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Development of a Novel Adaptive Geo-Environmental Control System Based on DLI, PAR, and AI-Driven Spatial Analysis for Resource-Efficient Agriculture in Controlled Environments

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Abstract

Controlled-environment agriculture (CEA) is a strategic approach for addressing global challenges related to water scarcity and resource optimization. Since agriculture accounts for approximately 70% of global freshwater withdrawals, adaptive environmental management systems are essential to improve resource efficiency while maintaining optimal growth conditions. This study presents a novel Adaptive Geo-Environmental Control System integrating environmental sensing, Daily Light Integral (DLI), Photosynthetically Active Radiation (PAR), and Artificial Intelligence (AI)-driven spatial analysis to enhance agricultural resource efficiency within controlled cultivation environments. The developed framework combines soil moisture, temperature, humidity, and light monitoring to generate adaptive environmental characterization and intelligent cultivation recommendations. Environmental data are processed using AI-assisted analytical mechanisms to support predictive environmental evaluation and resource allocation optimization. The architecture incorporates geo-environmental monitoring to dynamically evaluate cultivation conditions and support precision agriculture practices aimed at reducing resource consumption. DLI and PAR integration further enhance plant-light management strategies. System development, prototype refinement, and testing procedures were conducted through collaborative research environments involving King Abdulaziz University, King Saud University, and King Abdulaziz City for Science and Technology (KACST). Preliminary prototype implementation demonstrated operational feasibility under controlled testing conditions. Experimental observations indicated an estimated improvement ranging from 40% to 60% in reducing inefficient resource utilization compared to conventional monitoring approaches, supporting enhanced environmental control. The proposed framework contributes toward sustainable precision agriculture by integrating environmental sensing, adaptive control, and intelligent spatial analytical capabilities into a unified platform.

Keywords
Precision Agriculture, Controlled Environment Agriculture, Artificial Intelligence, DLI, PAR.

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Biographies

Jenan Mohammed Al-Dossary is a preparatory engineering student at the Faculty of Engineering, King Abdulaziz University, Jeddah, Saudi Arabia, with an academic ambition to specialize in Nuclear Engineering: Medical Physics. She is a distinguished member of the "Wa'ad Track" for talent recruitment and an active student innovator and researcher who frequently represents talent in international scientific exhibitions. Her research interests lie in Artificial Intelligence (AI), Internet of Things (IoT), and advanced environmental monitoring systems. She has received notable recognition for her work, including a Gold Medal at ITEX 2024, a Silver Medal at ITEX 2025 in Malaysia, a Bronze Medal at GCGC, and third place at the Riyadh Hackathon. Additionally, she is a co-founder and supervisor of the Motqaneen program, which supports and mentors students participating in international exhibitions.

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