

OPTIMIZING AGRICULTURAL SUSTAINABILITY THROUGH INDOOR SMART GARDENS¹

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Abstract

This study explores the integration of indoor smart gardens as a pivotal element for advancing sustainable development in agriculture. The implementation of smart technologies within indoor gardening systems offers a transformative approach to agricultural practices, fostering resource efficiency, environmental conservation, and increased crop yields. The research delves into the technological aspects of smart gardening, emphasizing sensor networks, automated climate control, and data-driven decision-making processes. By leveraging these innovations, farmers can maximize resource utilization, minimize environmental footprint, and boost agricultural productivity. Additionally, the study investigates the economic feasibility and scalability of indoor smart gardens, considering their potential to address food security challenges in a rapidly changing global climate. The findings highlight the significance of smart agriculture in contributing to sustainable development goals and shaping the future of agriculture. The primary objective of this research is to provide valuable insights for policymakers, farmers, and technology developers. This will contribute to the development of a more resilient and sustainable agricultural sector.

Key words: *indoor smart garden, sustainable agriculture, smart technologies, resource efficiency, agricultural productivity.*

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Introduction

Agriculture plays a crucial role in sustaining human existence by providing the essential nourishment needed for survival (Olawepo et al., 2020). As a result, the pursuit of sustainable development in agriculture has gained significant importance due to pressing global challenges, including population growth, climate change, and resource scarcity. Home gardening is recognized as a vital modern trend, reflecting society's growing environmental consciousness. The effective use of smart sensors for wireless communication offers economical solutions for real-time home gardening management systems (Min, Park, 2018). Indoor smart gardens have emerged as a promising solution to address these challenges by integrating advanced technologies and controlled environments. These gardens leverage smart technologies such as Internet of Things (IoT) devices, sensors, automation, and data analytics. By doing so, they offer a potential pathway towards achieving sustainable agricultural practices.

The main aim of this study is to investigate the contribution of indoor smart gardens to sustainable development in agriculture. Through a comprehensive review of the existing literature, our objective is to analyze the advantages and challenges associated with implementing indoor smart gardens. Furthermore, we will explore the implications of these gardens for promoting sustainable agricultural practices. Swift technological advancements have found application in numerous domains, including agriculture (Hadi et al., 2020). Indoor smart gardens offer a controlled environment where critical parameters such as light, temperature, humidity, and nutrient levels can be precisely regulated. This controlled environment offers several advantages over traditional farming methods. By mitigating external factors like adverse weather conditions, pests, and diseases, indoor smart gardens contribute to improved crop productivity and reduced yield losses. The controlled environment also enables year-round production, ensuring a consistent supply of fresh produce to meet the demands of a growing population.

The automation of garden monitoring processes has the potential to revolutionize garden irrigation. It can transform the traditional manual and static method into a smart and dynamic approach. This results in increased convenience, improved water efficiency, and reduced human supervision required (Al-Omary et al., 2018). The integration of smart technologies in indoor smart gardens enhances resource efficiency and reduces environmental impact. With

the utilization of IoT devices and sensors, these systems facilitate real-time monitoring and data collection. This enables data-driven decision-making and adaptive control, enhancing the overall efficiency and effectiveness of the garden management process. Advanced data analytics techniques can optimize resource utilization, minimizing water consumption, nutrient waste, and energy usage. Moreover, the targeted application of nutrients and the reduction of chemical pesticides contribute to improved food safety and environmental sustainability.

While indoor smart gardens show great promise for promoting sustainable agriculture, their widespread adoption faces certain challenges that need to be addressed. Key considerations include the initial investment costs, technological requirements, and scalability of these systems. Overcoming these challenges requires continuous research and development efforts, as well as the establishment of supportive policies and market mechanisms.

Through an exploration of indoor smart gardens as a catalyst for sustainable agricultural development, this study seeks to contribute to the scientific understanding of resource-efficient farming practices. The research findings have the potential to inform policymakers, farmers, and stakeholders, enabling them to make informed decisions regarding the adoption and integration of indoor smart gardens into their agricultural systems.

Application of smart technologies in modern agriculture

Smart agriculture has transformed from being a mere technology for improving human life to becoming a necessity, if not an obligation. This transformation is driven by the pressing need to meet the ever-increasing global food demand, which continues to multiply at an alarming rate (Bhuvaneshwari, Priyanka, 2021). The Earth's water resources are facing significant challenges due to population growth, rapid urbanization, and the impacts of climate change. To address this issue, the implementation of wireless networks of soil-moisture sensors can play a crucial role in monitoring soil water content. This approach enables highly efficient utilization of water resources, ensuring their effective management and conservation (Abbas et al., 2014).

The application of smart technologies in modern agriculture has revolutionized the way we cultivate crops and raise livestock. The collective advancements in agriculture, often referred to as "Precision Agriculture," hold immense potential for increasing productivity, minimizing resource wastage,

and fostering sustainable farming practices. One exciting innovation within this field is the concept of an indoor smart garden.

Namely, indoor smart gardens are a testament to the evolving landscape of agriculture. These systems leverage various smart technologies to cultivate plants indoors, regardless of external environmental conditions. Let's delve into the key aspects of indoor smart gardens and their role in modern agriculture. These gardens exemplify the innovative application of smart technologies in agriculture. These systems provide a platform for efficient, year-round cultivation with minimal environmental impact. As technology continues to advance, we can expect Indoor Smart Gardens to play an increasingly pivotal role in urban farming, local food production, and sustainable agriculture practices. Key components of indoor smart gardens:

- **Sensors:** indoor smart gardens are equipped with a variety of sensors that continuously monitor and collect data on crucial environmental conditions. These sensors measure parameters such as temperature, humidity, light levels, and soil moisture, providing valuable insights for efficient garden management. This data is crucial for ensuring optimal growing conditions. Advancements in technology are facilitating the retrofitting of existing machines with automation, giving rise to the emerging field of Internet of Things (IoT) (Kuppusamy, 2016).
- **Automation:** automatic garden monitoring and control involve the continuous, autonomous monitoring of all parameters without the need for human intervention (Ramya et al., 2021). Automation is a core element of these gardens. Based on data from the sensors, automated systems can control lighting, watering, and nutrient distribution, ensuring that plants receive the right care at the right time.
- **LED grow lights:** in the current era of mechanization, it is difficult to conceive of any activity that does not rely on technology (Muhtasim et al., 2018). To compensate for the absence of natural sunlight, indoor smart gardens use advanced LED grow lights, which can be customized to mimic the spectrum of natural sunlight. This boosts plant growth and helps maintain a steady supply of fresh produce year-round.

Indoor smart gardens function by utilizing a network of sensors and automated systems within a controlled environment. This setup enables precise monitoring and adjustment of variables such as humidity, light, temperature

and soil moisture. LED grow lights replicate natural sunlight, hydroponic or aeroponic systems provide optimal nutrient delivery, and automation ensures timely watering and care, facilitating year-round, resource-efficient, and climate-resilient cultivation, while minimizing pesticide use and offering educational opportunities.

Review of the leading smart garden brand

In the pursuit of greater resilience and a commitment to resource conservation, individuals are showing an increased inclination towards cultivating their own food. However, they often lack the necessary gardening expertise and education in water conservation practices (Penzenstadler et al., 2018). While farming and gardening have seen continuous improvements through the integration of computers and electronic devices over the years, the term “smart garden” typically pertains to compact indoor systems that employ diverse methods to signal users when it’s time to supplement nutrients (<https://www.pcmag.com>).

If one desires to cultivate herbs in a domestic setting or seeks to infuse vitality and vibrancy into their workspace or living area, Click & Grow emerges as the preeminent solution for smart indoor gardens. For those lacking innate botanical acumen, the endeavor of home cultivation may remain unexplored. However, Click & Grow, as the frontrunner in the realm of smart gardens, empowers individuals to engage in indoor plant cultivation through its streamlined installation process and low-maintenance garden systems. Exhibiting commendable proficiency in facilitating the growth of edible herbs, fruits, vegetables, as well as aesthetically pleasing ornamental plants and flowers, Click & Grow excels in simplifying gardening practices while ensuring optimal efficiency (<https://www.takealot.com>).

The act of growing herbs within the confines of one’s abode not only enhances the convenience of meal preparation but also facilitates the consumption of organically nurtured produce free from pesticides and toxic substances, thereby imbuing each culinary experience with self-nurtured nutrients. Nevertheless, the benefits of owning an indoor garden extend beyond the consumption of personally grown produce. While contemporary urban landscapes predominantly consist of concrete edifices, the splendor of nature remains unparalleled. When seeking respite from urban enclaves, individuals rarely seek solace in another urban environment, as the presence of nature constitutes an

essential element of the human experience. Herbs and plants, among other organic entities, offer profound emotional, mental, and spiritual benefits merely through their presence and interaction.

For those with an inherent agricultural inclination or embarking on their maiden foray into home farming, Click & Grow provides an unparalleled opportunity to sow seeds and reap the rewards firsthand. The rapid growth and the immersive experience of the entire process prove astonishing. Distinctive to these smart gardens is their remarkable low-maintenance nature. Merely setting up the system, plugging it in, and periodically monitoring water levels suffices. As the plants approach the overhead LED light, the primary task entails adjusting the distance between the light source and the plant by adding suitable attachments. Commence your journey into indoor gardening today, and revel in a more invigorating ambiance within the confines of your home or office.

Click & Grow offers a diverse selection of smart soil pods and smart indoor gardens, ranging from modest 3-pot systems to expansive 51-pot arrangements. From strawberries and tomatoes to basil and beyond, the possibilities for kitchen-based cultivation are virtually boundless with Click & Grow at one's disposal (<https://www.clickandgrow.com>).

The integration of aerogarden: a smart indoor garden revolutionizing home plant cultivation

With the evolution of digital technology, contemporary society is becoming increasingly knowledgeable and interconnected, with interactions occurring among humans, objects, and networks (Woo, Suh, 2021). If one is already acquainted with the seamless integration of the iPhone into daily life, they are undoubtedly aware of the heightened efficiency and enhanced experiences it brings to both work and leisure activities. The iPhone empowers users with control over calendars, communications, and overall connectivity. However, despite its remarkable capabilities, one domain that remains beyond the iPhone's reach is the autonomous cultivation of fresh produce. Enter AeroGarden, the smart indoor garden engineered to bridge this gap and revolutionize home plant cultivation.

For those harboring a desire to embark on home gardening endeavors but exhibiting hesitancy in testing their green thumb, AeroGarden seamlessly assimilates into one's everyday routine, much like the iPhone. Functioning as a low maintenance garden, AeroGarden shoulders the burdensome tasks

associated with home cultivation, liberating individuals from the arduous responsibilities (<https://www.aerogarden.com>).

In a manner befitting the iPhone's classification as a smartphone, AeroGarden assumes the role of a smart garden. Consequently, its operation entails minimal effort on the part of the user. Merely setting up the system initiates its enchanting capabilities. Ponder a world devoid of your iPhone's presence. To make a phone call, one would need to journey to the abode of a friend or family member and request the use of their device. A similar analogy can be drawn between AeroGarden and the local grocery store. While procuring fresh produce, including herbs and vegetables, from supermarkets has become second nature, envision the convenience of strolling over to your indoor garden and harvesting produce of your own creation. AeroGarden empowers individuals to cultivate vegetables within the confines of their homes, enabling the growth of salad essentials or the introduction of aesthetically pleasing plants to enhance their living spaces. The icing on the cake? Unlike traditional soil-based methods that necessitate weeks of anticipation, AeroGarden accelerates the growth process, yielding homegrown goodness five times faster.

Analogous to the iPhone's extended battery life that outlasts most individuals' social stamina, AeroGarden emerges as the smart indoor garden that packs a mighty punch in plant cultivation. Nevertheless, it is imperative to dispel any misconceptions. This indoor garden does not rely on batteries for operation; instead, it adopts a straightforward plug-in and setup configuration. AeroGarden nurtures plants by providing an optimal growing environment where their roots are exposed to a combination of air and water (<https://www.amazon.com/AeroGarden-901100-1200-Harvest-Black/>). This symbiotic relationship ensures an ideal nutrient balance, expediting the growth trajectory. The installation process merely involves inserting the plant pods, adding water and the provided plant food, switching on the system, and relinquishing control as the automated marvel takes charge, allowing users to unwind and indulge in relaxation.

Distinguished from its counterparts in the realm of smart indoor gardens, AeroGarden harnesses the full spectrum of plant-growing light to expedite the sprouting process. However, thanks to its fully automated system, users need not burden themselves with the intricacies of the scientific mechanisms at play.

For individuals harboring aspirations to cultivate vegetables, plants, or any other form of produce within the confines of their homes, AeroGarden emerg-

es as the supercharged smart garden solution, redefining the parameters of home plant cultivation.

Contribution of indoor smart gardens to sustainable agricultural development

Home gardening is an increasingly important trend driven by growing environmental consciousness in society. The use of smart sensors with wireless communication capabilities offers cost-effective solutions for real-time management systems in home gardening (Olawepo et al., 2020). Indeed, home gardening has emerged as a significant trend that reflects society's increasing environmental awareness. By leveraging efficient wireless communication through smart sensors, cost-effective solutions for real-time home gardening management systems can be achieved. Indoor smart gardens, an innovative application of precision agriculture and technology, offer significant contributions to the advancement of sustainable agricultural development. From a scientific standpoint, the following points emphasize their role (Mihailović et al., 2023):

- **Resource efficiency:** indoor smart gardens epitomize resource efficiency through precision agriculture. These systems utilize a suite of sensors and automation to fine-tune the conditions in which plants grow. By delivering the exact amount of water, nutrients, and light required, they minimize resource waste. This precision also leads to higher crop yields and quality, maximizing the efficient use of resources while reducing the need for excessive irrigation and fertilization.
- **Year-round cultivation:** traditional agriculture often faces seasonal limitations due to weather conditions. Indoor smart gardens, however, operate independent of external factors, allowing for uninterrupted crop cultivation throughout the year. This year-round production can significantly bolster food security by ensuring a continuous supply of fresh, locally grown produce. Moreover, it reduces the need for expanding farmland, which can lead to deforestation and habitat destruction.
- **Climate resilience:** as the world faces the challenges of a changing climate, indoor smart gardens offer a degree of resilience. By providing a controlled environment, these gardens can shield crops from extreme weather events, temperature fluctuations, and shifting precipitation patterns. This resilience is vital for maintaining stable food production in the face of unpredictable climate conditions.

- Reduction of pesticide use: the precise monitoring and early detection capabilities of indoor smart gardens empower growers to detect and address pests and diseases in a targeted manner. As a result, the reliance on chemical pesticides, which can have detrimental environmental impacts, is reduced. The diminished reliance on pesticides promotes healthier ecosystems and minimizes chemical residues in the harvested produce, enhancing food safety.
- Local food production: indoor smart gardens are well-suited for urban and localized food production. By bringing agriculture closer to consumers, indoor smart gardens help to minimize the carbon footprint associated with transporting food over long distances. This aligns with sustainable agricultural principles, emphasizing the importance of locally sourced products, which can support regional economies and reduce emissions from food transportation.
- Educational opportunities: indoor smart gardens serve as valuable educational tools. They engage individuals in hands-on experiences related to agriculture and horticulture, fostering a deeper understanding of plant growth and ecosystem dynamics. This education encourages more people to become involved in sustainable food production and promotes the adoption of eco-friendly practices. Additionally, these gardens can be integrated into educational institutions, further strengthening the knowledge base on sustainable agriculture.

In summary, indoor smart gardens offer multifaceted contributions to sustainable agricultural development. Their resource-efficient nature, year-round cultivation capabilities, climate resilience, reduced pesticide use, promotion of local food production, and educational potential collectively make them a powerful asset in addressing the challenges of modern agriculture while promoting environmental sustainability.

Conclusions

The indoor smart garden is not merely a technological innovation but a transformative force in agriculture, with far-reaching implications for sustainable development. Its multifaceted contributions, from resource efficiency and year-round cultivation to climate resilience and reduced pesticide usage, underscore its vital role in mitigating the environmental impact of traditional farming practices.

By promoting local food production and serving as an educational tool, it bridges the gap between consumers and producers, fostering community resilience and fostering a deeper understanding of the food production process. In an era marked by climate uncertainty and growing global populations, the indoor smart garden emerges as a crucial solution for ensuring food security and environmental sustainability. As we advance further into the 21st century, this technology stands as a beacon of hope, guiding us toward a more responsible, resilient, and sustainable future in agriculture.

Literature

1. Abbas, A. H., Mohammed, M. M., Ahmed, G. M., Ahmed, E. A., & Seoud, R. A. A. A. (2014, April). Smart watering system for gardens using wireless sensor networks. In *2014 International Conference on Engineering and Technology (ICET)*, IEEE, pp. 1-5.
2. Al-Omary, A., AlSabbagh, H. M., & Al-Rizzo, H. (2018). Cloud based IoT for smart garden watering system using Arduino Uno. <https://digital-library.theiet.org/content/conferences/10.1049/cp.2018.1401>
3. Bhuvanewari, P., Priyanka MG. (2021). Smart indoor vertical farming monitoring using IoT. *Journal of Contemporary Issues in Business and Government*, 27(3), pp. 1741-1753.
4. Hadi, M. S., Nugraha, P. A., Wirawan, I. M., Zaeni, I. A. E., Mizar, M. A., & Irvan, M. (2020, September). Iot based smart garden irrigation system. In *2020 4th International Conference on Vocational Education and Training (ICOVET)*, IEEE, pp. 361-365.
5. Kuppusamy, P. (2016). Smart home automation using sensors and internet of things. *Asian Journal Of Research In Social Sciences And Humanities*, 6(8), pp. 2642-2649.
6. Mihailović, B., Radosavljević, K., & Popović, V. (2023). The role of indoor smart gardens in the development of smart agriculture in urban areas. *Economic of Agriculture*, 70(2), pp. 453-468.
7. Muhtasim, M. A., Fariha, S. R., & Or nab, A. M. (2018, September). Smart garden automated and real time plant watering and lighting system with security features. In *2018 International Conference on Computing, Power and Communication Technologies (GUCON)*, IEEE, pp. 676-679.

8. Min, B., & Park, S. J. (2018). A smart indoor gardening system using IoT technology. In *Advances in Computer Science and Ubiquitous Computing: CSA-CUTE 17*, Springer Singapore, pp. 683-687.
9. Olawepo, S., Adebisi, A., Adebisi, M., & Okesola, O. (2020, March). An Overview of Smart Garden Automation. In *2020 International Conference in Mathematics, Computer Engineering and Computer Science (IC-MCECS)*, IEEE, pp. 1-6.
10. Penzenstadler, B., Khakurel, J., Plojo, C. J., Sanchez, M., Marin, R., & Tran, L. (2018). Resilient smart gardens—Exploration of a blueprint. *Sustainability*, 10(8), 2654.
11. Ramya, K. C., Abishek JS, and Arundhathy TS. (2021, May). Smart garden monitoring and control system with sensor technology. In *2021 3rd International Conference on Signal Processing and Communication (ICPSC)*, IEEE, pp. 93-97.
12. Woo, K. S., & Suh, J. H. (2021). Study on the Current Status of Smart Garden. *Journal of the Korean Institute of Landscape Architecture*, 49(2), pp. 51-60.
13. <https://www.takealot.com/click-grow-smart-garden-3-indoor-gardening-kit-white/PLID52219885> Accessed on 15/09/2023.
14. <https://www.pcmag.com/encyclopedia/term/smart-garden> Accessed on 15/09/2023
15. <https://www.clickandgrow.com/products/the-smart-garden-3> Accessed on 15/09/2023
16. <https://www.aerogarden.com/> Accessed on 04/10/2023
17. <https://www.amazon.com/AeroGarden-901100-1200-Harvest-Black/dp/B07CKK8Z78> Accessed on 04/10/2023