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GEOSPATIAL AI FOR LAND USE CLASSIFICATION AND SUSTAINABLE AGRICULTURAL ZONING

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Geospatial AI for Land Use Classification and Sustainable Agricultural Zoning

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Abstract

This book chapter explores the transformative role of geospatial artificial intelligence (AI) in agricultural land zoning, with a focus on balancing economic development and environmental sustainability. As global demands for food production intensify, sustainable land management practices become crucial to mitigating ecological degradation and promoting long-term agricultural productivity. The integration of AI-driven methodologies, particularly machine learning and deep learning, with geospatial data sources such as satellite imagery and remote sensing technologies, offers unprecedented accuracy in land use classification, resource allocation, and land suitability prediction. By incorporating environmental factors like soil health, water availability, and climate projections, AI models facilitate the identification of optimal agricultural zones while minimizing risks of land degradation. Furthermore, the chapter discusses the socio-economic implications of zoning, emphasizing the need for policies that support both agricultural productivity and ecosystem preservation. The potential of AI to address key challenges in land use planning, such as urban encroachment and climate change impacts, is also examined through case studies from diverse geographical contexts. This research highlights the critical intersection of technology, policy, and environmental stewardship in shaping sustainable agricultural futures.

Keywords: Geospatial AI, Agricultural Zoning, Land Suitability, Environmental Sustainability, Land Degradation, Machine Learning.

Introduction

The challenges associated with agricultural land zoning have grown increasingly complex in recent years, driven by factors such as global population growth, climate change, and urban expansion [1]. As the global demand for food continues to rise, there is a pressing need to allocate land efficiently to ensure both sustainable agricultural production and environmental protection [2]. Traditional land-use planning methods, while valuable, are often insufficient in addressing the dynamic and multifaceted nature of modern agricultural systems [3]. Advances in geospatial technologies, coupled with artificial intelligence (AI), offer promising solutions to overcome these limitations. AI's ability to analyze vast datasets and generate actionable insights can significantly enhance land-use classification, agricultural zoning, and resource management [4]. This chapter explores the role of AI in agricultural land zoning, focusing on how AI-powered techniques can improve land suitability assessments, optimize land allocation, and address critical challenges such as land degradation and climate change impacts [5].

Geospatial data, including satellite imagery, remote sensing, and geographic information systems (GIS), has become an essential component of land-use planning and management [6]. AI-driven techniques, particularly machine learning and deep learning models, have the capability to process and analyze these complex datasets with greater accuracy and efficiency than traditional methods [7]. For instance, convolutional neural networks (CNNs) have proven particularly effective in classifying land use types from satellite imagery, offering the ability to identify agricultural zones, forests, urban areas, and other land types with remarkable precision [8]. The integration of such AI algorithms with geospatial data enables a more comprehensive understanding of land suitability, considering factors like soil quality, water availability, topography, and climate conditions [9]. This data-driven approach not only improves the accuracy of zoning decisions but also allows for real-time monitoring of land use changes, providing critical insights for long-term land management [10].

Sustainable agricultural zoning is at the heart of the land-use planning process, aiming to allocate land in a way that maximizes agricultural productivity while minimizing environmental impacts [11]. Traditional zoning practices often fail to account for the complexities of modern agricultural systems, where land use is constantly changing due to factors like climate variability, market demand, and technological advancements [12]. By incorporating AI into the zoning process, land managers can create more adaptive and dynamic zoning strategies [13]. AI models can predict future land use changes based on historical data, climate projections, and socio-economic factors, ensuring that land allocation decisions are future-proofed against shifts in both environmental conditions and market trends [14]. Furthermore, AI’s ability to model various "what-if" scenarios allows decision-makers to test different zoning strategies and their potential outcomes, enabling more informed and resilient land-use policies [15].