Annexure-I

Ph.D. End Term Presentation

On

Designing of Novel Approach Using Metaverse Technology for Smart Agriculture System

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DOCTOR OF PHILOSOPHY

IN

(Computer Applications)

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Phagwara, Jalandhar, PUNJAB (144411)

May-June, 2025

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Chapter 1: Introduction to the Proposed work

Metaverse Technology is a shared, immersive and interactive virtual reality where users can create their own avatars and environments and engage with users in real time. The metaverse could be a potential successor to the internet, offering a more immersive and interactive way to connect with others. It could also be a potential platform for a wide range of applications including social media, entertainment, education and e-commerce. Data collected from farmers at ground zero can be used to process and create virtual module that imitates the Earth. In contrast to real world observation, virtual eco-system helps in sensing the acquisition of information of various attributes from multiple (IoT)[*1] sensors into a central dashboard. The IoT phenomenon is fetching data from various sensors that are collaborated to gathering information about the climatic conditions of Earth at a given point of time. The metaverse refers to persistent, shared, 3D virtual environments accessed via the internet, often using (AR)[*2] and (VR)[*3] devices which provides rich experience to user to get Immersive environments for simulation, training, and education. Metaverse Technology helps in creating a Digital Twins which is a Virtual replica of physical farms used for monitoring and decision-making, Blockchain & (NFTs)[*4] that helps to be the Owner of virtual assets like digital gold or paper gold and secure digital identities, AI Avatars and (NPCs)[*5] which can help Virtual assistants or guides in metaverse spaces to identify users that exist in real-world and virtual-world. The Metaverse eco-system is based on Cloud Computing which helps uses scalable infrastructure for hosting virtual environments.

(IoT)[*1] *stands for Internet of Things. It refers to the network of physical devices, vehicles, home appliances, and other items embedded with sensors, software, and connectivity, allowing them to collect and exchange data with other devices and systems over the internet. In agriculture, IoT can be used for:*

IoT Applications in Agriculture

1. Precision farming: Monitoring soil moisture, temperature, and crop health.

2. Automated irrigation: Controlling water usage based on real-time data.

3. Crop monitoring: Tracking crop growth and detecting potential issues.

IoT technology can help farmers optimize crop yields, reduce waste, and improve resource allocation.

(AR)[*2] *stands for Augmented Reality: Overlays digital information onto the real world, enhancing the user's experience.*

(VR)[*3] *Virtual Reality: Creates a completely immersive digital environment, shutting out the physical world.*

(NFTs)[*4] *stands for Non-Fungible Tokens these are unique digital assets that cannot be exchanged for another identical asset. They are often used to represent ownership or proof of authenticity for digital art, collectibles, and other unique items. In the context of the metaverse, NFTs can be used to represent virtual assets, such as digital land, art, or other unique items.*

(NPCs)[*5] *stands for non-Player Characters in the context of the metaverse, NPCs refer to virtual characters that are controlled by artificial intelligence (AI) and can interact with users in virtual environments. NPCs can be used as virtual assistants, guides, or even characters in games and simulations.*

Conventional approaches: Traditionally, approaches used in smart agriculture systems include:

1. **Precision Farming:**
    a. GPS and GIS: Using satellite imaging and geographic information systems to monitor and manage crops.
    b. Soil Sensors: Monitoring soil moisture, temperature, and nutrient levels.
    c. Crop Monitoring: Tracking crop health, growth, and development.
2. **Automation and Mechanization:**
    a. Drones: Using unmanned aerial vehicles (UAVs) for crop monitoring, spraying, and seeding.
    b. Automated Irrigation: Controlling water usage based on soil moisture levels and crop needs.
    c. Robotic Farming: Using robots for tasks such as planting, pruning, and harvesting.
3. **Data Analysis and Decision Support**
    a. Data Analytics: Analyzing data from various sources to optimize crop yields and reduce waste.
    b. Decision Support Systems: Providing farmers with insights and recommendations to inform their decisions.
4. **Integrated Pest Management (IPM)**: Using a holistic approach to manage pests and diseases.
5. **Crop Rotation and Planning**: Optimizing crop rotation and planning to improve soil health and reduce pests and diseases.
6. **Advanced Technologies**:
    a. Artificial Intelligence (AI): Using machine learning and deep learning to analyze data and make predictions.
    b. Machine Learning (ML): Developing models to predict crop yields, detect diseases, and optimize farming practices.
    c. Computer Vision: Analyzing images to detect crop health, pests, and diseases.
7. **Data-Driven Approaches:**
    a. Big Data Analytics: Analyzing large datasets to gain insights and optimize farming practices.
    b. Predictive Analytics: Using statistical models to predict crop yields, weather patterns, and pest outbreaks.
    c. Precision Livestock Farming: Using data analytics and sensors to monitor and manage livestock health and productivity.
8. **IoT and Sensor-Based Approaches:**
    a. Wireless Sensor Networks (WSNs): Using wireless sensors to monitor soil moisture, temperature, and other environmental factors.
    b. Smart Farming Sensors: Using sensors to monitor crop health, soil conditions, and weather patterns.
    c. Livestock Monitoring: Using sensors and wearables to monitor livestock health and behavior.

9. **Sustainability and Environmental Approaches:**
    a. Sustainable Agriculture: Using practices that promote environmental sustainability and social responsibility.
    b. Organic Farming: Using natural methods to control pests and diseases, and promote soil health.
    c. Regenerative Agriculture: Using practices that promote soil health, biodiversity, and ecosystem services.
10. **Other Approaches**
    a. Vertical Farming: Growing crops in vertically stacked layers, often in indoor environments.
    b. Hydroponics: Growing crops in nutrient-rich water rather than soil.
    c. Aquaponics: Combining fish and plant production in a closed-loop system.

Data collection and implementation in a traditional system requires extremely high, even impractical, resources in terms of expenses, time, and manpower for measuring the fields, integrating statistical results, and eliminating spatial and temporal errors. It is too difficult to manage and monitor resource for long-term solutions, for natural resources including agriculture, water, forestry, and coastal management for assessment and analysis. Among all natural resources, agriculture and attributes like water, climatic conditions have higher influence over natural resources that are fundamental for mankind to survive and to make living. Traditionally, all the approaches and systems that were developed and implemented with primary data source for the understanding the in and out of agriculture and its dynamics behaviour. Data collected through traditional approaches, but these approaches have declined dramatically in its usage and maintenance because of which the system has failed after being developed and deployed in agriculture sector. However, even in places where traditional approaches exist, legal and institutional restrictions often make the data unavailable for analysis, and scientific purposes. Therefore, assessing changes in the dynamic behaviour of agriculture and its resources at national and state level is exceedingly difficult to be available.

Precision Farming	Key Components	Benefits	Technologies Used	Applications	Challenges
Precision farming is a farming practice that uses advanced technology to optimize crop yields, reduce waste, and promote sustainability. It involves collecting and analyzing data on various factors such as soil moisture, temperature, crop health, and weather patterns to make informed decisions.	1. Data Collection: Collecting data from various sources such as sensors, drones, and satellites. 2. Data Analysis: Analyzing data to identify trends, patterns, and insights. 3. Decision Making: Using data-driven insights to make informed decisions on farming practices. 4. Precision Application: Applying inputs such as fertilizers, pesticides, and water precisely where and when they are needed.	1. Increased Crop Yields: Precision farming can help farmers optimize crop yields and reduce waste. 2. Reduced Input Costs: By applying inputs precisely where and when they are needed, farmers can reduce waste and save money. 3. Improved Sustainability: Precision farming can help reduce the environmental impact of farming by minimizing the use of chemicals and water. 4. Enhanced Decision Making: Precision farming provides farmers with data-driven insights to inform their decisions.	1. Precision Irrigation: Using sensors and automation to optimize water application. 2. Crop Monitoring: Using drones, satellites, and sensors to monitor crop health and development. 3. Soil Mapping: Creating detailed maps of soil type, moisture, and nutrient levels. 4. Variable Rate Technology: Applying inputs at varying rates based on soil type, crop needs, and other factors.	1. Crop Management: Precision farming can be used to optimize crop yields, reduce waste, and promote sustainability. 2. Livestock Management: Precision farming can be used to monitor and manage livestock health, nutrition, and behavior. 3. Farm Management: Precision farming can be used to optimize farm operations, reduce costs, and improve efficiency.	1. Data Management: Managing large amounts of data from various sources can be challenging. 2. Cost: Implementing precision farming technologies can be expensive. 3. Interoperability: Integrating different technologies and systems can be challenging. 4. Data Security: Protecting sensitive data from unauthorized access can be a concern.

Overall, precision farming has the potential to revolutionize the way we farm by providing farmers with data-driven insights to inform their decisions and optimize crop yields. Precision farming can fail in several areas like:

Technical Challenges

1. Data Quality Issues: Poor data quality can lead to inaccurate insights and decisions.
2. Interoperability: Integrating different technologies and systems can be challenging.
3. Connectivity: Limited internet connectivity in rural areas can hinder the use of precision farming technologies.
4. Cybersecurity: Protecting sensitive data from unauthorized access can be a concern.

Economic Challenges

1. High Upfront Costs: Implementing precision farming technologies can be expensive.
2. Return on Investment: Farmers may not see a significant return on investment, especially if they are not familiar with the technology.
3. Scalability: Precision farming technologies may not be scalable to smaller farms or farms with limited resources.

Human Factors

1. Lack of Technical Expertise: Farmers may not have the necessary technical expertise to use precision farming technologies effectively.
2. Resistance to Change: Some farmers may be resistant to adopting new technologies and practices.
3. Training and Support: Farmers may need training and support to effectively use precision farming technologies.

Data Analysis and Interpretation

1. Data Overload: Farmers may be overwhelmed by the amount of data generated by precision farming technologies.
2. Lack of Insights: Farmers may not know how to interpret the data or generate actionable insights.
3. Decision Making: Farmers may struggle to make decisions based on data-driven insights.

Regulatory and Policy Challenges

1. Regulatory Frameworks: Regulatory frameworks may not be in place to support the use of precision farming technologies.
2. Data Ownership: There may be concerns about data ownership and sharing.
3. Standards and Interoperability: There may be a lack of standards and interoperability between different precision farming technologies.

Automation and mechanization	**Key Components**	**Benefits**	**Technologies Used**	**Applications**	**Challenges**
Automation and mechanization are key components of smart agriculture systems, enabling farmers to optimize crop yields, reduce labour costs, and improve efficiency.	1. Autonomous Tractors: Tractors equipped with GPS, sensors, and AI to navigate and perform tasks autonomously. 2. Drones: Unmanned aerial vehicles (UAVs) used for crop monitoring, spraying, and seeding. 3. Robotic Farming: Robots designed to perform specific tasks such as pruning, harvesting, and weeding. 4. Automated Irrigation: Systems that use sensors and automation to optimize water application. 5. Sensors: Sensors can be used to collect data on soil moisture, temperature, and other factors. 6. Actuators: Actuators can be used to control systems such	1. Increased Efficiency: Automation and mechanization can reduce labour costs and improve efficiency. 2. Improved Accuracy: Automated systems can perform tasks with greater accuracy and precision. 3. Enhanced Crop Yields: Automation and mechanization can help optimize crop yields and reduce waste. 4. Reduced Labor Costs: Automation and mechanization can reduce the need for manual labour.	1. Artificial Intelligence (AI): AI algorithms can be used to analyze data and make decisions in real-time. 2. Internet of Things (IoT): IoT devices can be used to collect data from sensors and other sources. 3. Robotics: Robots can be used to perform tasks such as harvesting, pruning, and weeding. 4. Computer Vision: Computer vision can be used to analyze images and detect issues such as pests and diseases. 5. Machine Learning: Machine learning algorithms can be used to analyze data and make predictions.	1. Crop Monitoring: Automation and mechanization can be used to monitor crop health, growth, and development. 2. Precision Farming: Automation and mechanization can be used to optimize crop yields and reduce waste. 3. Livestock Management: Automation and mechanization can be used to monitor and manage livestock health, nutrition, and behavior. 4. Farm Management: Automation and mechanization can be used to optimize farm operations, reduce costs, and improve efficiency.	1. High Upfront Costs: Implementing automation and mechanization technologies can be expensive. 2. Technical Expertise: Farmers may need technical expertise to operate and maintain automated systems. 3. Data Management: Managing data from automated systems can be challenging. 4. Integration with Existing Systems: Integrating automated systems with existing farm equipment and infrastructure can be challenging.

	as irrigation and fertilization. 7. GPS and GIS: GPS and GIS can be used to track the location and movement of equipment and crops. 8. Automation Systems: Automation systems can be used to control and optimize farm equipment and processes. 9. Data Analytics: Data analytics can be used to analyze data and make informed decisions.				

Overall, automation and mechanization have the potential to revolutionize the way we farm, enabling farmers to optimize crop yields, reduce labour costs, and improve efficiency. automation and mechanization farming can fail in several areas like:

Technical Challenges

1. System Malfunctions: Technical issues with equipment and machinery can cause downtime and reduce productivity.
2. Data Quality Issues: Poor data quality can lead to inaccurate insights and decisions.
3. Interoperability: Integrating different systems and technologies can be challenging.
4. Cybersecurity: Protecting sensitive data and systems from cyber threats can be a concern.

Economic Challenges

1. High Upfront Costs: Implementing automation and mechanization technologies can be expensive.
2. Return on Investment: Farmers may not see a significant return on investment, especially if they are not familiar with the technology.
3. Scalability: Automation and mechanization technologies may not be scalable to smaller farms or farms with limited resources.

Human Factors

1. Lack of Technical Expertise: Farmers may not have the necessary technical expertise to operate and maintain automated systems.
2. Resistance to Change: Some farmers may be resistant to adopting new technologies and practices.
3. Training and Support: Farmers may need training and support to effectively use automation and mechanization technologies.

Environmental Factors

1. Weather Conditions: Extreme weather conditions can affect the performance and reliability of automated systems.
2. Soil and Crop Variability: Automation and mechanization technologies may not be able to account for variability in soil and crop conditions.

Regulatory and Policy Challenges

1. Regulatory Frameworks: Regulatory frameworks may not be in place to support the use of automation and mechanization technologies.
2. Liability and Insurance: There may be concerns about liability and insurance for automated systems.
3. Data Ownership and Sharing: There may be concerns about data ownership and sharing.

Data Analysis and Decision Support in smart agriculture can fail in several areas:

Data Quality Issues

1. Inaccurate Data: Inaccurate or incomplete data can lead to poor decision making.
2. Data Integration: Integrating data from different sources can be challenging.
3. Data Cleaning: Ensuring data is clean and free of errors can be time-consuming.

Analysis and Interpretation

1. Lack of Insights: Data analysis may not provide actionable insights.
2. Incorrect Interpretation: Incorrect interpretation of data can lead to poor decision making.
3. Limited Context: Data analysis may not take into account contextual factors.

Decision Support

1. Lack of Decision Support Tools: Limited availability of decision support tools and systems.
2. Inadequate Training: Farmers may not have the necessary training to use decision support tools effectively.
3. Overreliance on Technology: Overreliance on technology can lead to decreased critical thinking and decision-making skills.

Technical Challenges

1. Data Volume and Complexity: Managing large volumes of complex data can be challenging.
2. Data Security: Ensuring data security and protecting against cyber threats.
3. Interoperability: Ensuring different systems and tools can integrate seamlessly.

Human Factors

1. Lack of Technical Expertise: Farmers may not have the necessary technical expertise to use data analysis and decision support tools.
2. Resistance to Change: Some farmers may be resistant to adopting new technologies and practices.
3. Trust in Technology: Farmers may not trust technology to make decisions.

Consequences

1. Poor Decision Making: Poor data analysis and decision support can lead to poor decision making.
2. Reduced Productivity: Inaccurate or incomplete data can lead to reduced productivity.
3. Increased Costs: Poor decision making can lead to increased costs.

Integrated Pest Management (IPM) can fail in several areas:

Lack of Understanding

1. Insufficient Knowledge: Lack of understanding of pest biology, ecology, and behavior.
2. Inadequate Monitoring: Insufficient monitoring of pest populations and crop damage.

Ineffective Strategies

1. Overreliance on Chemical Controls: Overuse of chemical pesticides can lead to resistance and environmental harm.
2. Inadequate Cultural Controls: Failure to implement cultural practices that prevent pest infestations.
3. Insufficient Biological Controls: Limited use of biological control methods, such as beneficial insects.

Poor Implementation

1. Inconsistent Application: Inconsistent application of IPM strategies can lead to reduced effectiveness.
2. Lack of Coordination: Lack of coordination among farmers, researchers, and extension agents.
3. Inadequate Record Keeping: Failure to keep accurate records of pest management activities.

Environmental Factors

1. Climate Change: Climate change can alter pest populations and behavior, making IPM more challenging.
2. Weather Events: Extreme weather events can disrupt IPM strategies.

Economic and Social Factors

1. Economic Constraints: Limited financial resources can limit the adoption of IPM strategies.
2. Lack of Incentives: Lack of incentives for farmers to adopt IPM practices.
3. Social and Cultural Barriers: Social and cultural barriers can limit the adoption of IPM practices.

Consequences

1. Pest Resistance: Overuse of chemical pesticides can lead to pest resistance.
2. Environmental Harm: IPM failures can lead to environmental harm, such as water pollution and loss of biodiversity.
3. Reduced Crop Yields: IPM failures can lead to reduced crop yields and economic losses.

Crop Rotation and Planning can fail in several areas like:

Poor Planning

1. Inadequate Soil Analysis: Failure to analyze soil type, nutrient levels, and moisture content.
2. Insufficient Crop Selection: Choosing crops that are not suitable for the climate, soil, or market demand.
3. Inadequate Rotation Planning: Failure to plan crop rotations that optimize soil health, reduce pests and diseases, and improve yields.

Inadequate Implementation

1. Inconsistent Rotation: Failure to consistently implement crop rotation plans.
2. Inadequate Record Keeping: Failure to keep accurate records of crop rotations, yields, and soil health.
3. Lack of Flexibility: Failure to adjust crop rotation plans in response to changing weather, market, or pest conditions.

Soil and Environmental Factors

1. Soil Degradation: Crop rotation plans that do not account for soil health can lead to soil degradation.
2. Climate Change: Climate change can alter the effectiveness of crop rotation plans.
3. Water Management: Inadequate water management can lead to waterlogging, drought, or soil salinization.

Economic and Social Factors

1. Market Fluctuations: Changes in market demand or prices can affect the profitability of crop rotation plans.
2. Lack of Incentives: Lack of incentives for farmers to adopt crop rotation practices.
3. Limited Access to Resources: Limited access to resources, such as seeds, equipment, or expertise, can limit the effectiveness of crop rotation plans.

Consequences

1. Reduced Crop Yields: Poor crop rotation planning can lead to reduced crop yields and decreased productivity.
2. Soil Degradation: Inadequate crop rotation can lead to soil degradation, erosion, and loss of fertility.
3. Increased Pest and Disease Pressure: Poor crop rotation can lead to increased pest and disease pressure, reducing crop yields and increasing pesticide use.

AI failures can occur in various areas:

Data-Related Failures

1. Insufficient or Poor-Quality Data: AI models require large amounts of high-quality data to learn and make accurate predictions.
2. Biased Data: Biased data can lead to biased AI models, perpetuating existing inequalities.
3. Data Drift: Changes in data distributions over time can render AI models less effective.

Model-Related Failures

1. Overfitting or Underfitting: AI models that are too complex or too simple can fail to generalize well to new data.
2. Model Interpretability: Complex AI models can be difficult to interpret, making it challenging to understand their decisions.
3. Model Maintenance: AI models require regular updates and maintenance to ensure they remain effective.

Implementation-Related Failures

1. Inadequate Integration: AI solutions may not be properly integrated into existing systems or workflows.
2. Lack of User Adoption: AI solutions may not be user-friendly or may require significant changes to user behavior.
3. Insufficient Training: Users may not receive adequate training to effectively use AI solutions.

Ethical and Social Failures

1. Bias and Discrimination: AI models can perpetuate existing biases and discriminate against certain groups.
2. Lack of Transparency: AI decisions may not be transparent, leading to mistrust and accountability issues.
3. Job Displacement: AI solutions can displace human workers, leading to social and economic disruption.

Technical Failures

1. Technical Debt: AI solutions can accumulate technical debt, making them difficult to maintain and update.
2. Scalability Issues: AI solutions may not be scalable to meet the needs of large or complex systems.
3. Security Vulnerabilities: AI solutions can be vulnerable to cyber-attacks and data breaches.

ML Machine learning:

As available images are abundant, on which machine-learning approaches can be applied. When machine learning algorithms are applied to recognize objects in images, a high recognition rate is achieved. This is particularly evident in images with a complicated natural setting. This classification of complicated natural images can include satellite images. Satellite images contain a lot of information. Environmental monitoring, planning, and natural resource management are just a few of the applications that have led to the development of remote ML.

ML failures can occur in various areas:

Data-Related Failures

1. Insufficient Data: ML models require large amounts of data to learn and make accurate predictions.
2. Poor Data Quality: Noisy, incomplete, or biased data can lead to poor model performance.
3. Data Drift: Changes in data distributions over time can render ML models less effective.

Model-Related Failures

1. Overfitting: ML models that are too complex can fit the training data too closely, failing to generalize well to new data.
2. Underfitting: ML models that are too simple can fail to capture the underlying patterns in the data.
3. Model Selection: Choosing the wrong ML algorithm or hyperparameters can lead to poor model performance.

Training-Related Failures

1. Inadequate Training Data: Insufficient or poor-quality training data can lead to poor model performance.
2. Inadequate Hyperparameter Tuning: Failure to tune hyperparameters can lead to suboptimal model performance.
3. Overreliance on Automation: Overreliance on automated ML workflows can lead to lack of human oversight and quality control.

Deployment-Related Failures

1. Model Deployment: Poorly deployed models can lead to poor performance, scalability issues, or security vulnerabilities.
2. Model Monitoring: Failure to monitor model performance in production can lead to undetected issues.
3. Model Updates: Failure to update models regularly can lead to decreased performance over time.

Interpretability and Explainability Failures

1. Black Box Models: Complex ML models can be difficult to interpret, making it challenging to understand their decisions.
2. Lack of Explainability: Failure to provide explanations for ML model decisions can lead to mistrust and accountability issues.

Ethical and Social Failures

1. Bias and Discrimination: ML models can perpetuate existing biases and discriminate against certain groups.
2. Lack of Fairness: ML models can be unfair or discriminatory, leading to unequal treatment of individuals or groups.
3. Transparency and Accountability: Lack of transparency and accountability in ML decision-making can lead to mistrust and accountability issues.

Computer vision failures can occur in various areas:

Image Quality Issues

1. Poor Image Quality: Low-resolution, blurry, or noisy images can make it difficult for computer vision models to accurately detect or classify objects.
2. Variability in Lighting: Changes in lighting conditions can affect the performance of computer vision models.
3. Occlusion: Objects may be partially or fully occluded, making it challenging for computer vision models to detect or classify them.

Model-Related Failures

1. Insufficient Training Data: Computer vision models require large amounts of high-quality training data to learn and generalize well.
2. Overfitting: Computer vision models that are too complex can fit the training data too closely, failing to generalize well to new data.
3. Model Selection: Choosing the wrong computer vision algorithm or architecture can lead to poor model performance.

Object Detection Failures

1. Object Detection Errors: Computer vision models may fail to detect objects or detect objects that are not present.
2. Classification Errors: Computer vision models may misclassify objects or assign incorrect labels.
3. Localization Errors: Computer vision models may fail to accurately localize objects in images.

Contextual Understanding Failures

1. Lack of Contextual Understanding: Computer vision models may not understand the context in which objects are being used or interacted with.
2. Limited Domain Knowledge: Computer vision models may not have sufficient domain-specific knowledge to accurately interpret images.

Deployment-Related Failures

1. Real-Time Processing: Computer vision models may not be able to process images in real-time, leading to delays or performance issues.
2. Scalability: Computer vision models may not be scalable to handle large volumes of images or video data.
3. Security Vulnerabilities: Computer vision models may be vulnerable to cyber-attacks or data breaches.

Data-driven approaches can fail in various ways:

Data Quality Issues

1. Inaccurate Data: Inaccurate or incomplete data can lead to poor decision-making.
2. Biased Data: Biased data can perpetuate existing inequalities and lead to unfair outcomes.
3. Data Integrity: Poor data integrity can lead to incorrect insights and decisions.

Data Analysis Issues

1. Insufficient Analysis: Insufficient analysis can lead to missed insights and opportunities.
2. Incorrect Analysis: Incorrect analysis can lead to incorrect insights and decisions.
3. Lack of Context: Lack of context can lead to misinterpretation of data.

Decision-Making Issues

1. Overreliance on Data: Overreliance on data can lead to neglect of other important factors, such as intuition and experience.
2. Lack of Human Judgment: Lack of human judgment can lead to decisions that are not nuanced or contextual.
3. Poor Communication: Poor communication of data insights can lead to misunderstandings and misinterpretation.

Technical Issues

1. Data Storage and Management: Poor data storage and management can lead to data loss, corruption, or security breaches.
2. Data Integration: Difficulty integrating data from different sources can lead to incomplete or inaccurate insights.
3. Scalability: Data-driven approaches may not be scalable to meet the needs of large or complex organizations.

Organizational Issues

1. Cultural Resistance: Cultural resistance to data-driven approaches can limit adoption and effectiveness.
2. Lack of Skills: Lack of skills and expertise in data analysis and interpretation can limit the effectiveness of data-driven approaches.
3. Organizational Silos: Organizational silos can limit the sharing and integration of data across different departments or teams.

IoT and sensor-based approaches can fail in various ways:

Technical Issues

1. Sensor Accuracy: Inaccurate or unreliable sensor data can lead to poor decision-making.
2. Connectivity Issues: Connectivity problems can disrupt data transmission and affect system performance.
3. Scalability: IoT systems may not be scalable to meet the needs of large or complex applications.

Data Management Issues

1. Data Overload: Large amounts of sensor data can be overwhelming and difficult to manage.
2. Data Quality: Poor data quality can lead to incorrect insights and decisions.
3. Data Security: IoT systems may be vulnerable to cyber-attacks and data breaches.

Integration Issues

1. System Integration: Integrating IoT systems with existing infrastructure and systems can be challenging.
2. Interoperability: Different IoT devices and systems may not be compatible, leading to integration challenges.
3. Standardization: Lack of standardization can limit the effectiveness of IoT systems.

Operational Issues

1. Maintenance and Support: IoT systems require regular maintenance and support to ensure optimal performance.
2. Power Management: IoT devices may have limited power sources, requiring careful power management.
3. Environmental Factors: Environmental factors such as temperature, humidity, and weather can affect IoT system performance.

Security Issues

1. Cybersecurity Risks: IoT systems may be vulnerable to cyber-attacks, compromising data security and system integrity.
2. Data Privacy: IoT systems may collect sensitive data, raising concerns about data privacy and protection.
3. Physical Security: IoT devices may be vulnerable to physical tampering or theft.

Human Factors

1. User Adoption: User adoption and acceptance of IoT systems can be limited by factors such as usability and perceived value.
2. Training and Support: Users may require training and support to effectively use IoT systems.
3. Change Management: Implementing IoT systems may require significant changes to business processes and organizational culture.

Sustainability and environmental approaches can fail in various ways:

Environmental Factors

1. Climate Change: Climate change can impact the effectiveness of sustainability initiatives.
2. Resource Depletion: Overuse of natural resources can lead to depletion and decreased sustainability.
3. Pollution: Pollution can harm the environment and human health.

Social Factors

1. Lack of Awareness: Limited awareness about sustainability and environmental issues can hinder efforts.
2. Social Inequality: Sustainability initiatives may not address social inequality, leading to uneven benefits.
3. Community Engagement: Lack of community engagement and participation can limit the success of sustainability initiatives.

Economic Factors

1. Cost: Implementing sustainability initiatives can be costly, and the benefits may not be immediately apparent.
2. Economic Viability: Sustainability initiatives may not be economically viable, leading to financial challenges.
3. Return on Investment: The return on investment for sustainability initiatives may not be clear or immediate.

Technical Factors

1. Technological Limitations: Technological limitations can hinder the effectiveness of sustainability initiatives.
2. Infrastructure: Inadequate infrastructure can limit the implementation of sustainability initiatives.
3. Scalability: Sustainability initiatives may not be scalable, limiting their impact.

Policy and Regulatory Factors

1. Lack of Policy Support: Lack of policy support can limit the effectiveness of sustainability initiatives.
2. Regulatory Frameworks: Inadequate regulatory frameworks can hinder sustainability efforts.
3. Enforcement: Lack of enforcement can lead to non-compliance with sustainability regulations.

Measurement and Evaluation

1. Metrics and Indicators: Inadequate metrics and indicators can make it difficult to measure sustainability progress.
2. Data Collection: Inadequate data collection can limit the ability to evaluate sustainability initiatives.
3. Evaluation and Monitoring: Inadequate evaluation and monitoring can lead to ineffective sustainability initiatives.

Other Approaches
Vertical farming failures can be attributed to several key factors:
Economic Challenges
- High Initial Costs: Setting up a vertical farm requires significant investment in infrastructure, equipment, and technology, including expensive LED lighting, climate control systems, and hydroponic or aeroponic systems. - High Operational Costs: Energy consumption is a major concern, with artificial lighting and climate control systems driving up costs. Labor costs are also substantial, with some estimates suggesting that labour accounts for up to 57% of operational expenses. - Variable Costs: Energy prices, maintenance, and replacement of complex systems add to the financial burden.
Technical and Operational Issues
- Limited Crop Selection: Only a limited number of crops can be grown economically, with leafy greens and herbs being the primary crops due to their rapid growth cycle and high-profit margin. - Pollination Challenges: The absence of natural pollinators in vertical farms can lead to poor pollination rates, resulting in reduced yields and lower quality crops. - Reliance on Technology: Vertical farming's dependence on technology makes it vulnerable to equipment failures, power outages, and other technical issues.
Knowledge and Expertise
- Knowledge Gap: The industry still suffers from a lack of knowledge and expertise in areas like indoor farming, hydroponics, and aeroponics. - Need for Skilled Personnel: Running a vertical farm requires advanced technological and horticultural skills, which can be difficult to find and retain.
Market and Business Model Issues
- Product-Market Fit: Vertical farms need to align their crop selection with consumer demand and ensure that their products are economically viable. - Questionable Business Models: Some vertical farming companies have failed due to flawed business models, including unrealistic growth projections and poor unit economics.

- Lack of Agronomic Expertise: The absence of experienced agronomists or farmers in senior leadership positions can lead to suboptimal crop performance and reduced market competitiveness

Hydroponics failures can occur due to various reasons like:

- System Leaks: Leaks can happen at any joint or valve in the system, often due to blockages or inadequate reservoir capacity. To prevent this, test your system before planting, tighten valves, and ensure the reservoir can hold all the nutrient solution.
- Lighting Issues: Insufficient or incorrect lighting can hinder plant growth. LED and T5 fluorescent grow lights are popular choices. Calculate the required wattage based on your grow area's square footage, using approximately 65 watts per square foot.
- Nutrient Problems: Using the wrong fertilizer or failing to monitor nutrient levels can lead to deficiencies or toxicity. Use fertilizers specifically designed for hydroponics and regularly check nutrient solution levels.
- pH Imbalance: Hydroponic systems require precise pH control, as levels can fluctuate rapidly. Monitor pH levels daily or weekly, depending on system stability, and adjust as needed.
- Pests and Diseases: Regularly clean and sanitize your system to prevent infestations. Biological pest management techniques can also be effective.
- Pump Failure: Regularly check and maintain pumps to prevent failures, which can disrupt nutrient circulation and oxygen supply.
- Power Outages: Backup generators or battery systems can mitigate the risks of power outages, which can quickly harm plants.
- Water Quality Issues: Hard water can cause problems due to high levels of dissolved minerals. Consider using filtered or distilled water to prevent these issues.
- System Complexity: Hydroponics requires technical knowledge and regular maintenance, making it challenging for beginners.
- High Initial Costs: Setting up a hydroponics system can be expensive due to the need for specialized equipment and technology.
- Environmental Impact: Hydroponics can have a significant environmental impact, particularly regarding energy consumption and water usage. Implementing sustainable practices and energy-efficient systems can help mitigate these concerns.

To minimize the risk of failure, it's essential to:

- Monitor and adjust: Regularly check and adjust pH, nutrient levels, and other system parameters.

- Maintain equipment: Regularly inspect and maintain pumps, lights, and other equipment to prevent failures.
- Keep the system clean: Sanitize the system and surrounding area to prevent pests and diseases.
- Plan for contingencies: Have backup systems and emergency plans in place to address potential issues.

Aquaponics failures can occur due to various reasons, including:

System Design and Planning

1. Inadequate System Design: Poorly designed systems can lead to water quality issues, inadequate nutrient cycling, and reduced plant growth.
2. Insufficient Water Volume: Inadequate water volume can lead to water quality issues and reduced system stability.
3. Inadequate Biofilter Design: Poorly designed biofilters can lead to inadequate waste management and water quality issues.

Water Quality and Management

1. Water Quality Issues: Poor water quality can lead to reduced plant growth, fish health issues, and system failure.
2. Inadequate Water Circulation: Inadequate water circulation can lead to reduced oxygen levels, increased waste buildup, and reduced system performance.
3. pH Imbalance: pH imbalance can lead to reduced plant growth, fish health issues, and system failure.

Fish and Plant Health

1. Fish Health Issues: Poor fish health can lead to reduced system performance, increased waste production, and system failure.
2. Plant Health Issues: Poor plant health can lead to reduced system performance, reduced nutrient uptake, and system failure.
3. Disease and Parasite Management: Inadequate disease and parasite management can lead to reduced system performance and system failure.

Operational and Maintenance Issues

1. Inadequate System Maintenance: Inadequate system maintenance can lead to reduced system performance, increased waste production, and system failure.
2. Inadequate Monitoring: Inadequate monitoring of system parameters can lead to reduced system performance, increased waste production, and system failure.

3. Lack of Emergency Preparedness: Lack of emergency preparedness can lead to system failure, fish loss, and reduced system performance.

Other Factors

1. Climate and Environmental Factors: Climate and environmental factors, such as temperature fluctuations, can impact system performance and stability.
2. Energy Consumption: High energy consumption can lead to increased operational costs and reduced system sustainability.
3. Lack of Knowledge and Experience: Lack of knowledge and experience in aquaponics can lead to system failure, reduced system performance, and increased operational costs.

Deep learning failures can occur due to various reasons, including:

Data-Related Issues

1. Insufficient Training Data: Deep learning models require large amounts of high-quality training data to learn and generalize well.
2. Biased Data: Biased data can lead to biased models, perpetuating existing inequalities and leading to unfair outcomes.
3. Noisy or Poor-Quality Data: Noisy or poor-quality data can lead to reduced model performance and accuracy.

Model-Related Issues

1. Overfitting: Deep learning models can overfit the training data, failing to generalize well to new, unseen data.
2. Underfitting: Deep learning models can also underfit the training data, failing to capture the underlying patterns and relationships.
3. Model Complexity: Deep learning models can be overly complex, leading to difficulties in training, deployment, and interpretation.

Training-Related Issues

1. Inadequate Hyperparameter Tuning: Inadequate hyperparameter tuning can lead to suboptimal model performance and accuracy.
2. Inadequate Training Time: Insufficient training time can lead to underfitting, while excessive training time can lead to overfitting.
3. Optimizer Choice: Choosing the wrong optimizer or optimizer settings can impact model performance and convergence.

Deployment-Related Issues

1. Model Deployment Challenges: Deploying deep learning models in production environments can be challenging due to computational requirements, latency, and scalability issues.

2. Model Interpretability: Deep learning models can be difficult to interpret, making it challenging to understand their decisions and predictions.
3. Model Maintenance: Deep learning models require regular maintenance and updates to ensure continued performance and accuracy.

Other Issues

1. Adversarial Attacks: Deep learning models can be vulnerable to adversarial attacks, which can compromise their performance and security.
2. Lack of Explainability: Deep learning models can lack explainability, making it challenging to understand their decisions and predictions.
3. Computational Requirements: Deep learning models can require significant computational resources, leading to increased costs and environmental impact.

The overall loss that can be predicted in Modern smart agriculture system can be estimated to be:

1. Crop yield reduction: 10-30% loss in crop yields due to system failures.
2. Financial losses: 5-20% increase in operational costs due to system failures.
3. Resource waste: 5-15% waste of resources, such as water and fertilizers, due to system failures.

The metaverse can potentially help mitigate losses in smart agriculture systems by:

Virtual Farming and Simulation

1. Virtual testing and validation: The metaverse can enable virtual testing and validation of farming systems, reducing the risk of failures and losses.
2. Simulation-based training: Farmers and agricultural professionals can receive training in a virtual environment, improving their skills and reducing errors.

Data Analysis and Visualization

1. Immersive data visualization: The metaverse can provide immersive data visualization experiences, enabling farmers and agricultural professionals to better understand complex data insights.
2. Real-time monitoring: The metaverse can enable real-time monitoring of farming systems, allowing for quicker detection and response to potential issues.

Collaboration and Knowledge Sharing

1. Virtual collaboration: The metaverse can facilitate virtual collaboration among farmers, agricultural professionals, and experts, promoting knowledge sharing and best practices.
2. Access to expertise: The metaverse can provide access to expertise and knowledge from around the world, helping farmers and agricultural professionals make informed decisions.

Predictive Maintenance and Analytics

1. Predictive maintenance: The metaverse can enable predictive maintenance of farming equipment and infrastructure, reducing downtime and increasing efficiency.
2. Advanced analytics: The metaverse can provide advanced analytics capabilities, enabling farmers and agricultural professionals to make data-driven decisions.

Potential Benefits

1. Increased efficiency: The metaverse can help increase efficiency in farming operations, reducing losses and improving productivity.
2. Improved decision-making: The metaverse can provide farmers and agricultural professionals with better insights and decision-making tools, reducing the risk of losses.
3. Enhanced collaboration: The metaverse can facilitate collaboration and knowledge sharing, promoting best practices and reducing losses.

Problem Definition in Smart Agriculture Technologies
1. Data Quality and Integration: Ensuring accurate, reliable, and seamless integration of data from various sources, such as sensors, drones, and satellites. 2. Interoperability: Achieving interoperability among different technologies, platforms, and systems to enable efficient data sharing and analysis. 3. Scalability and Flexibility: Developing smart agriculture systems that can scale to meet the needs of diverse farming operations and adapt to changing conditions. 4. Cybersecurity: Protecting smart agriculture systems from cyber threats and ensuring the security and integrity of sensitive data. 5. User Adoption and Training: Ensuring that farmers and agricultural professionals have the necessary skills and knowledge to effectively use smart agriculture technologies.

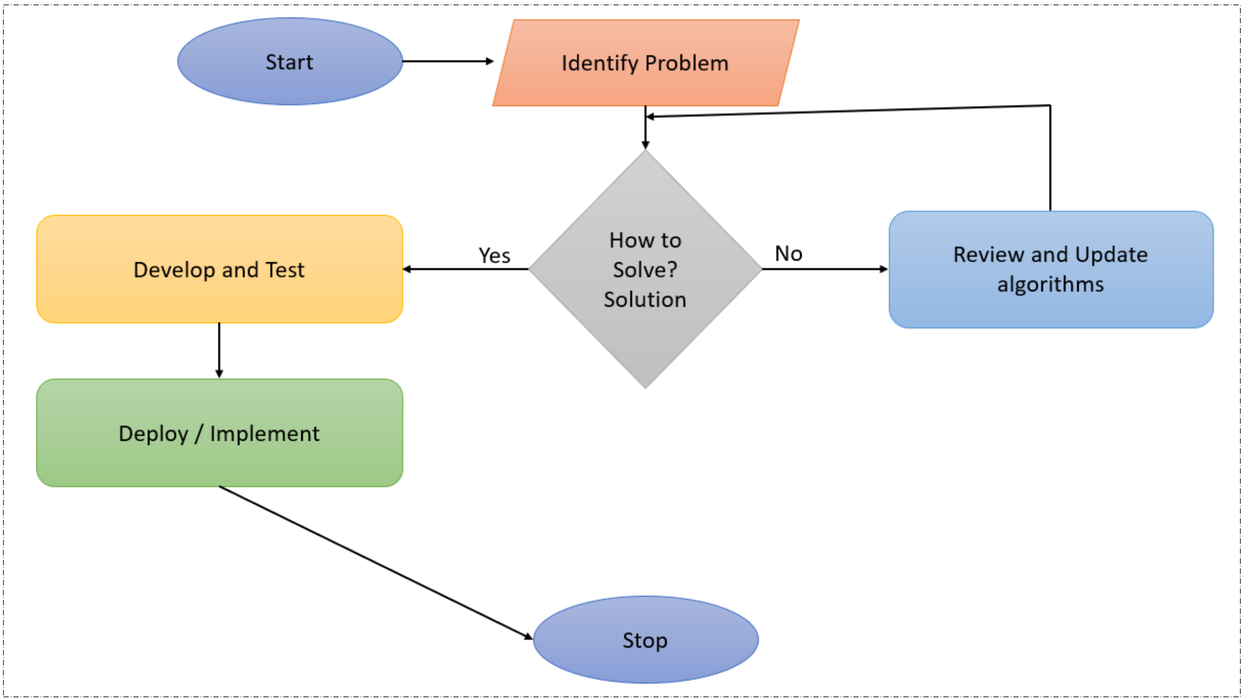


Figure 1: Illustration of problem statement

Figure 1 represents the process of identifying the problem, analysis of problem and finding its solution. If the solution is found deploy and test the found solution or else Review and update the algorithm and re-check and validate the solution with positive results once confirmed Deploy / Implement the identified logic.

Research Gaps in Traditional Technologies
1. Limited Integration with Emerging Technologies: Many traditional smart agriculture technologies lack integration with emerging technologies like AI, blockchain, and the metaverse. 2. Insufficient Focus on Sustainability: Traditional smart agriculture technologies often prioritize productivity and efficiency over sustainability and environmental impact. 3. Limited Accessibility for Small-Scale Farmers: Many traditional smart agriculture technologies are designed for large-scale farming operations, leaving small-scale farmers without access to these technologies. 4. Inadequate Data Analytics: Traditional smart agriculture technologies often lack advanced data analytics capabilities, limiting their ability to provide actionable insights. 5. Insufficient Emphasis on Farmer-Centric Design: Traditional smart agriculture technologies often prioritize technological innovation over farmer-centric design, leading to user adoption challenges.
Potential Research Directions
1. Integration of Emerging Technologies: Exploring the integration of emerging technologies like AI, blockchain, and the metaverse with traditional smart agriculture technologies. 2. Sustainable Smart Agriculture: Developing smart agriculture technologies that prioritize sustainability, environmental impact, and social responsibility. 3. Inclusive Smart Agriculture: Designing smart agriculture technologies that are accessible and usable by small-scale farmers, women, and other marginalized groups. 4. Advanced Data Analytics: Developing advanced data analytics capabilities for smart agriculture, including machine learning, predictive analytics, and data visualization. 5. Farmer-Centric Design: Prioritizing farmer-centric design in smart agriculture technologies, including user experience, usability, and accessibility.

Title of the Research:

Designing of Novel Approach Using Metaverse Technology for Smart Agriculture System

Objectives of the Research work:

1. To review the existing smart agriculture and metaverse technologies.
2. To collect the dataset from the southern region based on parameters such as soil, water, crop and climate conditions.
3. Development and implementation of proposed system using metaverse technology.
4. Comparison of developed system with the traditional systems.

Proposed Methodology

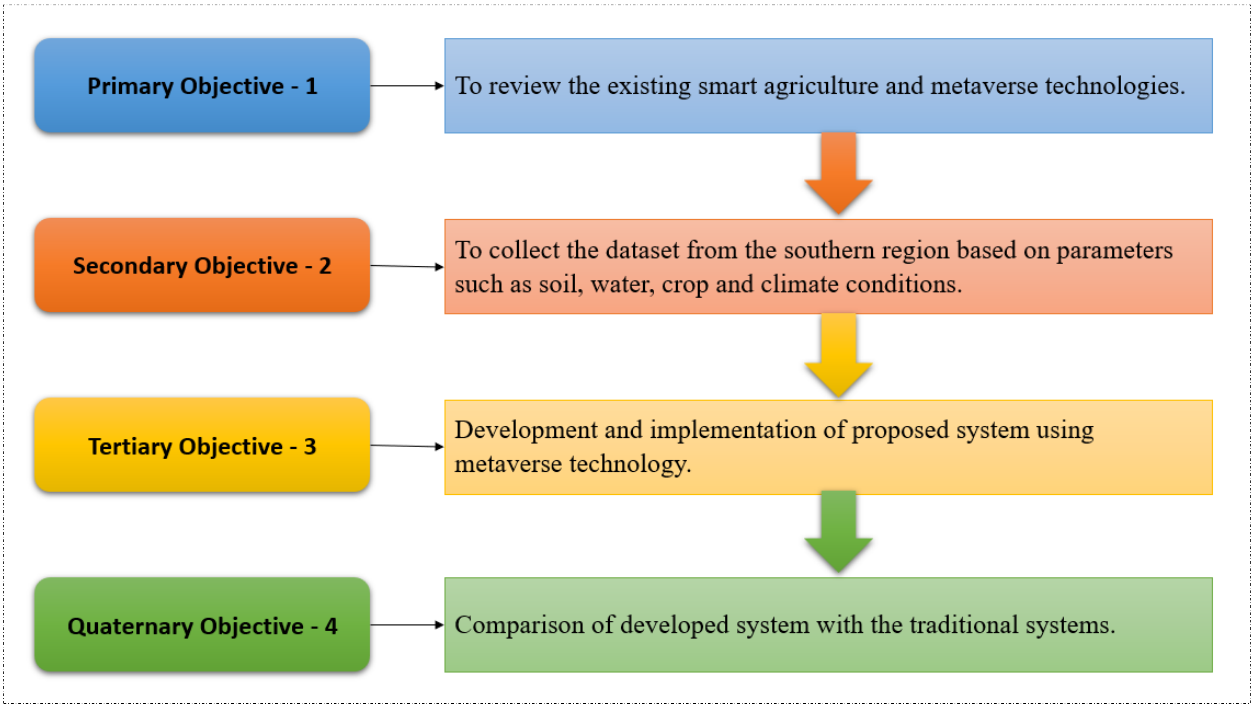


Figure 2: Illustration of Proposed Methodology

Figure 2 represents the objects and the proposed methodology being followed in sequence 1,2,3,4 to achieve the targeted objective comparing Developed system with traditional smart agriculture systems.

Achieving Objectives in Building a Metaverse Ecosystem for Smart Agriculture

The objectives outlined can be achieved through a comprehensive research approach:

Objective 1: Review of Existing Smart Agriculture and Metaverse Technologies

1. Literature Review: Conduct a thorough review of existing smart agriculture and metaverse technologies, including their applications, benefits, and limitations.
2. Expert Interviews: Conduct interviews with experts in smart agriculture and metaverse technologies to gain insights into current trends and future directions.

Objective 2: Data Collection

1. Dataset Collection: Collect a comprehensive dataset from the southern region, including parameters such as soil, water, crop, and climate conditions.
2. Data Preprocessing: Preprocess the collected data to ensure quality, consistency, and relevance to the research objectives.

Objective 3: Development and Implementation of Proposed System

1. System Design: Design a metaverse-based system for smart agriculture, incorporating the collected dataset and insights from the literature review.
2. System Development: Develop the proposed system using metaverse technology, ensuring scalability, flexibility, and user-friendliness.
3. System Implementation: Implement the developed system in a controlled environment or pilot project to test its effectiveness.

Objective 4: Comparison with Traditional Systems

1. Comparison Metrics: Establish metrics to compare the performance of the developed metaverse-based system with traditional smart agriculture systems.
2. Performance Evaluation: Evaluate the performance of both systems using the established metrics, including parameters such as crop yield, water usage, and farmer satisfaction.
3. Comparison Analysis: Analyze the results of the comparison, highlighting the benefits and limitations of the metaverse-based system.

Potential Outcomes

1. Improved Crop Yields: The metaverse-based system may lead to improved crop yields due to more accurate monitoring and management of soil, water, and climate conditions.
2. Increased Efficiency: The system may increase efficiency in farming operations, reducing waste and improving resource allocation.
3. Enhanced Decision-Making: The metaverse-based system may provide farmers with more accurate and timely insights, enabling better decision-making.
4. Increased Adoption: The system may increase adoption of smart agriculture technologies among farmers, particularly in regions with limited access to traditional smart agriculture systems.

Table 1: Methodology/ Tools/ Instruments to be used

Objective	Sample Size (Number of Participants)	Instrument/ Tool/ Sample Design	Sample Type	Category of the Sample Type	Level (State/ National/ International)
N/A					

Table 2: Methodology/ Tools/ Instruments to be Used

Objective Analysis to be Undertaken	Instruments/ Processes/ Software to be Used	Instruments/ processes/ software to be used	In-house Availability (Yes/No)	Organization/ Institute (where the facility is available)
To review the existing smart agriculture and metaverse technologies.	The literature review has been made for a better understanding of existing smart agriculture and the extent usage of metaverse technologies	N/A	N/A	N/A
To collect the dataset from the southern region based on parameters such as soil, water, crop and climate conditions.	After reviewing the literature data was collected from the southern region based on parameters such as soil, water, crop and climatic conditions	Form Designed using Python and GPS Coordinates Application	N/A	ICRISAT
Development and implementation of proposed system using metaverse technology.	Application Development and Deployment for proposed system using metaverse technology	Python 3.11.5, Blender 4.4.3	Yes	N/A
Comparison of developed system with the traditional systems.	The proposed system will be compared with other traditional systems.	Python 3.11.5, Blender 4.4.3 with other Technologies or No Technology	Yes	N/A

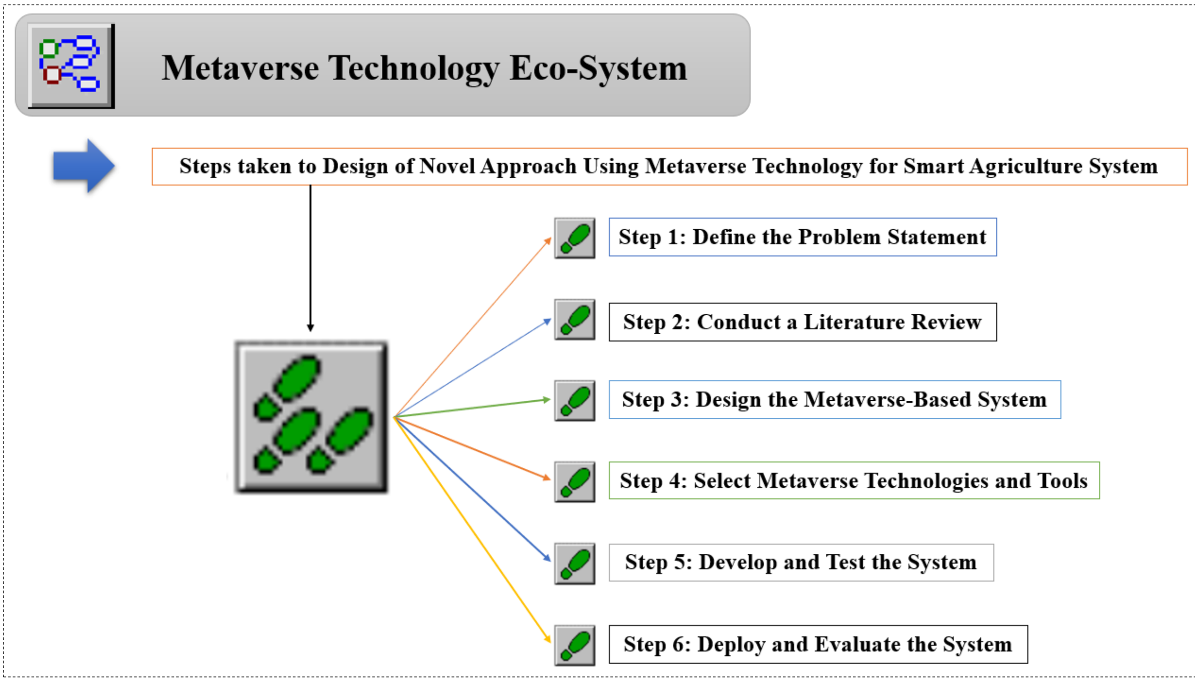


Figure 3: Illustration of Metaverse Technology Eco-System

Figure 3 represents the Business process at it core referring to Metaverse Technology Eco-System and the associated activities and steps taken to achieve the (IKIWISI) I Know It When I See It environment

Steps taken to Design of Novel Approach Using Metaverse Technology for Smart Agriculture System

To design a novel approach using metaverse technology for smart agriculture systems, follow these steps:

Step 1: Define the Problem Statement

1. Identify Key Challenges: Determine the specific challenges in smart agriculture that the metaverse technology can address, such as crop monitoring, predictive analytics, or farmer training.
2. Determine the Goals: Establish clear goals for the metaverse-based smart agriculture system, including improved crop yields, reduced water consumption, or enhanced farmer decision-making.

Step 2: Conduct a Literature Review

1. Research Existing Solutions: Investigate existing smart agriculture solutions and metaverse technologies to understand their strengths, weaknesses, and potential applications.
2. Identify Gaps and Opportunities: Identify gaps in current solutions and opportunities for innovation in smart agriculture using metaverse technology.

Step 3: Design the Metaverse-Based System

1. Develop a Conceptual Framework: Create a conceptual framework for the metaverse-based smart agriculture system, including its architecture, components, and interfaces.
2. Design the User Experience: Design an intuitive and user-friendly interface for farmers and agricultural professionals to interact with the metaverse-based system.

Step 4: Select Metaverse Technologies and Tools

1. Choose Metaverse Platforms: Select suitable metaverse platforms, such as virtual reality (VR) or augmented reality (AR), to build the smart agriculture system.
2. Select Data Analytics Tools: Choose data analytics tools and machine learning algorithms to analyze data from sensors, drones, and other sources.

Step 5: Develop and Test the System

1. Develop the System: Develop the metaverse-based smart agriculture system, incorporating the designed framework, user experience, and selected technologies.
2. Test and Validate: Test and validate the system in a controlled environment or pilot project to ensure its effectiveness and identify areas for improvement.

Step 6: Deploy and Evaluate the System

1. Deploy the System: Deploy the metaverse-based smart agriculture system in real-world farming operations, ensuring scalability and flexibility.
2. Evaluate the System: Evaluate the system's performance, including its impact on crop yields, water consumption, and farmer decision-making, to identify areas for further improvement.

Table-3: Literature survey till date

Detail of the Journal/ Book/ Chapter/ Website	Year of Publication	Indexing (Scopus/SCI)	Main Findings or Conclusions Relevant to Research	Remarks on the Paper
1. **Machine learning** in agriculture domain: A state-of-art survey	2021	Scopus (Elsevier journal)	This comprehensive survey categorizes ML applications in agriculture into pre-harvesting, harvesting, and post-harvesting. It highlights ML's role in soil analysis, crop disease detection, automated harvesting, and quality-based post-harvest sorting. The paper emphasizes the integration of ML with IoT and AutoML to enhance decision-making and reduce agricultural losses.	Excellent foundation for research in ML-driven agriculture. Detailed comparative studies and practical insights make it suitable for identifying gaps and innovations in precision farming systems.
2. A Crowdsourcing Inference Method based on Tempering: An Advancement in **Artificial Intelligence Algorithms**	2020	Scopus (Published in *Sensors*, MDPI)	Proposed a novel Variational Tempering Inference (VTI) algorithm to improve the quality and accuracy of crowdsourced data inference by incorporating both worker reliability and task difficulty into a scalable probabilistic model. Demonstrated improved convergence speed and reduced error rates on real datasets compared to existing methods.	Strong theoretical foundation and practical validation. Highly relevant for projects involving data labelling, social computing, or any AI requiring human-in-the-loop systems.
3. Variational Channel Estimation with Tempering: An **Artificial Intelligence Algorithm for Wireless Intelligent Networks**	2020	SCI, Scopus	Developed a low-complexity, high-accuracy variational inference-based algorithm (CEVTI) for channel estimation in wireless sensor networks, especially in massive MIMO/CDMA.	Offers robust performance in 5G/6G environments. Ensures better convergence and efficiency compared to traditional CE algorithms.

4. Coordinating a Three-Echelon Fresh **Agricultural Products** Supply Chain Considering Freshness-Keeping Effort with Asymmetric Information	2019	SCI, Scopus	Designed a model and coordination contract for managing freshness and profit in a three-echelon agri-supply chain under asymmetric demand info.	Integrates quality and quantity losses as effort-dependent variables. Eliminates hidden info incentives and improves system-wide profitability.
5. **AI and IoT-Enabled** Smart Exoskeleton System for **Rehabilitation of Paralyzed** People in Connected Communities (IEEE Access)	2021	SCI, Scopus	This paper presents a lightweight, AI-powered smart exoskeleton system (AI-IoT-SES) using SLAM, ANN, and LoRa-enabled IoT for the rehabilitation of paralyzed individuals. It enables real-time control, navigation, and remote monitoring via sensor fusion and big data analytics. MATLAB simulations demonstrate precise movement and reduced error in dynamic environments.	Technically comprehensive with AI navigation, EEG/EMG integration, and real-time decision-making. Valuable for smart healthcare and rehabilitation in connected communities.

Chapter 3: Work in Progress

Table-4: Action taken report for the recommendation received in the `last evaluation

Suggestion received from panel member as per previous evaluation	Point against which the suggestion was received	Action against the suggestion	Page number of the report where suggestion is incorporated (Scholar highlight must the incorporated action in yellow color)	Justification in case the suggestion is not incorporated
1. Scholar needs to identify the module where the novelty of the work lies. The need for a metaverse is required to be justified. Similarly, IoT's role in this work must be justified. 2. Publish your research work in quality journals.	Suggestion incorporated.	Sequential approach to achieve the suggestion given in previous ETP	Page No: [2-25]	Suggestion incorporated. Publish of research work in Quality Journals is in **Progress.**

Table-5: Progress of the proposed work

Proposed Objectives	Methodology used to achieve the objective	Status of work done till	Detail of work done since last evaluation	Detail of any inventive step/ process etc.	Expected Outcome (Publication/ IPR generation etc.)	Status of the outcome (Data collection/manuscript or IPR application is under progress or under review or revision or granted
To review the existing smart agriculture and metaverse technologies.	Efforts were made to review existing modules / technique used in Agriculture Sector	Various Technologies and techniques were found that were implemented in Smart Agriculture system	Literature review and technical updates were explored to implement metaverse technologies	Explore Online	Published 2 Papers and Given two Presentations	Received Certificate for presentation and received the URL link of published journal
To collect the dataset from the southern region based on parameters such as soil, water, crop and climate conditions.	Ground level dataset was collected from farmers from Telangana state	Data was Extracted, Transformed and Loaded into relation-based tables maintaining constraints at table level	Data was collected by recording the details into python created form with all the attributes	Collect data at ground Zero from farmers	Dataset Generated in .csv file to upload it into MySQL database table	Data collected for further processing to make it available from Metaverse eco-system
Development and implementation of proposed system using	Developed and implemented a collaborative model to integrate API calls made to sensors from metaverse eco-system	Application development, Integration and API collaboration completed	Created Metaverse environment for Avatar creation, Weather report, AI based chatbot, chat	Develop and implement metaverse using python, flask and blender	Application Developed and deployed on XAMPP using Python and Flask	Application Dashboard

metaverse technology.			interface with functionality			
Comparison of developed system with the traditional systems.	Comparison was performed with newly created eco-system with an existing traditional system developed using multiple technologies	Rigorous statistical tests and validation procedures validate its reliability and robustness. This comprehensive evaluation determines the suitability and efficacy of the Metaverse eco-system developed.	After framework development, the proposed solution's efficacy is gauged against existing technologies used in smart agriculture farming and the digital twin that replicates in metaverse eco-system. comparison has helped in understanding the insights into strengths and weaknesses, of traditional system and provided a guiding tool for refinement and validation of Metaverse eco-system.	Analyze data of traditional system and the current system developed and deployed	Improved and enhanced smart Agriculture System in a new updated technology	Working Model achieving IKIWISI

Dataset Generation

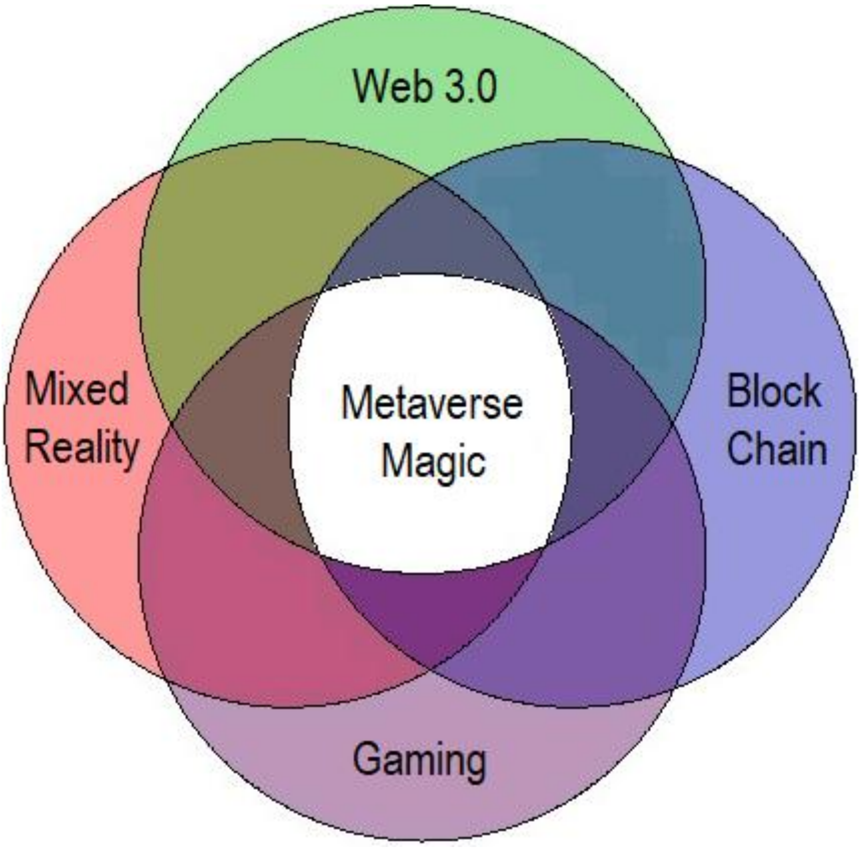


Figure 4: Illustration of Metaverse eco-System to implement Smart Agriculture System in Virtual Environment

Figure 4 represents the power of Metaverse Technology and the Eco-System game changer when associated and collaborated with Mixed Reality, Gaming, Block Chain and Web 3.0

Data Collection / Testing

Figure 5: Samples collected for mobile test lab on go

Figure 5 represents how the data was collected directly at ground zero from farmers working in Agriculture field.

Study Area

Soil Sampling

Figure 6: Samples collected and secured and identified based on the code assigned on the specific day of sample collection for processing and preparing recommendation to farmers based on health of soil

Figure 6 represents how the data was collected and organized for further process and test to analyze the soil health based on 14 input key parameters that help in providing details of fertilizers recommended for good quality and productive outcome of the crop in a given season.

Conceptual Framework

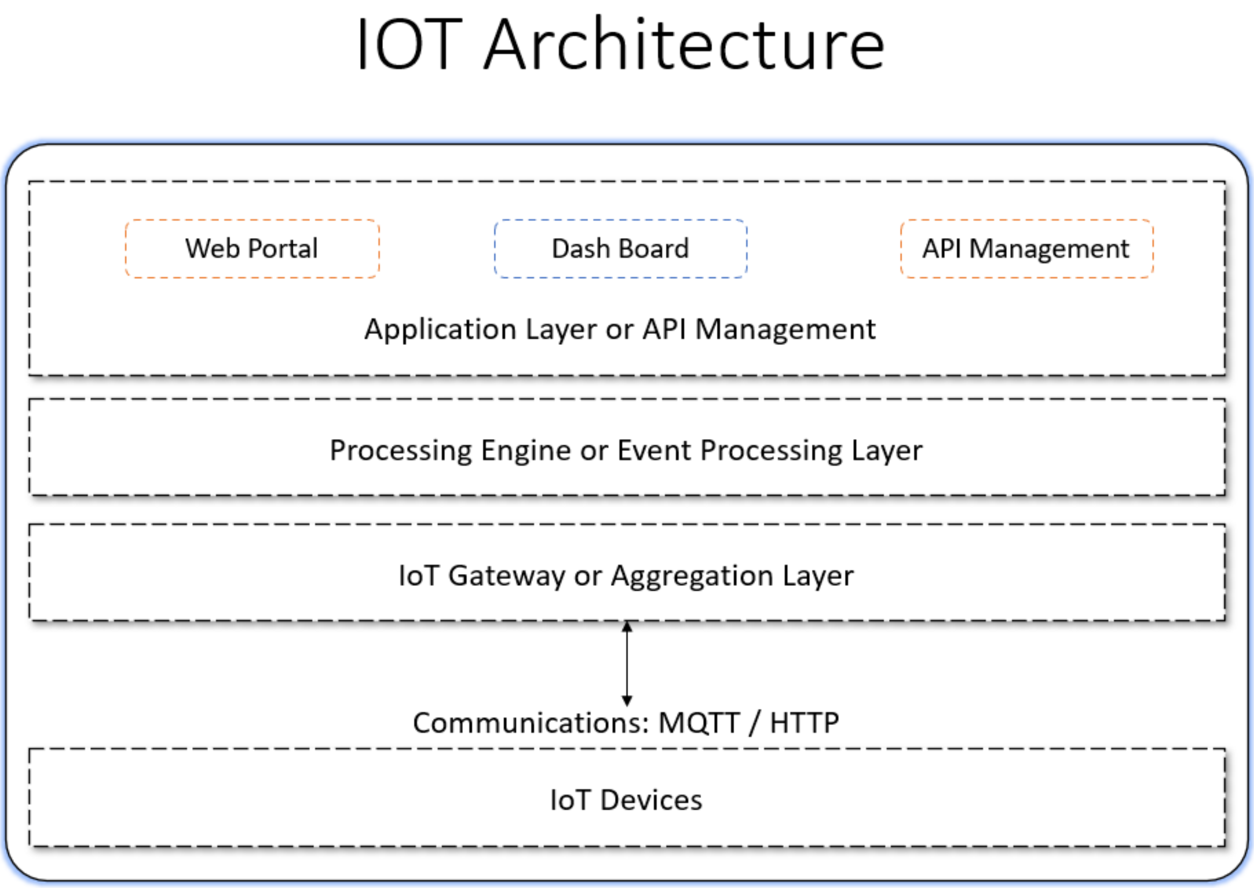


Figure 7: IoT architecture to stream live data using sensors

Figure 7 is the architecture representing the IoT sensors communicating and collaboration with the central dashboard of Metaverse eco-System.

Modular Sequence Diagram

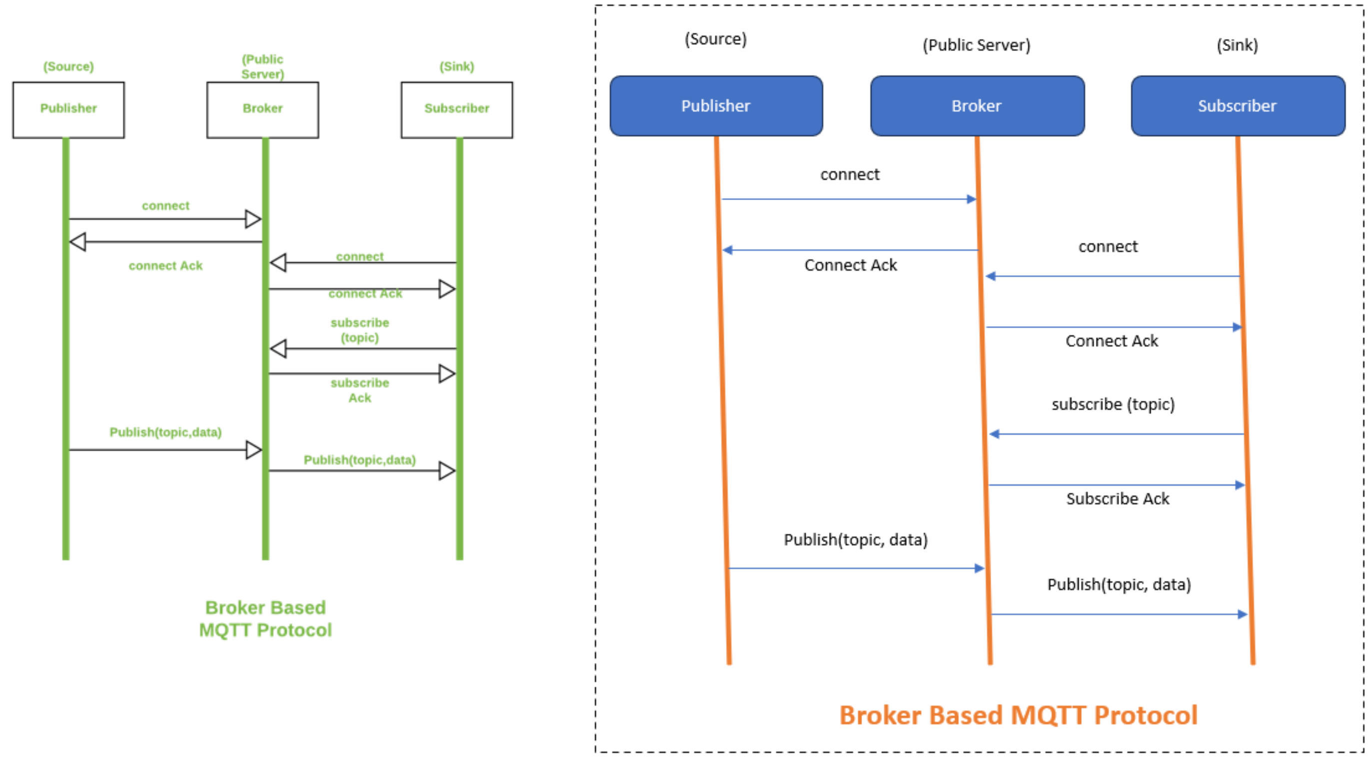


Figure 8: Sequence diagram of communication protocol that provides updates to central dashboard

Figure 8 is used to represent how the communication system works and interacts using MQTT Protocol which is used for IoT sensors.

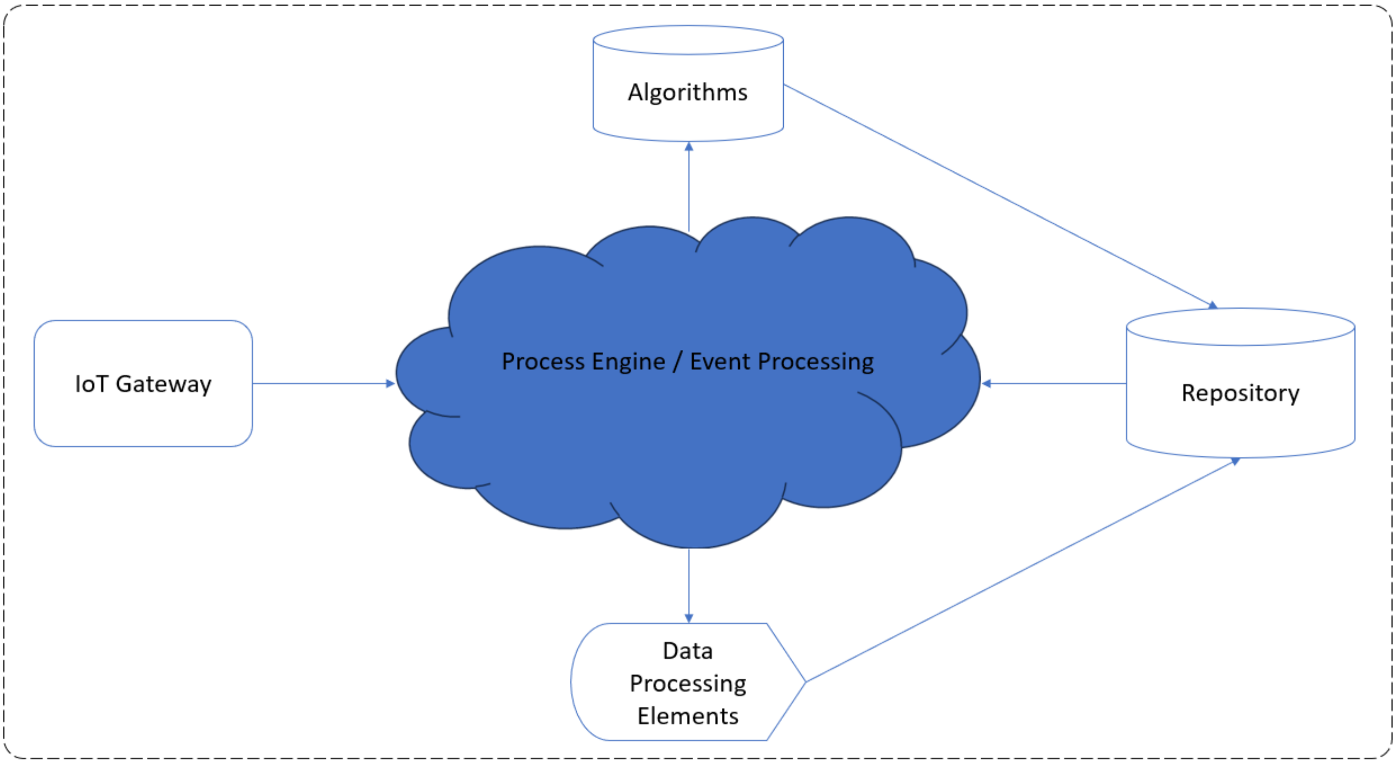


Figure 9: Cloud Architecture communicating with Repository, Data Processing Element and IoT Gateway based on algorithm

Figure 9 is used to represent the cloud platform that supports server and client communication and various source that provide information when in use to dashboard of Metaverse environment.

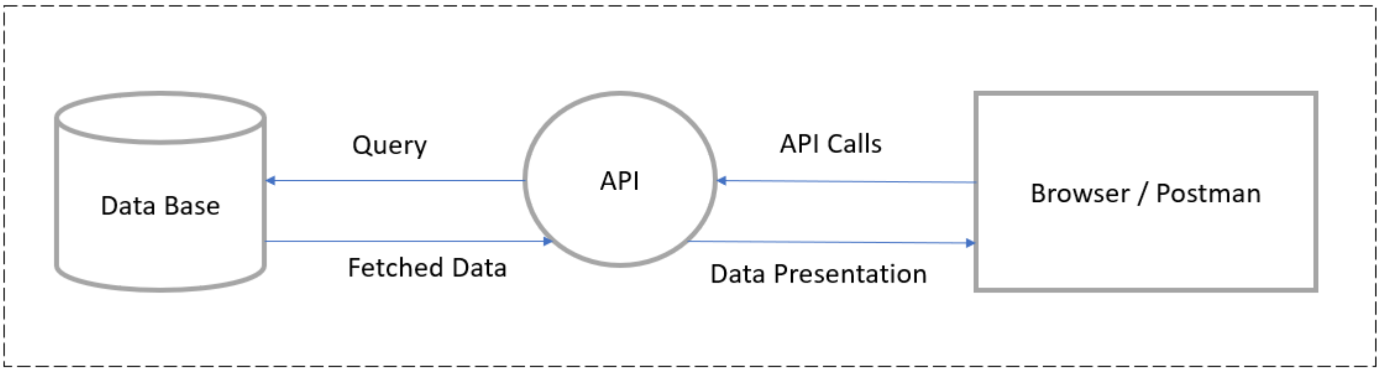


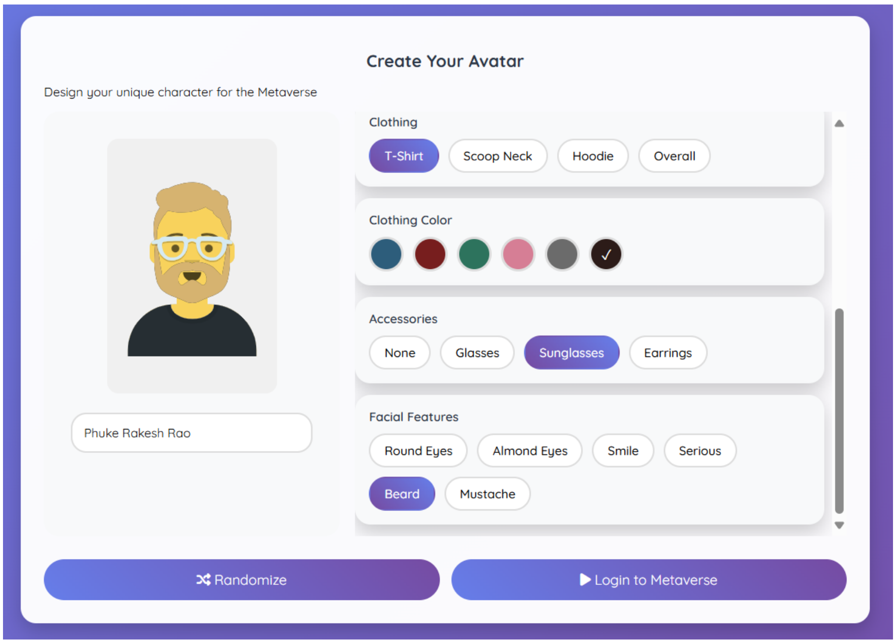
Figure 10: API calls to database and the client communication

Figure 10 is used to represent the client requesting for an API call that triggers a query to process and fetch data and represent to client either to browser or to the Postman from where the call is being made by the end user.

Chapter 4: Results and Discussions

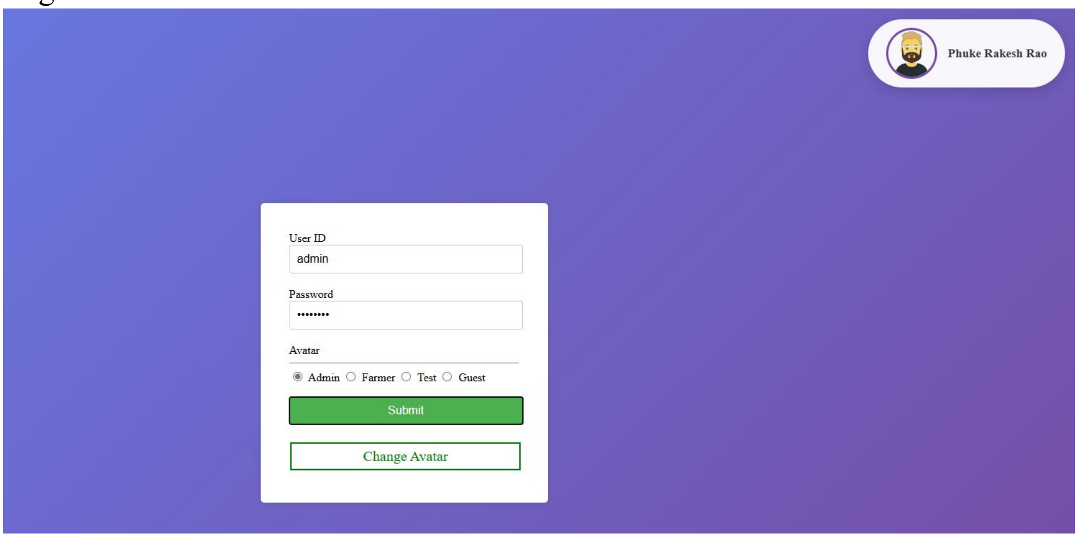
Application Design and Development, Implementation of Metaverse

1. Customization of Avatar before login into Metaverse eco-System
   URL to access to create a customized Avatar for metaverse
   http://localhost/dashboard/avatar.html



Note: The UI helps in creating a customize Avatar after selecting the attributes such as Gender of the user, skin Tone, Hair Style, Hair Color, Clothing, Clothing Color, Accessories, Facial Features, Avatar name or the UI also provides an option to create a Randomize Avatar by clicking on Randomize button. Login to Metaverse button helps in navigation to Login Screen to verify and validate user and user credentials fetched from Database (MySQL)

2. Login Screen

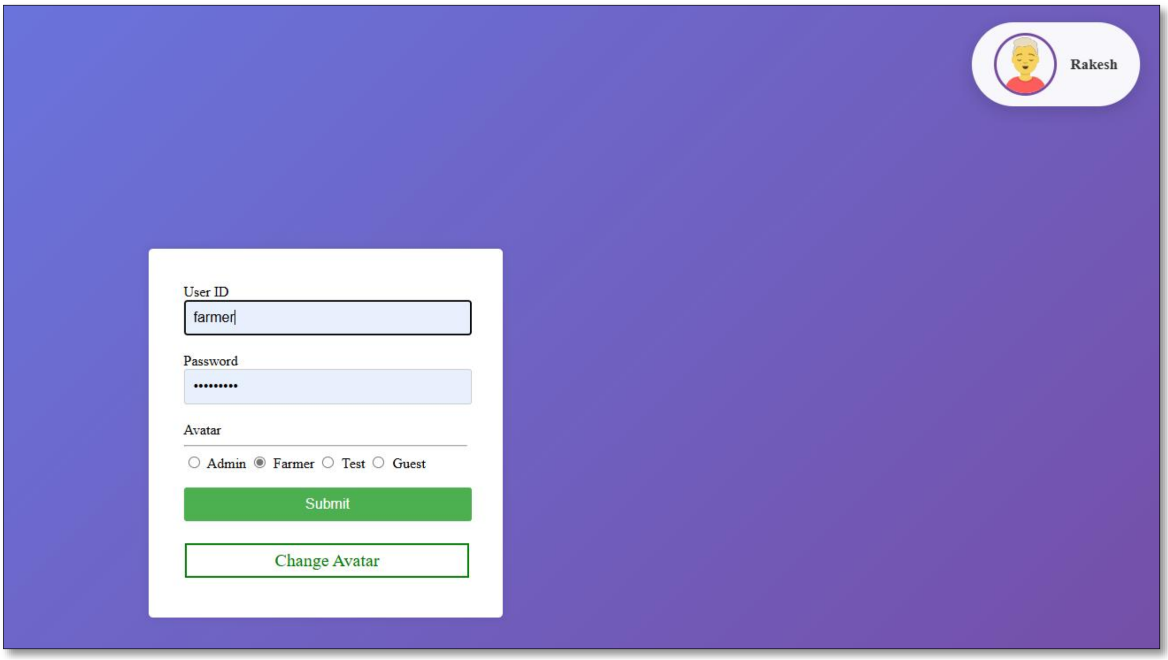


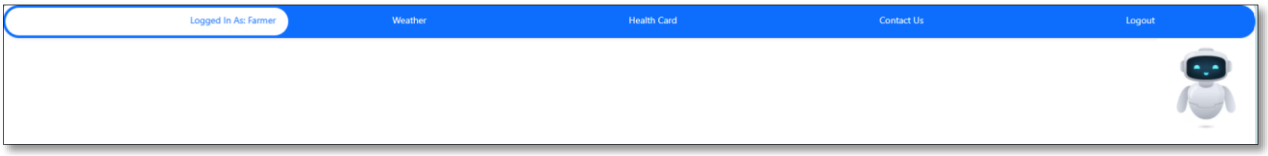
Note: Customized avatar appears at top right corner along with avatar name and the customized avatar image providing access to metaverse environment as "Admin", "Farmer", "Test" and "Guest" user credentials the inputs provided by user is verified and validated by the data stored in database when submit button is clicked. The Change Avatar button helps the user to re-visit to avatar creation page where the avatar can be customized if needed.

3. Admin access provides access to centralized repository where farmer details can be fetched based on criteria, Insert, Update, delete existing data of farmer or exit from Admin screen

Note: Admin credentials can only access details of farmers

4. Farmer access provides access to Weather reports based on Telangana Districts, Health Card of Soil that provides recommendations to Farmer, Contact Us to get access / Interaction by chat or by call or by login into metaverse environment. Farmer and post his questions at any point of time to get expert advice from a trained chatbot





Weather Information for Hyderabad

Weather: clear sky

Temperature: 28.42 °C

Humidity: 47%

Wind Speed: 4.04 m/s

Back

Weather Information for Jagital

Weather: clear sky

Temperature: 30.33 °C

Humidity: 48%

Wind Speed: 6.31 m/s

Back

Weather Information for Nizamabad

Weather: clear sky

Temperature: 30.16 °C

Humidity: 45%

Wind Speed: 5.91 m/s

Back

Note: Pointing and clicking on 33 districts available on Telangana map fetches data from live API that provides weather report which is live streamed, processed and displayed in Dashboard.

5. Health card of soil provides details which can be accessed by clicking on Reports that provide soil health, Chemical Analysis results, Fertilizers Recommendations based on soil sample collected and tested in a mobile lab.

Soil Health Card
Results of Soil Chemical Analysis
Fertilizers Recommendation to Farmer Based on Soil Test Results (Kg/ha)
Back

Soil Health Card

Farmer Name	Bilasah
Soil ID	Nashik 46
District	Nashik
Block	Sinner
Village	Ghorwad
Soil Type	Sandy loam
Latitude	19.826695
Longitude	73.891693
Month & Year of Sampling	June 2023
Back	

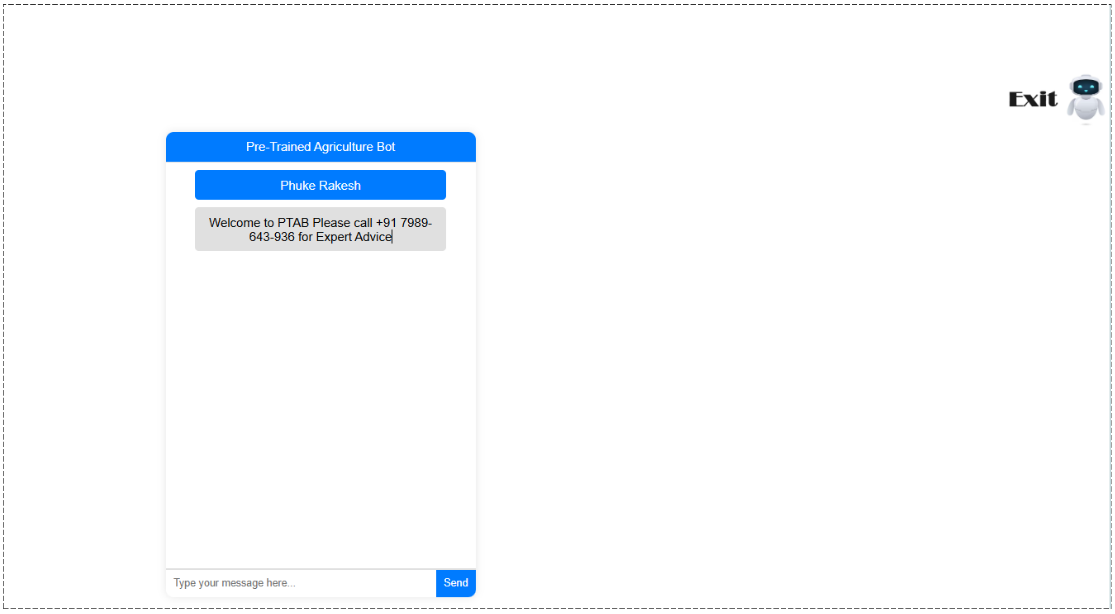
Results of Soil Chemical Analysis

Soil health information	Critical limit	Observed value	Soil Fertility Indicator
Soil pH (1:2 H_2O)	6.5-7.5	8.09	Alkaline
Electrical Conductivity (dS m^{-1})	1.0	0.25	Normal
Organic Carbon (OC) (%)	0.5-0.75	0.61	Medium
Macro Nutrients availability (kg ha^{-1})			
Available Phosphorus	9-22	38.16	High
Available Potassium	118-280	157	High
Secondary Nutrients availability (mg kg^{-1})			
Available Calcium	300	2113	High
Available Magnesium	120	579	High
Available Sulphur	10	17.27	Sufficient
Micro Nutrients availability (mg kg^{-1})			
Available Zinc	0.6	2.22	Sufficient
Available Boron	0.5	0.65	Sufficient
Available Iron	6.0	5.72	Sufficient
Available Copper	0.4	3.26	Sufficient
Available Manganese	4.0	13.00	Sufficient
Back			

Fertilizers Recommendation to Farmer Based on Soil Test Results (kg/ha)

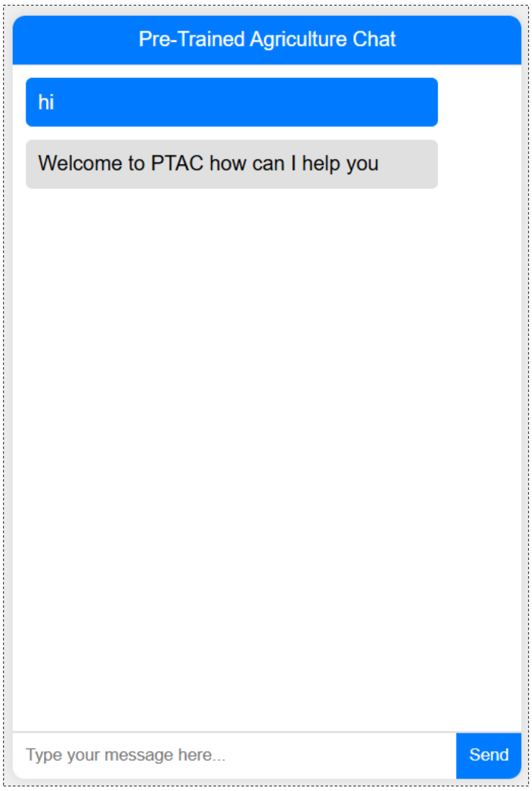
Crop	Using DAP					Using SSP				
	Urea	DAP	MOP	Gypsum	Zn SO4	Borax	Urea	SSP	MOP	Gypsum
Soybean	20	120	40	0	0	10	70	350	40	0
Pulses (Pigeonpea, Black gram, Green gram)	10	80	30	0	0	10	40	230	30	0
Pearl Millet (Light soil)	70	30	0	0	0	10	90	0	0	0
Pearl Millet (Medium soil)	50	50	0	0	0	10	130	140	0	0
Chickpea	20	70	50	0	0	10	40	190	50	0
Wheat Rainfed	30	80	0	0	0	10	90	0	0	0
Wheat (Protective irrigation)	110	50	0	0	0	10	260	280	80	0
Wheat Irrigated	220	100	80	0	0	10	260	280	80	0
Wheat (Late sown) Irrigated	150	70	0	0	0	10	170	190	50	0
Kharif Sorghum	150	70	50	0	0	10	170	190	50	0
Rabi Sorghum	20	40	30	0	0	10	110	120	30	0
Maize	220	100	40	0	0	10	260	280	40	0
Groundnut	20	80	40	0	0	10	50	230	40	0
Cabbage	190	80	60	0	0	10	220	230	60	0
Onion Irrigated	290	80	60	0	0	10	330	230	60	0
Onion (Late sown) Irrigated	290	80	0	0	0	10	330	230	0	0
Brinjal	100	80	0	0	0	10	130	230	0	0
Tomato	180	100	60	0	0	10	220	280	60	0
Okra	80	80	0	0	0	10	110	230	0	0
Cauliflower	190	80	0	0	0	10	220	230	0	0

Back



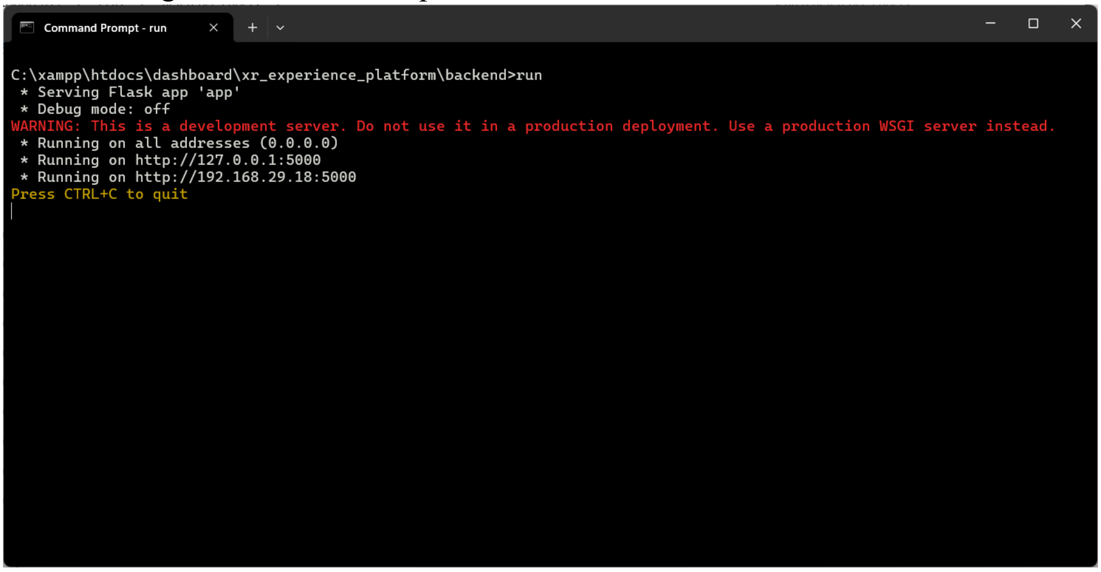
Note: The above results are processed, analyzed and recommendation is provided by a trained AI that provides details of how and what types of fertilizers should be used for a specific crop for higher yield and productive outcomes.

Note: The above AI (Agriculture Intelligence) UI provides a rich UX to farmers who can post any questions related with Agriculture to get prompt updates and right solution at right time. Farmers can upload the crop photo by selecting attachment / Upload button and get solutions to their problems instantly.



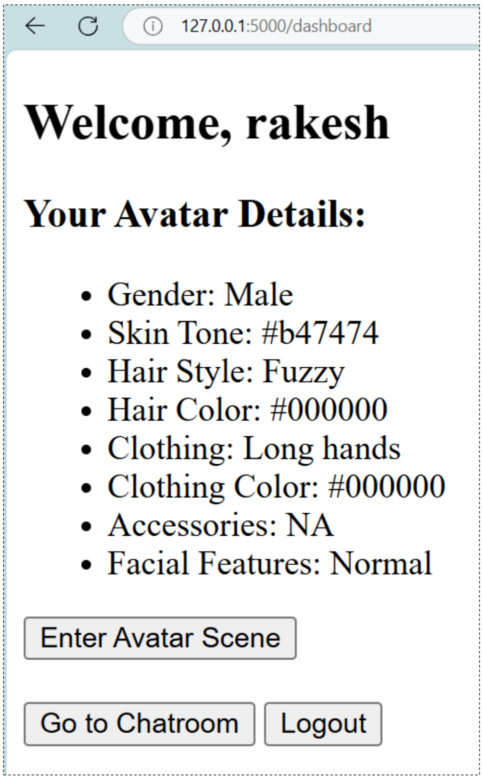
Note: The above is a customized suggestion expert Pre-Trained Agriculture Chat UI that suggest solutions for common problems that are faced by farmers at ground level.

6. Accessing Metaverse Environment by running Cloud Server for 3D Avatars that can be accessed using AR / VR headsets to get an immersive experience.

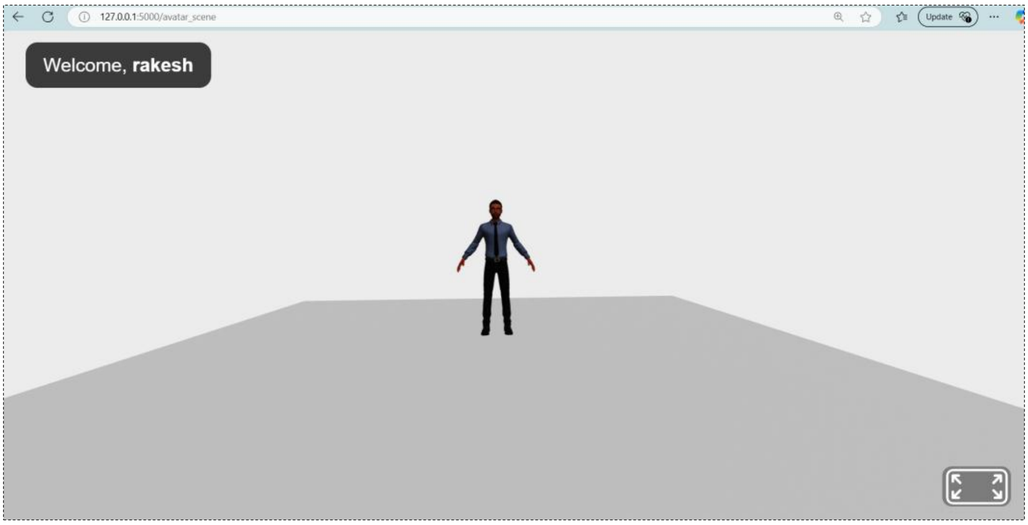


Note: To access Metaverse Environment server should be up and running on cloud: http://127.0.0.1:5000

Note: The above UI helps in creating Avatar which can be accessed in Metaverse eco-System providing the user to interact virtually or by login into chat environment after verification and validation of authorized and authenticated user.

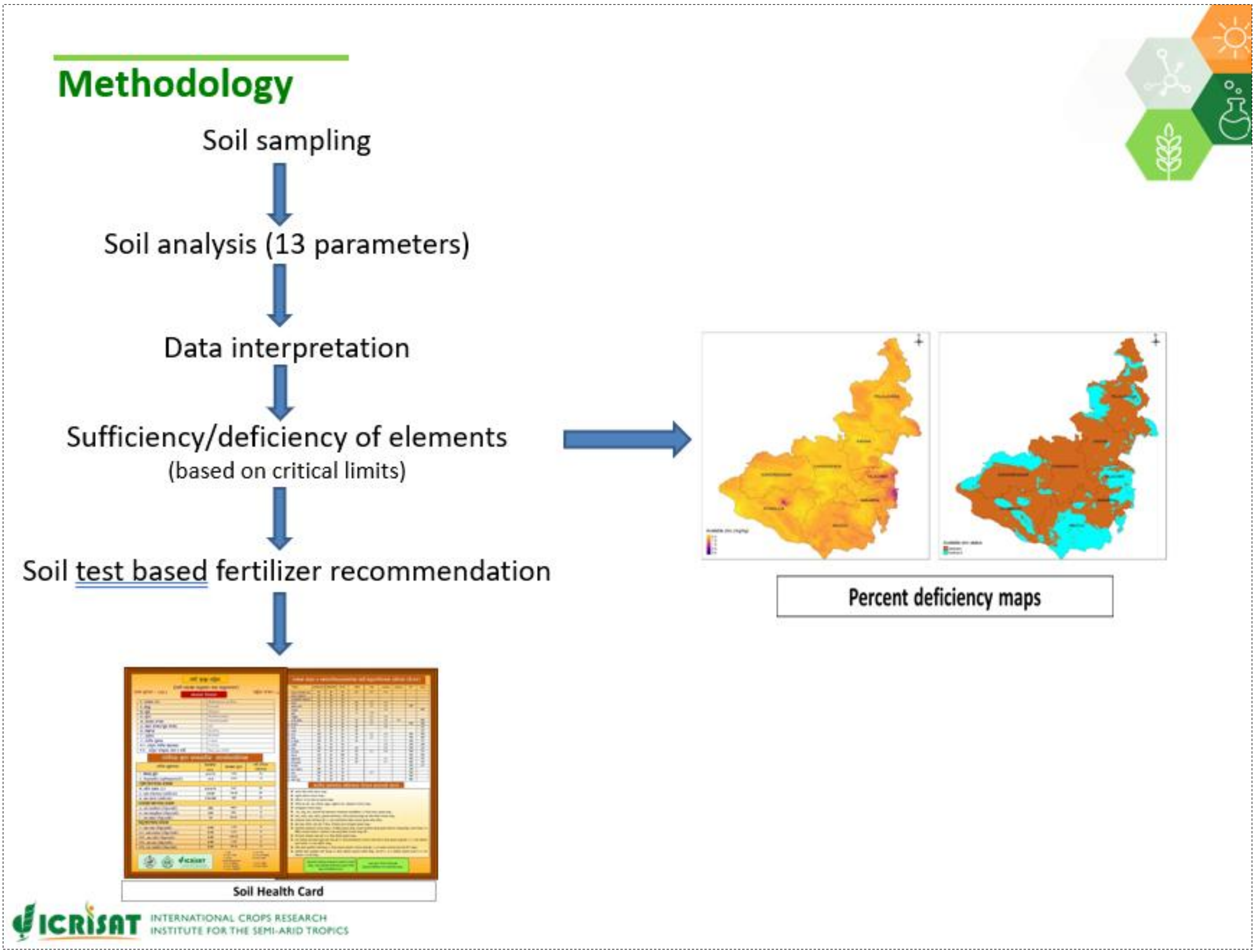


7. Virtual Environment helps the avatar navigate to Metaverse eco-System where the digital twin of the agriculture land, crops, sensor-based operations can be performed with the help of gestures and actions which are tracked and actions are performed based on finger tap action.



Note: Avatar can initiate a move and access digital twin of agriculture farm land, weather forecasting updates, Control rover, drone by performing actions and having a full control over the available resources.

Assessment metrics:



Recommendation of Fertilizer and the Calculation

Calculate the rate of nutrients to be applied per unit area. Identify the fertilizers that will supply the nutrients, either singly or in combinations. Then calculate the amount of fertilizer that will supply the required amount of nutrients ha^{-1}, m^{-2}, $plot^{-1}$, or for a row. Application rates for major nutrients are reported as kg ha^{-1}.

Procedure for Calculation

Calculate the quantity of a straight fertilizer to supply 120 kg of N ha^{-1} for total area 0.5 ha. The fertilizer to be used is ammonium sulphate.

Step 1. Ammonium sulphate contains 20% N or 20 kg N in each 100 kg.

Therefore, 120 kg N will be available from:

$$\frac{100 \text{ kg ammonium sulphate X } 120 \text{ kg N}}{20 \text{ kg N}} = 600 \text{ kg of ammonium sulphate.}$$

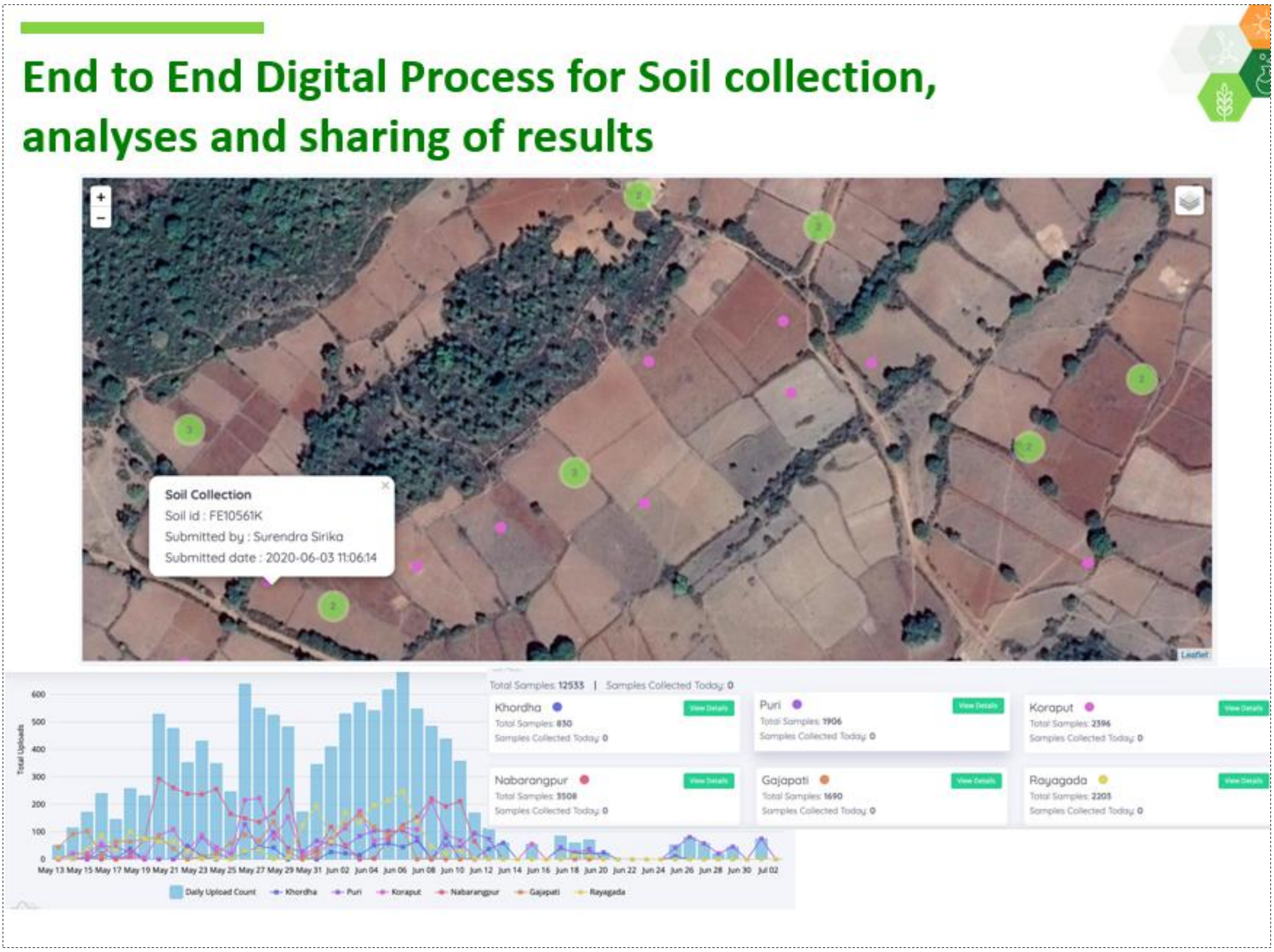
To supply 120 kg N requires 600 kg of ammonium sulphate for 1-hectare area

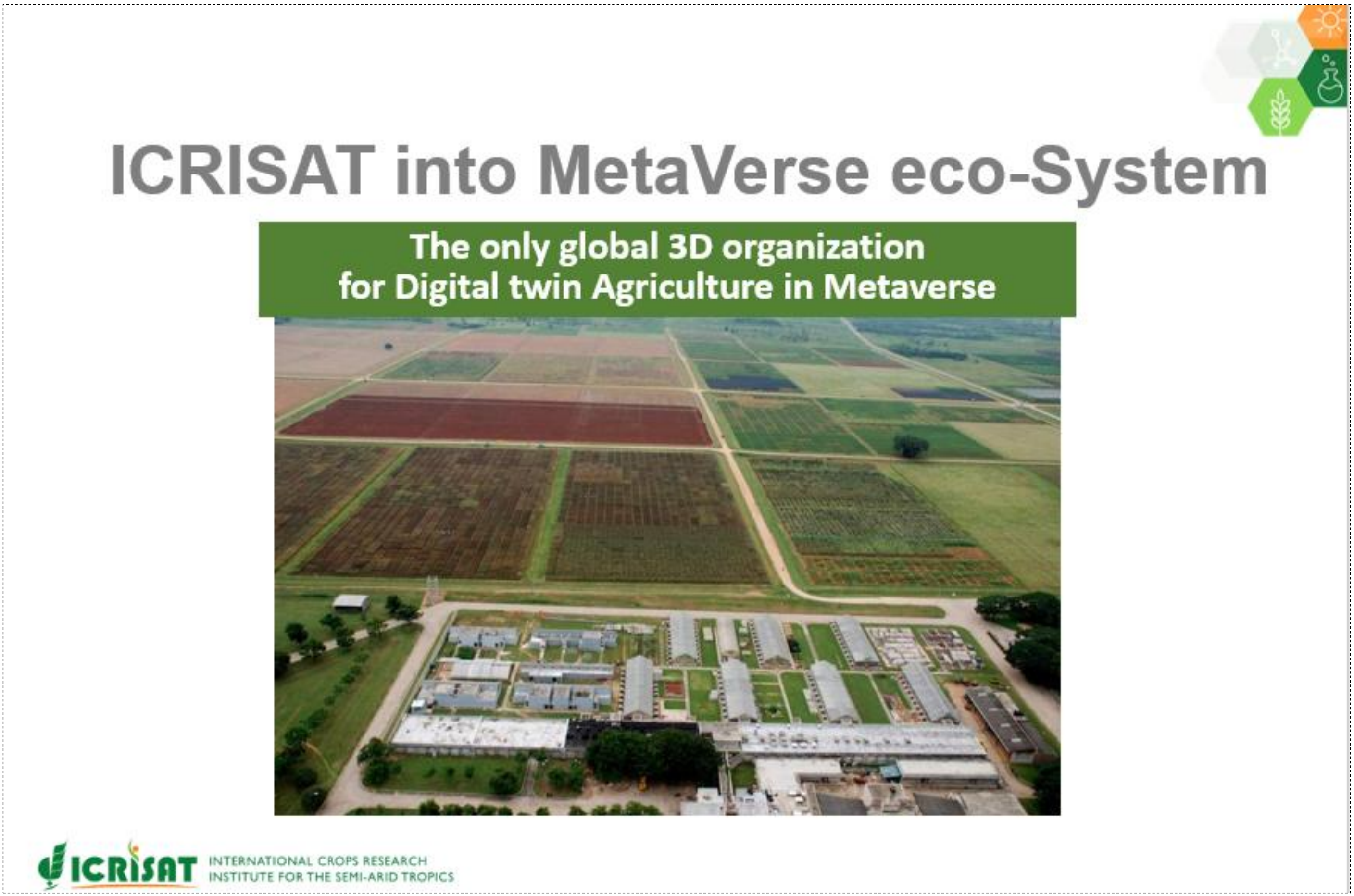
Step 2. The required ammonium sulphate for 0.5 ha to provide 120 kg N ha^{-1} will be:

$$\frac{600 \text{ kg ha}^{-1}}{2} = 300 \text{ kg of } (NH_4)_2SO_4$$

The amount of ammonium sulphate for a plot of 0.50 ha will be 300 kg

Similarly, the other two plant nutrients can be obtained by using straight fertilizers such as single superphosphate (7% P) or triple superphosphate (20% P), and murate of potash (50% K).




ICRISAT into MetaVerse eco-System
The only global 3D organization
for Digital twin Agriculture in Metaverse
ICRISAT
INTERNATIONAL CROPS RESEARCH
INSTITUTE FOR THE SEMI-ARID TROPICS


IDC ICRISAT DEVELOPMENT CENTER
UNDERTAKING
LARGE-SCALE UPTAKE OF
SCIENCE-BACKED
TECHNOLOGIES
To achieve major impact in reducing poverty, hunger, malnutrition and environmental degradation across ASIA and AFRICA
THIS IS HOW
IT WORKS
ICRISAT has 700 staff working on research projects
Pilot studies reach 100s or maybe 1,000s of farmers
Achieving proven technologies & practices in the field
NOW THE
BIGGEST
CHALLENGE
How do we reach all the people that can benefit to create a major impact on poverty
THIS IS WHAT THE ICRISAT
DEVELOPMENT CENTER
IS DOING
1
Taking (science-backed)
PROVEN TECHNOLOGIES
2
Working with the right partners to take these out on a very large scale
TO REACH THE PEOPLE
3
Capturing lessons on how to do
LARGE-SCALE ADOPTION

Conclusion:

This research introduces a multi layered architecture and multi device collaboration model, which is used to get data from various source which can be processed and provided to farmers with accurately providing the live updates using IoT and providing an infrastructure / Metaverse eco-System that can resolve and reduce the cost of loss in hi-end project. Metaverse uses real-time data which is inculcated with its digital twin. Any negative impact or loss can be predicted early so that the loss can be reduced and proper solutions can be made ready to perform point in time recovery or recovery based on timestamp. The successful transfer of relevant details and high-quality precision layers is achieved by implementing historical data in the new environment which can channelize, process and increase the chances of no-loss when any critical problem is predicted to come up at any point of time Metaverse, enhances various segments and provide information at any point of time. Additionally, to improve computational efficiency, pre-defined chatbot application, Agriculture Intelligence Application are significantly included to process the data quickly and crack into a perfect solution which can result in a significant reduction of cost, manpower, precision farming by considering all the attributes that influence the Agriculture Sector. The primary objective of is to bring in reliability, the second focuses is on restoring and recovering from natural disasters like floods. The newly developed eco-System Metaverse would give a real-time experience to new farmers who want to make Agriculture as an opportunity to service people.

Achievements:


ScrumAlliance®

Phuke Rakesh Rao

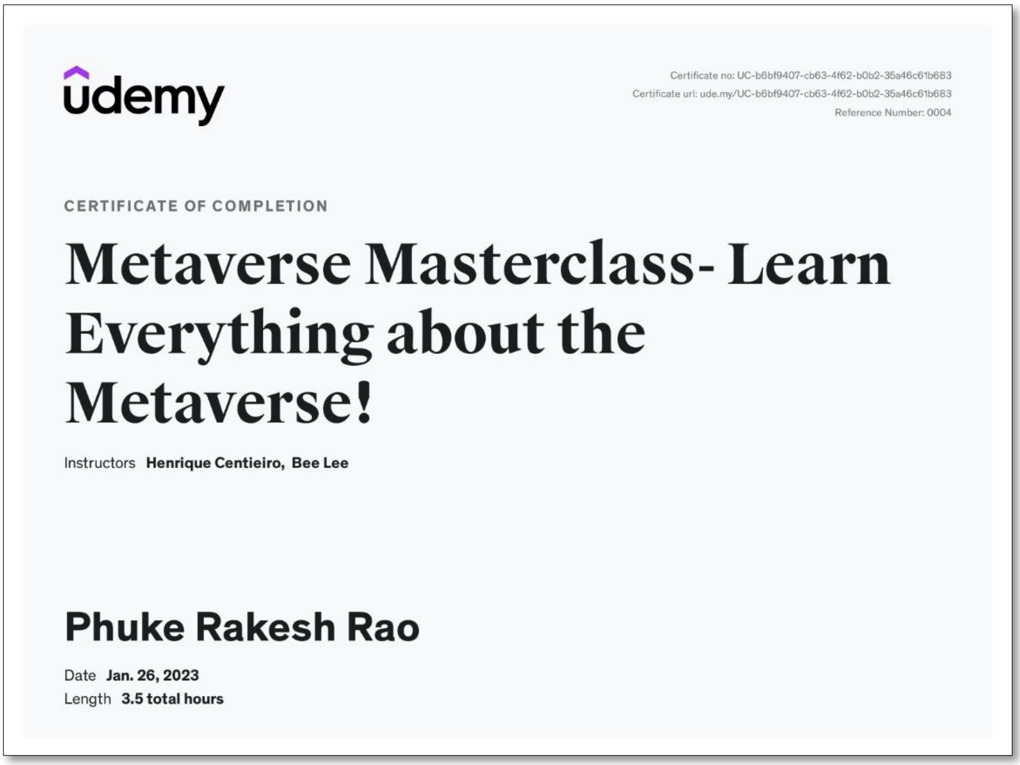
is awarded the designation
Certified Scrum Product Owner® on this day,
January 29, 2023, for completing the prescribed
requirements for this certification and is hereby entitled to
all privileges and benefits offered by SCRUM ALLIANCE®.

Scrum Alliance CSPO CERTIFIED

Certificant ID: 001476883 Certification Active through: 29 January 2025

Jaya Shrivastava
Certified Scrum Trainer®

Chairman of the Board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Certificate no: UC-b6bf9407-cb63-4f62-b0b2-35a46c61b683
Certificate url: ude.my/UC-b6bf9407-cb63-4f62-b0b2-35a46c61b683
Reference Number: 0004

CERTIFICATE OF COMPLETION

Metaverse Masterclass- Learn Everything about the Metaverse!

Instructors **Henrique Centieiro, Bee Lee**

Phuke Rakesh Rao

Date **Jan. 26, 2023**
Length **3.5 total hours**

EDORER MASTERCLASS

CERTIFICATE OF PARTICIPATION

edorer

This is to certify that

Phuke Rakesh Rao,

has participated and successfully completed Edorer's Masterclass on

MODERN AGRICULTURE : AI-POWERED SOIL AND CROP HEALTH MONITORING

held on **21 May 2024** by

Dr. Maryna Kuzmenko
Co Founder and CEO
Petiole, a UK-based Agritech Company, United Kingdom (UK)

We wish the participant a great career ahead.

Michelle Liu
Michelle Liu
Head of Outreach, Edorer

Chapter 5: Work plan for future

Designing of Novel Approach Using Metaverse Technology for Smart Agriculture System

16 Sep 2023 (SAS) Evaluation Recommended

OBJECTIVE	DESCRIPTION
Primary Objective - 1	To review the existing smart agriculture and metaverse technologies.
Secondary Objective - 2	To collect the dataset from the southern region based on parameters such as soil, water, crop and climate conditions.
Tertiary Objective - 3	Development and implementation of proposed system using metaverse technology.
Quaternary Objective - 4	Comparison of developed system with the traditional systems.

26 Dec 2024 (ETP) Evaluation Recommended

1. Scholar need to identify the module where the novelty of the work lies. The need for a metaverse is required to be justified. Similarly, IoT's role in this work must be justified.
2. Publish your research work in quality journals.

06 Jun 2024 (ETP) Evaluation Recommended

1. The scholar needs to focus on the fundamentals. It is recommended that scholar present his comparative analysis of existing models in a tabular format.
2. Needs to work more on literature review and existing work. Needs to come up clearly on the novelty of the approach.

Detail work Plan and future work:

Activities	Duration (Months)					
Year	**2023**		**2024**		**2025**	
Months	**1-6**	**7-12**	**1-6**	**7-12**	**1-5**	
Literature Survey						
Data Collection and Analysis						
Metaverse eco-System						
Development of Framework						
Performance evaluation and summary of research work performed						

Table 6: Work plan for future

Objective of the proposed work	Achievement till date	Future plan	Methodology, tools process etc. to be used	Detail of inventive step, process etc. to be utilized
To review the existing smart agriculture and metaverse technologies.	Review completed	Update reviews	Online search and review of published papers from top Journals	N/A
To collect the dataset from the southern region based on parameters such as soil, water, crop and climate conditions.	Data collection and processing data completed	Upgrade the data with latest updates	ETP – Extraction Transformation and Process	Collected data from farmers on field
Development and implementation of proposed system using metaverse technology.	Developed centralized dashboard with metaverse technology using python, flask and blender to create 3D environment	Updata the digital twins that replicate the real world	Design and Develop Metaverse eco-System to create a digital twin of real-world agriculture environment	Feasible study, Analysis, Design, Develop, Test, Documentation, Implementation, Upgrade
Comparison of developed system with the traditional systems.	Performed a comparative study on existing available environment that helps in automation and implementation of latest technology in Smart Agriculture System	Review and update the latest technology getting improved and targeted towards improving the Smart Agriculture System	(ECEU) - Explore, Conquer, Enhance, Update	(IKIWISI) - I Know It When I See It

List of publications and Presentations

Reference URL: https://www.semanticscholar.org/author/Phuke-Rakesh-Rao/2302286125

Paper Presentation 1:

IEEE 11th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO 2024) organized at AMITY UNIVERSITY (UTTAR PRADESH)

IEEE11thICRITO/________

AMITY UNIVERSITY
UTTAR PRADESH

IEEE UP SECTION (INDIA)

AMITY INSTITUTE OF INFORMATION TECHNOLOGY

IEEE 11th INTERNATIONAL CONFERENCE

ON

RELIABILITY, INFOCOM TECHNOLOGIES AND OPTIMIZATION (ICRITO 2024)
(TRENDS AND FUTURE DIRECTIONS)

CERTIFICATE OF PARTICIPATION

This is to certify that Prof./Dr./Ms./Mr. Phuke Rakesh Rao of School of Computer Application, Lovely Professional University, Phagwara, India has participated and presented paper titled Farmer Well-Being with Metaverse Innovations in Agriculture during the IEEE 11th International Conference on Reliability, Infocom Technologies and Optimization (ICRITO 2024) organised by Amity Institute of Information Technology from March 14-15, 2024 at Amity University Uttar Pradesh, India.

Prof. (Dr.) Rekha Agarwal, General Chair, ICRITO 2024

Prof. (Dr.) Sunil Kumar Khatri, General Chair, ICRITO 2024

Prof. (Dr.) K.M. Soni, General Chair, ICRITO 2024

Prof. (Dr.) Balvinder Shukla, Co-Patron, ICRITO 2024, Vice Chancellor, AUUP

15th March 2024

Paper Publication 1:

Link:

https://www.semanticscholar.org/paper/Farmer-Well-Being-with-Metaverse-Innovations-in-Rao-Sandhu/6962a63b8137752fc7dc792dacf68bd19b983a2c

- DOI:10.1109/ICRITO61523.2024.10522137
- Corpus ID: 269776800
- **Title:** Farmer Well-Being with Metaverse Innovations in Agriculture
- Phuke Rakesh Rao, Ramandeep Sandhu
- Published in 11th International Conference… 14 March 2024
- Agricultural and Food Sciences, Computer Science, Environmental Science
- 2024 11th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)

Paper Presentation 2:

Link: https://www.semanticscholar.org/paper/ReIoT-Powered-Smart-Agriculture-in-Controlled-Rao-Sandhu/e54c8a920994af7ec749e4d952441a83ec551aae

Title: ReIoT-Powered Smart Agriculture in Controlled Environments

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08 - 09 FEBRUARY 2025

IEEE Record No. 64145

CERTIFICATE OF PRESENTATION

This is to certify that **Phuke Rakesh Rao** of **Lovely Professional University, Phagwara, Jalandhar, Punjab, India** presented his/her research paper titled **ReIoT-Powered Smart Agriculture in Controlled Environments** In the **"International Conference on Pervasive Computational Technologies (ICPCT-2025)"**, organized by Department of Computer Science Engineering (AIML), GL Bajaj Institute of Technology and Management, Greater Noida, UP, India, held on 8th - 9th February, 2025.

Conference Chair
Dr. Naresh Kumar

Conference Secretory
Dr. Shashank Awasthi

References

1	2000	Anesthesiology	*Monitoring Depth of Anesthesia: With Emphasis on the Application of the Bispectral Index and the Middle Latency Auditory Evoked Response to the Prevention of Recall*
2	2008	aaai.org	*Asilomar Study on Long-Term AI Futures*
3	2014	Hindawi	*Computer-Based Diagnostic Expert Systems in Rheumatology: Where Do We Stand in 2014?*
4	2016	obamawhitehouse.archives	*Preparing for the Future of Artificial Intelligence*
5	2018	Intechopen	*Physical Properties of Soils Affected by the Use of Agricultural Waste*
6	2018	Nuffieldbioethics	*Artificial intelligence (AI) in healthcare and research*
7	2018	ResearchGate	*Delaying When all Dogs to go to Heaven: Virtual Reality Canine Anatomy Education Pilot Study*
8	2020	Researchgate	*M-learning for Promoting Advancements in Agriculture: An Innovative Educational Model for Ethiopia Farmers*
9	2020	ResearchGate	*Adapting a Virtual Reality Anatomy Teaching Tool for Mobility: Pilot Study*
10	2020	IEEE Xplore	*A Virtual Reality Platform for Learning Aspects of Entrepreneurship*
11	2020	reunir	*Augmented reality-based application to foster sustainable agriculture in the context of aquaponics*
12	2021	India AI	*AI impact on India: How AI will transform Indian agriculture*
13	2022	ScienceDirect	*Artificial intelligence for the metaverse: A survey*
14	2022	IEEE Xplore	*Adaptive of New Technology for Agriculture Online Learning by Metaverse: A Case Study in Faculty of Agriculture, National University of Laos*
15	2023	ScienceDirect	*Learning impact of recent ICT advances based on virtual reality IoT sensors in a metaverse environment*
16	2023	ScienceDirect	*Nitrogen management in farming systems under the use of agricultural wastes and circular economy*
17	2017	Sciencedirect	*Biotic resource loss beyond food waste: Agriculture leaks worst*
18	2018	wiley	*Nitrogen Mineralization in Chernozemic Soils Amended with Manure from Cattle Fed Dried Distillers Grains with Solubles*
19	2020	Springer	*Fate of nitrogen in agriculture and environment: agronomic, eco-physiological and molecular approaches to improve nitrogen use efciency*
20	2020	Sciencedirect	*Cross-Attentional Bracket-shaped Convolutional Network for semantic image segmentation*
21	2018	Sciencedirectite	*Automated 3D segmentation of brain tumor using visual saliency*
22	2014	Sciencedirectite	*Low-level and high-level prior learning for visual saliency estimation*
23	2018	Sciencedirectite	*Video saliency detection via bagging-based prediction and spatiotemporal propagation*
24	2015	Sciencedirect	*Saccadic model of eye movements for free-viewing condition*
25	2004	Sciencedirect	*Modelling gaze shift as a constrained random walk*
26	2015	Sciencedirect	*Integral formula for elliptic SOS models with domain walls and a reflecting end*
27	2015	Sciencedirect	*Polarization in nuclear excitation by electron impact*
28	2012	Scopus Preview	*Document details - Active inhibition and memory promote exploration and search of natural scenes*
29	2005	Scopus Preview	*Document details - Optimal eye movement strategies in visual search*
30	2021	IEEE Xplore	*Research on Metaverse: Concept, development and standard system*

Detail of the journal/ Book / Book chapter/ website link	Year of Publication	Indexing of journal (Scopus/ SCI index etc.)	Main findings or conclusion relevant to proposed research work	Remarks
[1] Journal of Metaverse Link: https://dergipark.org.tr/en/download/article-file/3294107	2023-2024	SCIE	The MVRG was designed to be run on the HMD device in order to get a high immersive level. Oculus Quest 2 was selected as the HMD device to play the Gamelan music MVRG. The MVRG supports users from all over the world	Meta Listed

			gathering and experiencing in a virtual Gamelan world.	
[2] MDPI Link: https://www.mdpi.com/2673-8392/2/1/31	2022	SCIE	Metaverse-powered online distance education, can emerge to allow rich, hybrid formal and informal learning experiences in online 3D virtual campuses. Online learning in the Metaverse will be able to break the final frontier of social connection and informal learning.	Meta Listed

			Physical presence in a classroom will cease to be a privileged educational experience.	
[3] S. Vikrant, S. Sayyad, A. Kumar, K. Vengatesan, and A. Singhal, "M-learning for promoting advancements in agriculture: An innovative educational model for Ethiopian farmers," *Advances in Mathematics: Scientific Journal*, vol. 9, no. 7, pp. 5057-5064, 2020.	2020	SCIE	The major outcome expected from this research is successful and productive E-Learning by introducing latest tools and technologies. It is expected from the course instructor to design the course in such a way that farmers can easily understand	Agri Listed

			the concepts and practical implementation of the course.	
[4] Hou, K. M., Diao, X., Shi, H., Ding, H., Zhou, H., & de Vaulx, C. (2023). Trends and challenges in IoT/IIoT/IoT implementation. Sensors, 23(11), 5074.	2023	SCIE	Smart everything is underway, driven by the development of digital twins, metaverse, Industry 4.0 and autonomous vehicles, and it has enjoyed an incredible synergy of advancements in its core hardware and software.	IoT Listed
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			addressing critical challenges like food security and environmental sustainability.	
[6] Jafarpanah, I., & Karshenas, A. (2024). technological trends in smart agriculture. Journal of Entreneurship and Agriculture, 9-0. URL: http://jea.sanru.ac.ir/browse.php?a_id=367&sid=1&slc_lang=en&ftxt=0 http://jea.sanru.ac.ir/article-1-367-en.pdf	2024	SCIE	Based on the identified trends, it is clear that government intervention is essential for fostering the development of smart agriculture.	Agri Listed
[7] H. Alder, B. A. Michel, C. Marx, G. Tamborrini, T. Langenegger, P. Bruehlmann, J. Steurer, and L. M. Wildi, "Computer-based diagnostic expert systems in rheumatology: where do we stand in 2014," *International Journal of Rheumatology*, 2014. URL: https://europepmc.org/article/pmc/4119620	2014	SCIE	systematic review shows that the many attempts made for an ideal expert system in rheumatology in the past decades have	Tech Listed

			not yet resulted in convincing validated tools allowing for reliable application in daily practice.	
[8] M. B. Almendro-Candel, I. G. Lucas, J. Navarro-Pedreño, and A. A. Zorpas, "Physical properties of soils affected by the use of agricultural waste," *Agricultural Waste and Residues*, vol. 2, no. 1, pp. 77-99, 2018. URL: https://www.researchgate.net/publication/327299699_Physical_Properties_of_Soils_Affected_by_the_Use_of_Agricultural_Waste	2018	SCIE	It is important to consider which type of soil characteristics should be improved when applying agricultural wastes.	Agri Listed
[9] Annoni, A., Nativi, S., Çöltekin, A., Desha, C., Eremchenko, E., Gevaert, C. M., ... & Tumampos, S. (2023). Digital earth: yesterday, today, and tomorrow. International Journal of Digital Earth, 16(1), 1022-1072. URL: https://www.tandfonline.com/doi/epdf/10.1080/17538947.2023.2187467?needAccess=true	2023	SCIE	This review and perspective paper tries to answer three important questions: what is DE today? What could DE be	Agri Listed

			in the future ? And what is neede d to make DE a reality ? Today, it is possib leto assum e that the DE vision remain s valid becaus e it is define d at a more abstra ct level (i.e. ameta-level) than its attemp ts to imple ment over time.	
[10] S. Escolar Díaz, J. Carretero Pérez, A. Calderón Mateos, M.-C. Marinescu, and B. Bergua Guerra, "A novel methodology for the monitoring of the agricultural production process based on wireless sensor networks," Computers and Electronics in Agriculture, vol. 76, pp. 252–265, 2011. URL: https://www.researchgate.net/publication/233860203_Original_papers_A_novel_methodology_for_the_monitoring_of_the_agricultural_production_process_based_on_wireless_sensor_networks	2011	SCI E	Agricu ltural monit oring is one of the WSN applic ations with import ant benefit s to the farmer s.This article	Agri List ed

			presents a methodology that can successfully guide the process of building monitoring applications for agricultural production based on WSN technology.	
[11] Rao, Phuke Rakesh, and Ramandeep Sandhu. "Farmer Well-Being with Metaverse Innovations in Agriculture." In 2024 11th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)(ICRITO), pp. 1-6. IEEE, 2024. URL: https://www.semanticscholar.org/paper/Farmer-Well-Being-with-Metaverse-Innovations-in-Rao-Sandhu/6962a63b8137752fc7dc792dacf68bd19b983a2c Farmer Well-Being with Metaverse Innovations in Agriculture | IEEE Conference Publication | IEEE Xplore	2024	SCIE	The future of the metaverse holds immense promise for the transformation of the agricultural sector into a technologically advanced and sustainable landscape. The integra	Meta & Agri Listed

			tion of virtual reality, augmented reality, and mixed reality technologies into smart agriculture offers a plethora of opportunities to enhance productivity, efficiency, and environmental stewardship.	
[12] Vishnoi, S., & Goel, R. K. (2024). Climate-smart agriculture for sustainable productivity and healthy landscapes. Environmental Science & Policy, 151, 103600.	2024	SCIE	Climatic conditions play a major role in sustainability	Agri Listed
[13] T. Rodríguez-Espinosa, I. Papamichael, I. Voukkali, A. P. Gimeno, M. B. A. Candel, J. Navarro-Pedreño, A. A. Zorpas, and I. G. Lucas, "Nitrogen management in farming systems under the use of agricultural wastes and circular economy," Science of The Total Environment, vol. 876, p. 162666, 2023.	2023	SCIE	Nitrogen management in farming systems under the use of agricultural wastes and	Agri Listed

			circular economy	
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[15] Zawish, M., Dharejo, F. A., Khowaja, S. A., Raza, S., Davy, S., Dev, K., & Bellavista, P. (2024). AI and 6G into the metaverse: Fundamentals, challenges, and future research trends. IEEE Open Journal of the Communications Society, 5, 730-778.	2024	SCIE		Meta Listed
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			most appropriate transitions to curriculum and education for our students and their future.	
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P. Rameshrao
03/05/2025

Signature of Scholar with date

Remarks of the Supervisor/ Co-Supervisor.

Certification by the Supervisor/ Co-Supervisor:

1) It is hereby certified that the information, and details presented above are true to the best of my knowledge.
2) The performance and progress of research work of the candidate is satisfactory.

Signature of Supervisor/Co-Supervisor with date