASPCA Act was the first U.S. law specifically addressing animal welfare, with other

countries, including the European Union, subsequently implementing similar laws. These laws mandate provision of adequate food, water, and living space for animals, and prohibit certain practices, such as gestation crates for pregnant pigs (Carey et al., 2020).

Recently, demand for stricter animal welfare laws has grown due to high-profile animal cruelty cases raising public awareness. Despite debates surrounding their necessity and effectiveness, many countries have implemented laws governing animal treatment, reflecting increasing concern for animal welfare.

2.1.2. Future of Animal Farming in the Metaverse

The transformative potential of virtual environments in redefining animal farming by mitigating cruelty and enhancing welfare is garnering substantial interest. By replicating natural habitats, these environments can effectively alleviate stress and anxiety in animals, stemming from confinement and isolation, ultimately contributing to improved health and welfare. Virtual and augmented reality technologies present novel opportunities for farmers and consumers to engage with animals, such as simulating farming experiences and disseminating welfare-related information. Additionally, immersive virtual experiences play a crucial role in educating consumers about contemporary animal farming practices, fostering ethical approaches.

Beyond promoting animal welfare, virtual environments offer valuable advantages to farmers and the food industry. They equip farmers with precise, real-time data on animal health and behavior, facilitating informed decision-making and heightened efficiency. Moreover, virtual environments can decrease traditional farming costs and minimize environmental impacts by preserving land, water, and other essential resources required for food production. Nevertheless, it is imperative to thoroughly examine the limitations and ethical implications of these technologies.

2.1.3. Virtual and Augmented Reality in Animal Farming

Virtual and augmented reality (VR/AR) technologies are emerging as pivotal tools in animal farming, with the capacity to enhance animal welfare, boost efficiency, and mitigate the environmental impact of farming practices. These innovative technologies find application in diverse areas, such as training, education, simulating farming scenarios, monitoring animal health, alleviating stress, and promoting sustainable agricultural practices (Radianti et al., 2020; Kim et al., 2019; Neethirajan and Kemp, 2021; Phupattanasilp et al., 2019; Fejzic et al., 2019; Ronaghi et al., 2021). These advancements substantially affect both farmers and animals, shaping the future of animal farming.

2.1.4. Overall Benefits of Virtual Environments on Animal Welfare

More Enhanced space and freedom: Virtual environments offer animals increased space and freedom, leading to substantial improvements in their welfare. By simulating outdoor grazing areas or natural habitats, these environments enable animals to move around and engage in natural behaviors (Klaas et al., 2021).

Reduced stress and anxiety: Virtual environments contribute to diminished stress and anxiety in animals, thereby significantly enhancing their welfare. Providing comfortable and natural settings helps mitigate the adverse effects of confinement and isolation (Norouzi et al., 2022).

Improved health and nutrition: Virtual environments can be employed to monitor and optimize animal health and nutrition, further promoting their welfare. These environments enable tracking of feed intake, early detection of diseases, and provision of targeted treatments.

Decreased use of antibiotics: Virtual environments facilitate a reduction in antibiotic usage in animal farming by ameliorating animal welfare and curtailing disease prevalence. Offering comfortable and natural surroundings helps alleviate stress and disease, which often contribute to antibiotic overuse (Fejzic et al., 2019).

Enhanced research and development: Virtual environments can simulate various animal farming practices and evaluate their impact on animal welfare. This approach assists researchers and

farmers in developing more efficient and humane farming practices, ultimately improving animal welfare and reducing animal suffering.

Diminished animal cruelty: Virtual environments present a more humane and ethical alternative to animal farming. They can improve animal health and establish better, more humane practices without testing on real animals. Additionally, these environments promote animal welfare by minimizing the need for painful physical interventions such as castration, tail docking, and dehorning.

Increased public awareness and understanding: Virtual environments foster greater public awareness and comprehension of animal welfare and ethical treatment in animal farming. By offering immersive and realistic experiences of animal farming, these environments facilitate more informed and ethical decision-making.

2.1.5. Limitations and Drawbacks of the use of Virtual Environments for Animal Welfare

While the potential benefits of virtual environments for animal welfare and human-animal interactions are significant, it is crucial to carefully consider the limitations and ethical implications of these technologies.

Long-term Effects: Concerns exist regarding the potential long-term impacts of virtual environments on animal behavior and stress levels. Initial studies indicate that virtual environments can reduce stress levels and improve animal behavior, but the sustainability of these effects remains uncertain. There is a risk that prolonged exposure to virtual environments could lead to desensitization or habituation, ultimately harming animal welfare (Naik et al., 2019).

Ethical Concerns: Ethical issues arise from the use of virtual environments in animal farming, particularly if employed to replace or reduce the need for physical environments. While virtual environments can enhance living conditions for animals, they may also justify the continued use of animals for human consumption without addressing underlying ethical concerns.

Limited Impact: The metaverse's impact on animal welfare in the physical world may be limited if virtual environments are not combined with changes to farming practices. Although virtual environments can improve animal welfare, they may not address the root causes of animal suffering, which could be related to the broader animal farming system (Stowers et al., 2017).

Cost and Accessibility: Implementing virtual environments in animal farming can be expensive and may not be accessible to all farmers, particularly smaller ones. Virtual environments necessitate significant technological infrastructure and may require specialized skills and resources (Bower et al., 2020).

Potential for Misrepresentation: Virtual environments can misrepresent animal behavior or their environment, leading to inadequate decision-making by farmers. While virtual environments can simulate natural habitats for animals, they may not accurately replicate real-life environments' complexity and subtleties (Neo et al., 2021).

Lack of Physical Stimulation: Virtual environments may not offer the same level of physical stimulation as real-life environments, potentially negatively affecting animal welfare. Animals in virtual environments may become bored or frustrated due to a lack of natural stimuli such as sunlight, wind, or natural substrates. This may impact their physical health, including musculoskeletal development or immune function, as they may be unable to engage in natural behaviors such as running, climbing, or grazing (Sagehorn et al., 2023).

3. Ethical Implications of Metaverse in Modern Animal Farming

Ethical Concerns: The metaverse's use in animal farming can lead to the potential commodification and objectification of animals in the virtual world. This disconnect may result in a lack of empathy and understanding of animal needs, normalizing unethical practices such as genetic modification or invasive procedures without proper justification (Rollin, 2011). However, it is essential to recognize that virtual and augmented reality technologies are not inherently unethical. These technologies have the potential to promote empathy and understanding of animals in

innovative ways, such as simulating the experiences of animals in the wild, allowing people to gain a deeper understanding of their behaviors and needs (Bertrand et al., 2018).

Accountability and Responsibility: As the lines between virtual and physical worlds blur, questions arise about accountability and responsibility in modern animal farming. It may become more challenging to hold individuals and corporations accountable for their actions, such as cruel or unethical treatment of animals in the metaverse. Determining responsibility and accountability for such behavior can be problematic.

The Potential for Positive Impact: The metaverse's use in modern animal farming is not inherently unethical. Virtual reality and augmented reality technologies can provide new ways of interacting with animals and promoting empathy and understanding. Simulating the experiences of animals in the wild can allow people to gain a deeper understanding of their behaviors and needs. It is crucial to ensure that these technologies follow ethical principles that prioritize animal well-being and dignity and that they do not perpetuate a culture that normalizes animal exploitation and neglect.

3.1. Socio-Economic Implications of Metaverse in Modern Animal Farming

The Cost Reduction and Efficiency: The metaverse's use in animal farming can help reduce costs associated with traditional farming practices, making animal farming more accessible and affordable, particularly for small-scale farmers who may struggle with the expenses of traditional methods. Furthermore, virtual environments can improve animal farming sustainability by reducing the environmental impact of conventional farming practices. By creating more sustainable and environmentally friendly farming systems, virtual environments can help mitigate the negative impact of animal farming on the environment while promoting ethical and sustainable practices.

Impact on Traditional Farming Practices and Livelihoods: The metaverse's adoption may have implications for traditional farming practices and the livelihoods of those who depend on them. As virtual environments become more prevalent, there could be a shift in the way animal farming is conducted, potentially affecting the job market for farmers and related industries. On the one hand, virtual environments may lead to job losses in traditional farming sectors; on the other, they could create new opportunities in the tech and virtual farming industries.

Digital Divide and Accessibility: The metaverse's widespread use in animal farming may exacerbate the digital divide between large and small-scale farmers. Small-scale farmers may lack the necessary resources to access and utilize virtual environments, putting them at a disadvantage compared to larger farms with the means to invest in such technologies. Consequently, this disparity could widen the gap between small and large-scale farms and further strain the livelihoods of small-scale farmers.

Public Perception and Trust: The integration of the metaverse into animal farming can influence public perception and trust in the industry. While virtual environments have the potential to improve transparency and awareness of animal welfare issues, they could also lead to skepticism regarding the authenticity of the information presented. Ensuring that virtual environments accurately represent farming practices and animal welfare will be crucial in maintaining public trust and promoting ethical consumption.

Regulatory and Legal Considerations: The metaverse's implementation in animal farming will require the development of new regulatory frameworks and legal structures to govern its use and address potential ethical concerns. Policymakers and stakeholders will need to collaborate to establish guidelines and regulations that ensure the responsible application of virtual environments in animal farming while safeguarding animal welfare, farmer livelihoods, and consumer interests.

Education and Training: The adoption of the metaverse in modern animal farming necessitates new educational and training programs to equip farmers and industry professionals with the skills and knowledge required to navigate and utilize virtual environments effectively. The development of specialized courses, workshops, and resources can help facilitate the transition to virtual farming practices and ensure that farmers can maximize the benefits of these technologies for animal welfare and farm productivity.

Ethical Consumerism: The metaverse's use in animal farming can contribute to the rise of ethical consumerism by providing consumers with immersive experiences that raise awareness of animal welfare issues and sustainable farming practices. These experiences can influence consumer behavior and promote the demand for ethically produced animal products, driving the industry towards more humane and environmentally friendly practices. However, it is essential to balance the promotion of ethical consumerism with the need to maintain an accurate representation of animal farming practices and avoid potential misrepresentation or greenwashing.

3.2. Economic Impact of Virtual Environments on Animal Farming

The use of virtual environments in animal farming can have a significant economic impact on the industry. Virtual environments can help to reduce costs associated with traditional farming practices, while also increasing efficiency, productivity, and profitability.

One of the primary economic benefits of virtual environments is that they can help to reduce the cost of feed and other inputs. In traditional animal farming, feed and other inputs can be a significant expense for farmers. However, virtual environments can help to reduce this cost by creating more efficient and sustainable farming systems. For example, virtual environments can be designed to optimize the use of feed, by tracking the dietary needs of individual animals and adjusting their feed accordingly. This can help to reduce waste and increase the efficiency of the farming system.

Furthermore, virtual environments can help to increase productivity and efficiency in animal farming. By creating more efficient and sustainable farming systems, virtual environments can help farmers to produce more food with fewer resources. This can help to increase profitability and make animal farming more accessible and affordable for small-scale farmers.

In addition to reducing the cost of inputs, virtual environments can also help to reduce the need for expensive medication and other treatments. By creating more sustainable and healthy farming systems, virtual environments can help to reduce the incidence of disease and other health problems in animals, which can be a significant expense for farmers. This can help to reduce the cost of animal healthcare and increase the profitability of animal farming. However, there are also economic costs associated with the adoption of virtual environments in animal farming. The adoption of new technologies, such as virtual environments, can require significant investment in terms of equipment, software, and training. This can be a significant barrier for some farmers, particularly small-scale farmers who may struggle with the costs of adopting new technologies.

Moreover, the adoption of virtual environments may also have implications for the labor force in animal farming. While virtual environments may reduce the need for labor in some aspects of animal farming, such as feeding and monitoring, they may also require new types of labor, such as software engineers and virtual environment designers. This can lead to a shift in the types of jobs available in animal farming and may require farmers and other stakeholders to adapt to new forms of labor and technology.

The economic benefits (Table 1) can help farmers to increase profitability and make animal farming more accessible and affordable for small-scale farmers. By adopting virtual environments, farmers can drive sustainable value and create a more ethical and sustainable animal farming system.

Table 1. Economic Impact of Virtual Environments on Animal Farming.

Impact	Description	Potential Benefits
Cost Reduction	Reduction in the cost of feed and other inputs by creating more efficient and sustainable farming systems. Optimization of the use of feed by tracking the dietary needs of individual animals and adjusting their feed accordingly, which can reduce waste and increase efficiency.	More accessible and affordable animal farming, increased profitability, reduced waste.
Productivity and Efficiency	Produce more food with fewer resources by creating more efficient and sustainable farming systems. This can increase productivity, efficiency and profitability, and make animal farming more accessible and affordable for small-scale farmers.	Increased productivity and profitability, more accessible and affordable animal farming.

Impact	Description	Potential Benefits
Sustainability	Can promote sustainability by reducing the environmental impact of traditional farming practices. By creating more sustainable and environmentally-friendly farming systems, virtual environments can reduce the negative impact of animal farming on the environment, while also promoting more ethical and sustainable farming practices.	Reduced environmental impact, promotion of more ethical and sustainable farming practices.
Animal Welfare	Virtual environments can help farmers monitor their animals' behavior and health, enabling early intervention and reducing stress. By improving animal welfare, farmers can create value and gain a competitive advantage in the market.	Improved animal welfare, creation of value and competitive advantage.
Data Analysis	Virtual environments generate vast amounts of data that farmers can use to optimize their production processes, reduce waste, and increase efficiency. By analyzing data, farmers can identify areas where improvements can be made, leading to increased productivity and profitability.	Increased productivity and profitability, reduced waste.
Training and Education	Investing in training and education can help farmers build the skills and knowledge necessary to effectively utilize virtual environments. By providing farmers with the necessary resources, they can maximize the benefits of virtual environments and drive sustainable value.	Increased skills and knowledge, maximized benefits of virtual environments, sustainable value creation.
Collaboration	Collaborating with other stakeholders, including animal welfare advocates, food safety experts, and technology providers, can help farmers leverage their expertise and create new opportunities for value creation. By working together, stakeholders can develop innovative solutions to improve animal welfare, increase productivity, and promote sustainable agriculture.	Innovative solutions for improving animal welfare, increased productivity, promotion of sustainable agriculture.
Regulatory Compliance	Ensuring regulatory compliance is critical to the long-term sustainability of virtual livestock farming. Farmers must adhere to regulations governing animal welfare, food safety, and data privacy to maintain their credibility and access to markets.	Maintained credibility, access to markets.
Technological Advancements	By adopting new technologies, such as artificial intelligence and machine learning, farmers can optimize their production processes, reduce costs, and increase efficiency.	Optimized production processes, reduced costs, increased efficiency.
Customer Relationships	Fostering relationships with customers is important for creating sustainable value in virtual livestock farming. By engaging with customers and providing transparent information about their farming practices, farmers can build trust and loyalty, leading to increased demand for their products.	Increased demand for products, trust and loyalty from customers.

3.3. Strategies For Creating Economic Opportunities and Sustainable Value in Virtual Farming:

Create value by improving animal welfare: Virtual environments can help farmers monitor their animal's behavior and health, enabling early intervention and reducing stress. By improving animal welfare, farmers can create value and gain a competitive advantage in the market.

Use data to increase productivity: Virtual environments generate vast amounts of data that farmers can use to optimize their production processes, reduce waste, and increase efficiency. By analyzing data, farmers can identify areas where improvements can be made, leading to increased productivity and profitability.

Invest in training and education: Investing in training and education can help farmers build the skills and knowledge necessary to effectively utilize virtual environments. By providing farmers with the necessary resources, they can maximize the benefits of virtual environments and drive sustainable value.

Collaborate with other stakeholders: Collaborating with other stakeholders, including animal welfare advocates, food safety experts, and technology providers, can help farmers leverage their expertise and create new opportunities for value creation. By working together, stakeholders can develop innovative solutions to improve animal welfare, increase productivity, and promote sustainable agriculture.

Ensure regulatory compliance: Ensuring regulatory compliance is critical to the long-term sustainability of virtual livestock farming. Farmers must adhere to regulations governing animal welfare, food safety, and data privacy to maintain their credibility and access to markets.

Embrace technological advancements: The agricultural industry is constantly evolving, and farmers must embrace technological advancements to stay competitive. By adopting new technologies, such as artificial intelligence and machine learning, farmers can optimize their production processes, reduce costs, and increase efficiency.

Foster relationships with customers: Creating sustainable value in virtual livestock farming also requires fostering relationships with customers. By engaging with customers and providing transparent information about their farming practices, farmers can build trust and loyalty, leading to increased demand for their products.

Consider alternative revenue streams: Virtual livestock farming can open up new revenue streams for farmers, such as selling access to data or providing consulting services. By diversifying their revenue streams, farmers can reduce their reliance on traditional farming practices and create more sustainable business models.

Promote environmental sustainability: Virtual livestock farming can also promote environmental sustainability by reducing the carbon footprint of the agricultural industry. By optimizing production processes and reducing waste, farmers can minimize their impact on the environment and promote a more sustainable food system.

4. Social Implications of Virtual Environments for Animal Farming

The use of virtual environments in animal farming can also have significant social implications, affecting a range of stakeholders, including farmers, consumers, and animal welfare advocates.

The adoption of virtual environments can offer a range of mainly economic benefits, including increased efficiency and profitability, as well as reduced labor costs to the farmers, this has clear social implications and it can help to make animal farming more accessible and profitable for small-scale farmers, as well as larger commercial operations. Additionally, the use of virtual environments may allow farmers to meet the growing demand for sustainably produced and ethically sourced food, which is becoming increasingly important to consumers.

Consumers may also benefit from the use of virtual environments in animal farming, as it can provide greater transparency and traceability in the food supply chain. By tracking the dietary needs and health of individual animals, virtual environments can help to ensure that food products are produced in a safe, ethical, and sustainable manner. This can also help to increase consumer confidence in the food supply chain, which is becoming increasingly important in the wake of food safety scandals and concerns about animal welfare.

Higher efficiency and productivity of animal farming operations, also, influence food industry and security, both locally and globally. By allowing for greater control over animal nutrition, health, and living conditions, virtual environments can help to reduce the risk of disease outbreaks and other issues that can negatively impact animal welfare and productivity. This can help to increase the

overall supply of food products, which is particularly important in regions where food security is a concern.

4.1. Role of Virtual Environments in Creating New Forms of Value Distribution And Accessibility

The adoption of virtual environments in animal farming has the potential to create new forms of value distribution and accessibility. This can enable greater access to food and promote a more equitable distribution of value across the industry stakeholders.

One way in which virtual environments can facilitate value distribution is by increasing the efficiency of distribution systems. By creating more accurate and real-time data on production, farmers can better manage their resources, optimize their operations, and speed up processes. This can lead to increased yields, improved quality, and lower costs of production, which can be passed on to consumers in the form of more affordable food and better distribution.

Moreover, the use of virtual environments can promote a more equitable distribution of value across the supply chain. By providing farmers with greater transparency and data on the price of their products, they can negotiate fairer prices with distributors and retailers, reducing the concentration of power in the hands of large agribusinesses.

4.2. Inclusion, Equity, and Governance in the Metaverse

The discussion on inclusion, equity, and diversity in the metaverse and animal farming highlights the importance of considering the socio-economic impact of virtual environments and the need to ensure that these technologies are developed and used in ways that are socially responsible and sustainable.

By involving a wide range of stakeholders in the development and use of virtual environments, including farmers, animal welfare experts, technology experts, policymakers, and members of the public, it is possible to identify potential biases or unintended consequences of virtual environments and to develop solutions that address them. This can help to ensure that the benefits of virtual environments are shared equitably and that vulnerable groups are not left behind.

Moreover, the cost and accessibility, as previously discussed, of virtual environments in animal farming can have significant socio-economic implications. The use of virtual environments may be expensive and may not be accessible to all farmers, particularly smaller farmers who may not have the necessary resources to adopt this technology. Ensuring that virtual environments are designed and used in ways that are inclusive and equitable can help to address these concerns and to ensure that virtual environments do not exacerbate existing socio-economic inequalities.

4.3. Potential for Virtual Environments to Promote Inclusion, Equity, And Diversity

In traditional animal farming, there are often barriers to entry for small-scale farmers, particularly those from marginalized communities, due to the high costs of equipment, land, and other resources. In contrast, virtual environments have lower barriers to entry, as they can be accessed from anywhere with an internet connection and a computer. This could enable more diverse groups of people to enter the animal farming industry and increase equity.

However, there are also risks of perpetuating existing inequalities in animal farming through virtual environments. For example, if only those who have access to technology and the resources to invest in virtual animal farming can participate, then the digital divide could be further exacerbated. It is important to ensure that virtual animal farming is accessible to all, regardless of their socio-economic background.

In addition, it is important to consider the ethical implications of creating digital representations of farm animals. If virtual animals are designed to appeal only to certain demographics or perpetuate harmful stereotypes, this could have negative consequences for inclusion and diversity in animal farming.

Virtual environments have the potential to promote inclusion, equity, and diversity in animal farming by providing a platform for collaboration and knowledge sharing among stakeholders.

These platforms can provide opportunities for small and marginalized farmers to participate in the industry and access new markets. Additionally, virtual environments can help break down language barriers by providing translation services, making it easier for farmers from different countries and backgrounds to communicate and share knowledge.

Virtual environments can also help to promote social equality and animal welfare by providing access to education and training. For example, virtual reality simulations can provide farmers with a safe and controlled environment to learn new techniques for handling and caring for animals. Additionally, virtual environments can help to increase public awareness and education around animal welfare issues, leading to more informed and responsible consumer behavior.

Moreover, farmers with mobility impairments may find it challenging to engage in traditional animal husbandry, such as physically herding livestock or cleaning animal enclosures. Virtual environments can provide a platform for these farmers to engage in animal farming in a way that accommodates their physical limitations. This can lead to greater inclusion of farmers with disabilities and promote greater equality in the industry.

The potential of virtual environments to promote inclusion, equity, and diversity in animal farming and to improve animal welfare is significant. However, careful consideration must be given to the ethical, social, economic, and technological implications of their implementation. Furthermore, it is important to consider the perspectives of various stakeholders, including farmers, consumers, and animal welfare advocates, in developing and implementing virtual environments in animal farming. By doing so, we can ensure that these technologies are used to promote the common good and contribute to a more sustainable and equitable agricultural industry.

5. Governance of Metaverse in Modern Animal Farming

Technology governance plays a significant role in ensuring that digital tools are deployed equitably and effectively (Matheny et al., 2019). Without proper governance, there is a risk that only large-scale, well-funded operations will be able to benefit from the advantages of virtual environments, exacerbating existing social and economic disparities. By promoting equity and inclusivity, technology governance can help ensure that the benefits of digital technologies are shared by all farmers, regardless of their resources or location.

Technology governance plays a crucial role in the socio-economic impact of virtual environments in livestock farming. It encompasses the policies, procedures, and regulations that guide the development and deployment of digital technologies, ensuring equitable access and promoting inclusivity.

In the context of virtual environments in animal farming, technology governance can ensure that all farmers have access to the necessary tools to improve animal welfare, increase productivity, and ensure food safety. This involves developing digital tools with input from all stakeholders, providing training and support for farmers, and establishing clear guidelines and regulations around the use of virtual environments.

Moreover, technology governance can ensure that the deployment of digital technologies does not exacerbate existing social and economic disparities. Governments can promote equity and inclusivity in the agricultural industry by providing subsidies or grants to farmers who lack the resources to purchase and implement virtual environments.

One of the key roles of governance in promoting animal welfare in the metaverse is to establish clear guidelines and regulations around the use of virtual environments in animal farming. These guidelines can help ensure that virtual environments are used responsibly and ethically and that the welfare of animals is prioritized. Governance can also promote transparency in animal farming by requiring the public disclosure of information related to animal welfare outcomes, building trust and confidence in the use of virtual environments in animal farming among all stakeholders.

5.1. Human-Animal Interactions in Virtual Farming

While virtual environments have the potential to improve animal welfare, concerns arise regarding the possible reduction in human-animal interactions and decreased empathy for animal

suffering. The influence of virtual environments on human-animal interactions in livestock farming is a multifaceted issue that demands thorough examination and evaluation. Fostering trust, bonding, empathy, and emotional intelligence in virtual settings is crucial to ensure animal welfare and optimize agricultural outcomes. As the adoption of virtual environments in agriculture expands, it is vital to understand the potential consequences on animal welfare and the emotional connection between farmers and their livestock. Livestock, being social animals, have evolved to interact with humans, and insufficient social interaction can result in stress and anxiety. To ensure that virtual environments contribute positively to animal welfare, it is imperative to facilitate trust and bonding between farmers and their animals within these settings. Building rapport between humans and animals can alleviate stress and anxiety, promoting a healthier and more productive environment for livestock. By enabling farmers to connect emotionally with their livestock and better understand their needs and wants, these skills contribute significantly to the welfare of animals in virtual environments. Additionally, cultivating empathy and emotional intelligence can foster more ethical treatment of livestock and enhance agricultural outcomes. By incorporating features that promote meaningful human-animal interactions, virtual environments can help farmers establish strong connections with their animals and better cater to their needs.

5.2. Role of empathy and emotional intelligence in virtual interactions with animals

The role of empathy and emotional intelligence is increasingly being recognized in virtual interactions with animals. As the world continues to move towards virtual and remote interactions, especially with the ongoing COVID-19 pandemic, people are increasingly turning to technology to interact with animals in a variety of contexts, such as virtual zoos, aquariums, and even pet therapy sessions.

Empathy is the ability to understand and share the feelings of others, and it is crucial in virtual interactions with animals because it allows us to connect with them emotionally. When we empathize with animals, we can see things from their perspective and understand their needs and wants (Fox, 2021). This can help us provide them with better care and improve our interactions with them.

Emotional intelligence is also important in virtual interactions with animals. Emotional intelligence is the ability to recognize and manage one's own emotions, as well as the emotions of others. In virtual interactions with animals, emotional intelligence allows us to regulate our own emotions, which can be helpful in situations where animals may be unpredictable or in cases where we may encounter an animal in distress.

In virtual interactions with animals, technology can provide a unique opportunity to connect with animals in a way that may not be possible in person. For example, virtual reality can allow us to experience what it is like to be in an animal's habitat, which can help us better understand their behavior and needs. Additionally, virtual interactions with animals can be a powerful tool for education and conservation efforts, as it allows people to connect with animals that may be endangered or difficult to see in person.

However, it is important to note that virtual interactions with animals should not replace in-person interactions or be the sole means of connecting with animals. In-person interactions provide important sensory information (Vigors and Lawrence, 2019) that is difficult to replicate virtually, such as the smells and sounds of an animal's environment. Additionally, in-person interactions allow for more meaningful connections and can provide a deeper understanding of an animal's behavior and needs.

5.3. Trust and bonding between farmers and their animals in virtual environments

The importance of building trust and bonding between farmers and their animals in virtual environments cannot be overstated. With the rise of digital technologies, virtual interactions have become increasingly common in the agricultural industry, and farmers are turning to technology to connect with their animals remotely.

In the absence of physical proximity, farmers must rely on virtual tools to create a bond with their animals. This can be achieved through virtual tours, video calls, and live streaming of the

animals. It is essential to establish a consistent routine for these interactions to ensure that the animals are comfortable and receptive to the virtual environment.

Building trust is a critical component of the bonding process. Farmers must be patient and take the time to understand their animals' behavior and body language, even in a virtual setting. This understanding can help farmers anticipate their animals' needs and respond appropriately, further strengthening the bond between them.

Moreover, farmers must create an environment that is conducive to their animals' well-being. This includes providing a comfortable space for them to rest, ensuring that they have access to water and food, and creating a safe and secure environment.

The ultimate goal of building trust and bonding between farmers and their animals is to improve animal welfare and productivity (Rault et al., 2020). A strong bond can help reduce stress, which can impact the animals' health and productivity. By creating a virtual environment that fosters trust and bonding, farmers can enhance their animals' welfare and ultimately improve their bottom line.

6. Designing Ethical Metaverse for Animal Farming

Virtual environments hold the potential to transform animal farming practices for both farmers and animals. However, it is important to recognize that the introduction of new technologies does not automatically address all concerns and challenges. Therefore, the development of an ethical metaverse must incorporate certain principles that have been established through prior discussions.

First, it is important to consider the well-being of the animals themselves. The virtual environment should be designed to meet the animals' basic needs, such as access to food and water, as well as space for movement and socialization. The virtual environment should also be free from stressors and potential harm to the animals.

Second, the ethical considerations for designing virtual environments for livestock farming include ensuring that the virtual environment is accessible to all animals, regardless of their age, size, or breed. This is particularly important in situations where certain animals are considered more valuable or desirable than others.

Third, virtual environments should be designed to promote animal welfare and reduce the overall suffering of animals in livestock farming. This can be achieved by designing virtual environments that provide animals with a sense of safety and security, as well as opportunities for natural behavior and enrichment.

Fourth, it is important to consider the ethical implications of virtual environments on human labor and employment. Virtual environments may have the potential to automate some tasks traditionally done by farm workers, which could lead to job displacement or changes in employment structures. It is important to consider the social and economic impact of these changes and to work towards creating equitable and just working conditions.

Fifth, virtual environments may have the potential to change the nature of human-animal interactions in livestock farming. As such, it is important to consider how the virtual environment might impact the relationship between humans and animals and to design the environment in a way that promotes positive interactions and relationships.

Table 2 summarizes the principles for designing an ethical metaverse for animal farming. It provides an overview of the key ethical considerations and principles that must be taken into account when developing and implementing virtual environments in animal farming. The table can be used as a quick reference guide for farmers, animal scientists, bioengineers, veterinarians, policymakers, consumers, and business-to-business clients who are interested in adopting virtual environments in animal farming, to ensure that ethical considerations are met, and the technology is used responsibly.

Table 2. Principles for Designing an Ethical Metaverse for Animal Farming.

Principle	Description
Animal well-being	

Principle	Description
	Virtual environments should meet the basic needs of animals such as access to food, water, space for movement, and socialization. The virtual environment should be free from stressors and potential harm to the animals.
Accessibility	The virtual environment should be designed to be accessible to all animals, regardless of their age, size, or breed.
Animal welfare	Virtual environments should be designed to promote animal welfare and reduce overall suffering by providing a sense of safety and security, as well as opportunities for natural behavior and enrichment.
Human labor and employment	Ethical implications of virtual environments on human labor and employment should be considered, with a focus on creating equitable and just working conditions.
Human-animal interactions	Virtual environments should be designed to promote positive interactions and relationships between humans and animals.
Transparency and accountability	The virtual environment should adopt an open and transparent approach to the design, operation, and management of the system, and be accountable to stakeholders, including farmers, consumers, and animal welfare advocates.
Monitoring and evaluation	Regular monitoring and evaluation should be carried out to assess the impact of virtual environments on animal welfare.
Sustainability and environmental responsibility	Designers of virtual environments should consider the environmental impact of the system and take measures to minimize its footprint.
Accessibility	Virtual environments should make livestock farming more accessible to people who live in areas where traditional farming is not possible, due to a lack of land or resources.
Innovation	Virtual environments should create opportunities for innovation in the livestock farming industry, leading to the development of new technologies that could improve the efficiency and effectiveness of livestock farming.
Productivity	Virtual environments can provide farmers with a more efficient way of managing their livestock, enabling them to monitor their animals remotely and detect issues before they become significant problems.
Human expertise	Maintaining a strong focus on human expertise and skills can be achieved through investment in training and education programs, as well as support for research and development in areas such as animal behavior, welfare, and nutrition.
Collaboration	Fostering collaboration between farmers, scientists, and other stakeholders can help ensure that new technologies and strategies are developed in a way that reflects the needs and values of all stakeholders.

7. Best Practices for Virtual Environments that Promote Animal Welfare and More Efficient Farming

The urgency of exploring best practices for designing and implementing virtual environments that promote animal welfare, enhance agricultural efficiency, and contribute to a more sustainable and eco-friendly future cannot be overstated. As the world faces mounting challenges related to climate change, resource scarcity, and a growing global population, it is imperative that innovative solutions are developed to address these pressing concerns.

By leveraging cutting-edge technologies and adopting best practices in virtual environments, we can create a paradigm shift in the livestock farming industry. These practices will not only ensure the ethical treatment of animals but also optimize resource utilization, reduce environmental impacts, and improve overall agricultural efficiency. By investing in research and development, promoting innovation, and supporting the adoption of best practices in virtual environments, we can pave the way for a more sustainable and eco-friendly future in livestock farming. This will not only improve the well-being of animals but also contribute to global food security and economic growth, ensuring a better quality of life for all.

By simulating natural habitats, the virtual environments can provide animals with a more humane and ethical living experience, while also offering farmers increased efficiency and productivity. Below provides a list of comprehensive guides to best practices for designing virtual environments that prioritize animal welfare and promote efficient farming.

Access to Food, Water, and Adequate Living Conditions

Animals in virtual environments must have access to an adequate supply of food and water that meets their nutritional needs. The virtual environment should simulate the animal's natural habitat, incorporating ample space, temperature control, ventilation, and lighting that mimic natural conditions. A diverse array of food sources should be provided, reflecting the unique dietary requirements of each animal species.

Space and Freedom of Movement

Ensuring animals have enough space to move around freely, stretch their limbs, and exhibit natural behaviors is crucial for their well-being in virtual environments. By providing adequate room for animals to move, interact, and socialize with one another, virtual environments can help reduce stress and improve overall animal welfare.

Health and Medical Care

Adequate health care must be provided to animals in virtual environments, mirroring the standards found in real-life farming. This includes regular check-ups and prompt medical attention for any health issues that may arise.

Reduction of Stress and Pain

Virtual environments must be designed to meet the physical and emotional needs of animals, minimizing stress and pain. By allowing animals to move freely, socialize, and interact positively with humans, virtual environments can provide a more humane and ethical living experience.

Catering to Animal-Specific Needs

Different animal species have unique needs and behaviors that should be considered in the design of virtual environments. For example, laying hens require nesting areas, while pigs need space to root and forage. Designing environments that cater to animal-specific needs can enhance animal welfare and promote ethical treatment.

Transparency and Accountability

Virtual environments should adopt an open and transparent approach to their design, operation, and management. By being accountable to stakeholders, including farmers, consumers, and animal welfare advocates, virtual environments can help ensure ethical treatment and animal welfare.

Monitoring and Evaluation

Regular monitoring and evaluation should be carried out to assess the impact of virtual environments on animal welfare. Any issues related to animal welfare should be addressed immediately to ensure the well-being of the animals.

Promoting Sustainability and Environmental Responsibility

Designers of virtual environments must consider the environmental impact of the system and take measures to minimize its footprint. This includes reducing energy consumption, minimizing water usage, and managing waste production. Ultimately, virtual environments can play a significant role in promoting sustainability and environmental responsibility in animal farming, contributing to a more sustainable and eco-friendly future.

Increasing Accessibility

Virtual environments should make livestock farming more accessible to people who live in areas where traditional farming is not possible due to a lack of land or resources. Virtual livestock farming could provide these individuals with an opportunity to participate in agriculture, promoting economic growth and improving food security.

Fostering Innovation

Virtual environments should create opportunities for innovation in the livestock farming industry. For example, the use of virtual environments could lead to the development of new technologies, such as sensors and artificial intelligence, which could improve the efficiency and effectiveness of livestock farming.

Enhancing Productivity

Virtual environments can provide farmers with a more efficient way of managing their livestock, enabling them to monitor their animals remotely and detect issues before they become significant problems. This approach can lead to increased productivity and efficiency, as farmers can make decisions based on real-time data, rather than relying on traditional methods.

Fostering Human Expertise

While emerging technologies can improve the efficiency of livestock farming, it is important to maintain a strong focus on human expertise and skills. This can be achieved through investment in training and education programs, as well as support for research and development in areas such as animal behavior, welfare, and nutrition.

Encouraging Collaboration

To ensure that the future of livestock farming in the metaverse remains focused on human needs, it is important to foster collaboration between farmers, scientists, and other stakeholders. This can help to ensure that new technologies and strategies are developed in a way that reflects the needs and values of all stakeholders.

Virtual environments have the potential to revolutionize the livestock farming industry by promoting animal welfare, enhancing agricultural efficiency, and contributing to a more sustainable and eco-friendly future. By implementing best practices in the design and management of virtual environments, we can ensure that these systems prioritize animal welfare, while also fostering innovation, collaboration, and human expertise. As the metaverse continues to expand, it is crucial that we seize this opportunity to reshape the livestock farming industry in a way that benefits animals, farmers, and the environment alike.

8. The Future of Farming

The future of livestock farming in the metaverse is full of potential and promise. By embracing new technologies and practices, we can transform the industry for the better, improving efficiency, productivity, and sustainability, while also enhancing animal welfare and human well-being. Emerging technologies, such as artificial intelligence (AI) and robotics, have the potential to revolutionize the livestock farming industry (Neethirajan & Kemp, 2021). These technologies can be used to improve the efficiency, productivity, and sustainability of livestock farming, while also enhancing animal welfare. Here are some examples of how these technologies can be used in livestock farming:

Artificial intelligence (AI): AI can be used to monitor and analyze data from livestock farms, providing farmers with real-time insights into animal health, behavior, and productivity. This can help farmers make informed decisions about breeding, feeding, and other aspects of livestock management. For example, AI can be used to predict the onset of disease, enabling farmers to take early action to prevent an outbreak.

Robotics: Robotics can be used in various aspects of livestock farming, from feeding and cleaning to milking and shearing (Lovarelli et al., 2020). Robotic milkers, for example, can milk cows more efficiently and with less stress for the animals. Robotic feeders can provide animals with precise amounts of feed, reducing waste and improving efficiency.

Sensors: Sensors can be used to monitor various aspects of animal health and behavior, such as temperature, heart rate, and activity level (Neethirajan, 2020). This information can be used to identify potential health issues or stressors, enabling farmers to intervene early and improve animal welfare.

Smart farming systems: Smart farming systems combine various technologies, such as AI, robotics, and sensors, to create a comprehensive system for managing livestock farms (Neethirajan, 2023). These systems can provide farmers with real-time data and insights, enabling them to make informed decisions and improve efficiency.

Precision (or) Digital Livestock Farming: Precision agriculture uses technologies such as GPS and remote sensing to create precise maps of farms, enabling farmers to manage their land and resources more efficiently. This can lead to reduced inputs, such as water and fertilizer, while also improving productivity and reducing environmental impact.

One of the most promising areas of development in virtual livestock farming is the use of artificial intelligence and robotics. These technologies have the potential to revolutionize the industry, improving efficiency, productivity, and sustainability, while also enhancing animal welfare. For example, AI systems can be used to monitor and manage animal health and nutrition, while robotics can be used to automate tasks such as feeding and cleaning. However, it is important to ensure that these technologies are developed responsibly and sustainably, with a focus on human values and needs, as well as the welfare of animals, according to the aforementioned principles.

9. Conclusions

As we look to the future of animal farming, virtual environments provide exciting new possibilities for improving animal welfare, reducing stress and anxiety, and promoting sustainable and ethical practices. However, we must also consider the potential limitations and drawbacks of their use, including ethical concerns, long-term effects on animal behavior, cost and accessibility, and lack of physical stimulation.

It is essential that animal welfare remains at the forefront of the development of the metaverse in animal farming. By prioritizing ethical considerations and diversity and equity, we can ensure that virtual environments are implemented in a responsible and humane way. This requires a thoughtful and well-informed approach that takes into account the social and economic implications of this technology.

While the implementation of virtual environments in animal farming presents significant challenges, it also offers immense opportunities for improving the lives of animals and creating a more sustainable and equitable agricultural industry. By embracing this technology and addressing

its limitations with a responsible and ethical approach, we can pave the way for a brighter future for animal farming.

In conclusion, the implementation of virtual environments in animal farming requires a careful balance of technological advancement, ethical considerations, and sustainability. By approaching this challenge with a responsible and ethical mindset, we can harness the potential benefits of the metaverse while ensuring that animal welfare and equity remain at the forefront of our efforts. Let us strive for a future where animal farming is both sustainable and humane, and where virtual environments serve as a tool to help us achieve this goal.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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