An Analysis of Disruptive Technologies in Urban Agriculture

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Abstract. The exacerbation of the need for sustenance is attributable to a diminution in arable terrain, which has been reassigned to facilitate the proliferation of urbanized regions. In urban areas, various agricultural methods are employed. However, it is essential to note that the initiatives mentioned earlier are expected to yield minimal effects on the agricultural sector. In light of this, enhancing these capabilities and advantages by integrating technological advancements is imperative. This article examines the effects of various emerging technologies on urban agriculture. These technologies encompass many advancements, such as The Internet of Things, Automation, Robotics, Mesh Technology, Blockchain, Artificial Intelligence, Atmega16 Microcontroller**,** Digital Twins, Genetic Modification, Additive Manufacturing, Renewable Energy, Climate-Smart Agriculture Techniques**,** and Nanotechnology. The investigation employed a methodological strategy that conformed to the mixed-method research paradigm, encompassing a comprehensive literature review and examining multiple case studies. The analysis of every technology encompasses evaluating its various applications and examining its inherent advantages and limitations. Furthermore, this study offers valuable insights and suggestions for potential future research and development avenues.
Keywords: Disruptive technologies, agricultural techniques

1 Introduction

The agricultural sector holds significant significance in numerous countries, with particular attention directed towards Indonesia. The term "agricultural cultivation" pertains to the deliberate and systematic approach employed within the agricultural industry to selectively propagate plants that possess desirable traits and are in high demand within the market. The cultivation of crops in Indonesia is currently posing notable challenges for farmers due to the emergence of a land crisis in the country. One salient factor contributing to the observed phenomenon is converting agricultural land for purposes other than agricultural activities.

As a fundamental economic activity, agriculture plays a crucial role in sustaining and driving economic growth. Both endeavors necessitate a fundamental comprehension of marketing principles, product assortment, distribution logistics, processing methodologies, and packaging practices. Additionally, proficiency in business administration, seed and seedling curation, cultivation procedures, and organizational management is essential for success. Farmers who prioritize efficiency to maximize profitability adopt a farming practice known as intensive farming.

The present discourse revolves around the advancements and breakthroughs witnessed in urban agriculture [1]. This burgeoning field encompasses various innovative practices and techniques developed to address the challenges and opportunities associated with cultivating crops and raising livestock. The phenomenon of global expansion in novel urban agriculture systems, commonly known as "innovative urban

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agriculture," is currently experiencing a notable upsurge. Combining cutting-edge agricultural technologies with urban optimization gives rise to diverse manifestations of urban agriculture, encompassing small-scale practices, medium-scale endeavors like community food gardens, and large-scale initiatives such as establishing vegetable factories within urban settings. The observed form of urban agriculture is frequently regarded as exhibiting an elevated environmental sustainability. The technological advancements have resulted in a global upsurge in crop production, concomitantly diminishing the necessity for upkeep and resources.

Implementing this approach is considered one of the key strategies for ensuring universal access to a dependable supply of nutritious food within households. Urban agriculture is being promoted as a potential solution to tackle the issue of food security and enhance public accessibility to nutritious and fresh food in various geographical areas, such as Brazil, the United States, and multiple African nations.

The present study aims to examine the degree of acceptance of urban agriculture, with a specific focus on the strategies and approaches employed by local governmental and non-governmental organizations. This study aims to promote urban dwellers' engagement in urban agriculture as a potential solution to the limited availability of agricultural land. The present study is expected to yield significant findings regarding urban agriculture's current state, encompassing its obstacles and potential to ensure future food security.

2. Method

Urban agriculture has garnered considerable attention in recent years and has emerged as a distinct and potentially advantageous alternative to conventional agricultural methods. The observed shift in perception can be attributed to the various advantages that urban agriculture presents. To fully harness the potential of urban agriculture and capitalize on its inherent benefits, there is an increasingly prominent focus on the imperative of conducting comprehensive research and effectively implementing novel technological advancements.

The complete realization of the potential of urban agriculture necessitates the implementation of this measure. The primary aim of this study is to undertake comprehensive research and analysis on a diverse range of emerging and advancing technologies that have potential applications in urban agriculture. The primary aim of the literature review is to meticulously examine a corpus of journal articles and conference papers written in English and Indonesian. The focus will be on sources obtained from esteemed academic research outlets, ensuring the credibility and reliability of the information gathered.

3. Results and Discussion

3.1. Urban Agriculture

Urban agriculture possesses the inherent capacity to mitigate various unfavorable circumstances commonly observed in urban environments. Insufficient management practices nevertheless possess the capacity to engender environmental and public health issues. Urban agriculture has been found to provide a multitude of health benefits. These advantages encompass broader accessibility to nutritious food options, an augmented consumption of fruits and vegetables, increased participation in physical activities, improved mental well-being, an enhanced quality of life, and an overall state of wellness.

The potential benefits of implementing urban agriculture are manifold, encompassing various domains such as the environment, society, economics, health, and nutrition. Consequently, the adoption of urban agriculture holds promise for long-term community-wide advantages. Moreover, it significantly impacts the holistic mental and physical well-being of the populace. However, growing vegetables in soil with high levels of lead is a matter of great concern, as it can potentially cause detrimental health effects. Consequently, this raises apprehensions regarding the possible adverse consequences of urban agriculture. The potential health implications may arise due to lead or other heavy metals.

3.2. Disruptive Technologies For Urban Agriculture

The Internet of Things (IoT)

IoT refers to an entity's ability to communicate data over the internet without human or computer intervention. Both in-person and distant interactions can utilize IoT. Mobile apps may access and analyze sensor data sent to a cloud-based infrastructure for monitoring. Contrary to widespread belief, smartphone apps may provide remote operation management over the IoT [2]. In urban agriculture, a reliable cyber-physical system, including IoT, is crucial. IoT sensor nodes enable agricultural data collection and transfer. These technologies use HTTP, MQTT, and CoAP to communicate information.

This permits a quick response to prevent agricultural concerns from escalating. Integrating IoT technology into farms creates integrated communication channels that allow agricultural units to share relevant information [3]. Smart phones make IoT connectivity easy. Farmers may monitor their fields' environmental conditions remotely and in real time. IoT data analytics streamlines pattern recognition in large datasets. It provides new insights on agricultural development, animal health, and operational methods for future undertakings. This analytical method improves problem-solving and decision-making. Additionally, it has minimized human error. The IoT may improve energy, water, and land resource use, as well as waste reduction. IoT networks and devices remain vulnerable to security and privacy threats. These systems need a steady power source and constant internet connectivity to work. The Green IoT offers several ways to cut energy use and carbon emissions. Numerous methods exist to address challenges. These strategies are incomplete; other methods may solve the problems.

Automation

Many fields use automation systems, which evaluate input signals based on user-set thresholds. Sensors identify abnormalities, and controllers use actuator instructions to fix them [4]. Urban agricultural operations benefit from automation since it can effectively handle many laborious and repetitive jobs. Sensors may improve hydroponic automation by monitoring vital environmental factors. Farm operators may use SMS and instant messaging to obtain immediate notice of changes to their operations and uncommon events [5].

Automation might drastically reduce monotonous jobs. Fully automated farming may allow a single farmer to handle vast farms. Reduced frequency of involvement by agricultural workers reduces human error.

Robotics

Since their creation, robots have improved industrial processes. Agriculture, military operations, logistical management, medicinal applications, professional cleaning, and space exploration all use robotics. The observed phenomenon is attributed to computational advances and rising robotic technology prices.

Drones and robots can perform repetitive agricultural duties like watering and monitoring. Robotic devices can precisely distribute fertilizer and insecticide to plants. Robotic surveyors can explore agricultural areas' varied terrain, enabling data collection and feedback measurement [6]. Robots with greater mobility have proven beneficial in towering vertical development towers. Robots' enhanced mobility streamlines crop and growth bed inspections. Additionally, robots can detect and identify insect pests and plant illnesses, which helps evaluate the agricultural ecology. Unmanned aerial vehicles (UAVs), or drones, may fly for lengthy periods. Thus, these gadgets may solve insect problems and provide a new viewpoint on rooftop gardening.

Urban agriculture may benefit from fixed and free-moving robotic arms. Long-term water exposure oxidizes pH and electrical conductivity sensors. By immersing specialized sensors in a medium, robotic arms may conduct specified operations and collect data at certain times. This approach may improve the sensor's operational durability. Robotic arms may simplify seed harvesting and planting. Thus, one farm operator may manage numerous farms.

Robotic technology has revolutionized agriculture by allowing farmers to remotely monitor and control their operations. This technology lets them manage their farms from home. Disposable robots can perform dangerous tasks like handling chemicals and running machines at high altitudes. Drones are prohibited near urban farms. Concerns about noise pollution and privacy breaches drove this ban [7].

Mesh Technology

Water data analysis reveals the water's physical and environmental features. Recently, water resource management has become a major issue across industries. Traditional techniques of water quality assessment have been shown to provide accurate data, but they require a lot of time and people.

Data access methods have changed due to disruptive technologies like IoT and wireless technology. This paradigm shift allows users to access real-time data from anywhere. The sensors measure water temperature, dissolved oxygen (DO), pH, and electroconductivity.

The mesh protocol allows a central master node and numerous slave nodes to communicate, like a spider web. This research has developed a notable node-validation system. When the slave node provides vital data, the master node re-evaluates it using adjacent nodes' data. We use this procedure to reduce false alerts. The server activates a red-spot alert once it receives verified water pollution data. As planned, the spider platform has increased data transmission accuracy by 30% and reduced data loss by 25% [8].

Blockchain

Blockchain technology creates a decentralized, open network of cryptographically protected blocks. This contrasts with the traditional practice of storing data on a central server. Blocks store separate transactions. Links between transactions and blocks depend on hash functions. This connection generates time-stamped records of all past transactions. All network users hinder modifications by accessing this information chain [9].

Blockchain technology makes food regulation simpler to manage and more effective by tracking food items, particularly at the farm level, and revealing where the food comes from. Blockchain technology enables quick tracing of Walmart mangoes, in contrast to conventional methods that require weeks. This innovative method covered the complete process from field cultivation to customer consumption in 2.3 seconds. Transparency in agriculture builds confidence and improves customer-producer interactions, encouraging investment. Additionally, blockchain technology provides a reliable and resilient way to track food throughout the supply chain [10].

AI

AI is a subset of computer science. Its main goal is to enable computers and other computational devices to do human-like activities and assessments. ML methods enhance the autonomous decision-making of computers and other devices. Supervised, unsupervised, semi-supervised, and reinforcement learning algorithms exist. Machine learning includes a variety of methods used in different applications. We utilize various methods such as decision trees, random forests, k-nearest neighbors, logistic regression, SVMs, Naive Bayes, and linear regression [11].

Using AI to develop and execute farming strategies has improved many agricultural production systems. AI-enabled agricultural robots and drones have improved irrigation optimization, weed identification, crop monitoring, and spraying management. Since adoption, labor needs have decreased, but productivity has grown. Sensors, satellites, and AI-enabled devices may improve automation, productivity, and product quality in conventional outdoor agriculture.

AI has potential for optimizing plant irrigation, improving pesticide and fertilizer application, and reducing crop loss. AI can accurately monitor and evaluate soil and water conditions, allowing for prompt and targeted treatments for individual plants. This technology has the potential to transform agriculture and improve crop management and resource utilization.

Additionally, AI can detect pests, weeds, and sick plants. AI has enormous potential to improve water management. AI can also help predict the growth and development of aquatic plants and fish. Visual perception and understanding are possible with computer vision-based AI. Fish and plant auto-sorting systems have the potential to improve labor-intensive food grading and quality checks. AI reduces the uncertainty of human judgment in plant health assessments. With AI, manufacturing resource allocation is more precise and effective. Thus, it significantly reduces waste and pollution. Farm operators may benefit from self-sufficient urban agricultural systems. A farming community may share AI system data to improve agricultural practices in an area [12].

A comprehensive store of AI-derived data and insights suited to agricultural entrepreneurs is lacking. AI systems struggle with insufficient training and test datasets, or low-quality datasets. Sensor deterioration due to environmental variables may lead to incorrect data generation. These issues include poor illumination, the environment, insects or plants, and camera lens cloudiness. AI-powered robots are expensive and complicated.

ATMEGA16 Controller

A microprocessor controls an automated pump system that automatically irrigates plants. This method meets the nutritional needs of plant growth and development. This study programs the ATMega16 microcontroller to analyze input signals and generate output. DHT11 sensors measure temperature and humidity. In contrast, a water pump used for irrigation in pipes represents the output. This system produces a 16x2 LCD in addition to its other components. This LCD displays temperature and humidity data [13]. Hydroponics with an automatic watering system may save energy and simplify plant upkeep. Hydroponic growth mediums may also boost system efficiency.

Digital Twins

A "digital twin" is a virtual copy of a physical system. To accurately reproduce a system's properties and actions in real life, the suggested technique uses simulation and artificial intelligence [14]. The simulation framework includes all relevant system statuses and data. The digital representation of the physical system can accurately duplicate any changes. Because prototypes are not available, digital twins may assist in decision-making. This computational model accurately depicts real system responses in numerous design contexts [15].

Digital twins allow agricultural workers to remotely monitor, control, coordinate, and execute operations. Modeling vertical grow bed layers with different configurations optimizes construction resources. Virtual models of farm operating characteristics like electricity and water use might help farmers make decisions. These models may optimize agricultural yields while minimizing energy and water use. Implementing digital twin technology in agriculture is difficult and time-consuming. Modeling and simulating agricultural variables, especially those related to live creatures, is difficult [16].

Genetic Modification

In cell manipulation procedures, genetic alteration approaches are prevalent. We add or remove targeted gene sequences from cell DNA to alter characteristic expression and achieve desired consequences. Genetic engineering might improve agricultural attributes. The example includes manipulating agricultural genes to improve genetically engineered plant light absorption. It's achievable by matching grow light wavelengths with plant wavelengths [17].

Artificial lighting may boost agricultural productivity. Gene editing in crop modification might change plants' temperature and humidity preferences, enhancing their environmental adaptation. By modifying plant pathogen receptors or removing recessive and vulnerable genes, genetic engineering may make plants more disease- and pest-resistant. The detected genetic change may increase the product's lifetime. Consumers have expressed concern about genetically modified crop-derived goods due to anticipated long-term health dangers [18].

Additive Manufacturing (AM)

Amidst globalization and interconnection, AM is essential. It is due to its capacity to use cutting-edge technology, produce custom-made components in various numbers, and use a variety of materials. The design and development of catering and agriculture equipment require a lot of customization.

AM may make bespoke or innovative coffee, pizza, burgers, biscuits, cakes, chocolates, and more. This is because it can fulfill component amount, shape, and color criteria. AM has revolutionized the agriculture industry by allowing the fabrication of custom physical prototypes that meet farm needs. Before producing agricultural equipment at the industrial plant, the method outlined earlier allows a full assessment of final design flaws and effectiveness. Farmers may buy ergonomically designed, proportioned, and built agricultural equipment [19].

AM has outstanding potential to change food business manufacturing methods. With pureed turkey and celery paste, you can make several attractive edible food designs. This flexibility's versatility allows for several dietary demands and preferences. Households may reduce food waste and meet calorie needs by using 3D food printers to make precise food products.

Renewable Energy

Sustainable energy sources include solar and wind. Photovoltaic (PV) panels convert the sun's radiant radiation—heat and light—into usable solar energy. Wind turbines collect and transform the kinetic energy of the air relative to the Earth's surface [20]. This equipment allows for the use of solar and wind electricity in agriculture [21].

Agrivoltaics, also known as solar sharing or photovoltaic agriculture, is a revolutionary and innovative technology that uses land for solar energy production and farming. We install PV panels on cropland to enable the coexistence of solar power generation and agriculture. In dry situations, the shade from the panels reduces plant surface temperature and evaporation. Thus, stress reduction boosts biomass production. Thus, plants are essential for successfully adjusting panel temperature and minimizing heat load. It is important to realize that hydrogen collection, preservation, and transportation are all expensive.

Climate-Smart Farming

Global warming and severe weather events are two major effects of climate change, mostly driven by humans. The empirical data implies that rising temperatures may cause heat stress in agricultural crops, reducing crop yields and quality. Farmers use a variety of adaptation tactics to overcome climate change concerns. These solutions include changing planting times and choosing crop varieties that can withstand changing weather. Altering precipitation patterns, typified by erratic or insufficient rainfall, may cause drought. Drought may desiccate agricultural soil, causing crop losses. However, excessive precipitation might cause floods [22].

The inundations might damage crops and soil, disrupting agricultural activity, particularly in monsoonal areas. Soil conservation, precision agriculture, and urban food production help accomplish food security and resource recycling. Improving irrigation and water management is essential to addressing water shortages. Climate change is a major problem for agricultural pest populations, according to scientists. This recognition arises because of its potential impact on global food security. Numerous adaptation measures are being implemented. These tactics include traditional methods, resource conservation technology, and socioeconomic initiatives. The empirical data suggests that climate-smart agricultural technology, particularly precision agriculture, may boost crop yields and farming system resilience. Success depends on location, finances, and teamwork. The agricultural industry operates in a complex socio-ecological setting with policy dynamics, economic effects, and climatic variability. Small-scale farmers' resilience and food security depend on climate-smart agricultural strategies adapted to their region. Using publicly funded agricultural extension services may help spread agricultural innovations.

Nanotechnology

Nanotechnology might improve sustainable agriculture. Sustainable agriculture is essential to meeting the food needs of a growing global population. Due to their unique physicochemical features, nanoparticles are popular in agriculture. The deterministic interaction between nanomaterials and soil components has an impact on soil quality and plant development. Researchers have conducted extensive research to understand the impact of nanoparticles on plant growth [23].

Researchers have applied nanotechnology to fruits and vegetables to enhance their quality and minimize post-harvest losses. This paper examines the most recent research on nanotechnology's use in agriculture, primarily as nanobiofertilizer. This project aims to maximize plant development and productivity while providing a rich nutrition source for agricultural crops. Nanotechnology may improve seed germination and agricultural product quality, according to this research. Nanotechnology's use in food processing and packaging may also reduce food waste and contamination. Nanotechnology involves manipulating and regulating nanoparticles below 100 nanometers. Furthermore, plants can only absorb a small amount of this chemical, leading to its release into the environment and subsequent pollution [24].

Additionally, nanomaterial sensors offer extraordinary sensitivity, mobility, and compact size. This technology will transform the area of agricultural system monitoring and management. Using nanosensors with GPS allows precise and rapid crop monitoring [25].

4. Conclusions

The urban agricultural sector is currently facing some challenges, such as a decrease in arable land and the expansion of urbanized regions. However, there are opportunities for innovation and adaptation to overcome these obstacles. In order to tackle this challenge, it is crucial to embrace and integrate various technological advancements such as the Internet of Things, automation, robotics, mesh technology, blockchain, artificial intelligence, and more. This article explores the impact of these technologies on urban agriculture, with a specific focus on their applications, benefits, and constraints. The study employs a mixed-methods research paradigm, examining literature reviews and case studies, and provides valuable insights for future research and development. The study's goal is to encourage urban dwellers to actively participate in urban agriculture as a viable solution to the challenge of limited agricultural land availability.

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