AI Technology in Cultivated Land Protection

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Application and research of artificial intelligence (AI) in intelligent agricultural systems can provide valuable insights for cultivated land management. While the integration of AI with cultivated land protection holds immense potential, challenges such as data privacy concerns, the need for extensive databases, and the adoption of AI by farmers, particularly in developing regions, must be addressed.

Keywords: AI technology ; cultivated land ; food security ; ecological security ; retention responsibility ; compensation for cultivated land protection

1. Introduction

With the acceleration of urbanization and the continuous growth of the population, China's cultivated land resources are facing an increasingly tense situation [1]. Traditional cultivated land management methods are becoming increasingly inadequate in the current technological and economic contexts. Considering this, the application and research of artificial intelligence (AI) in intelligent agricultural systems can provide valuable insights for cultivated land management.

AI has proven its potential in optimizing resource allocation, crop monitoring, and decision-making processes in agriculture. By harnessing the power of AI, farmers can make more informed choices, leading to increased crop yields and reduced resource wastage. This interdisciplinary approach not only enhances productivity but also contributes to the conservation of valuable cultivated land resources, ultimately benefiting farmers and the nation as a whole.

Historically, China's responsibilities and compensation mechanisms for cultivated land preservation have primarily focused on safeguarding the fundamental rights of farmers, ensuring they possess sufficient land for agricultural production [2]. However, with the evolution of the economy and the advent of technologies such as AI, which can be applied to aspects such as land optimization and crop forecasting, there is a potential to reshape conventional land management and allocation methodologies [3]. Such advancements might aid in the more efficient and scientific utilization of land, reduce waste, and enhance yield outputs.

At present, the applications of AI in agriculture encompass but are not limited to soil quality detection, climate forecasting, pest and disease detection and prevention, and crop-planting recommendations. These technological interventions offer substantial assistance in addressing China's current cultivated land dilemmas: strategies optimized through AI can achieve higher yields on limited land; AI-driven weather predictions enable farmers to prepare in advance, reducing weather-induced losses; and soil testing facilitates more rational land resource allocation and utilization.

Nevertheless, relying solely on technology will not resolve all challenges, and striking a balance between technology and traditional land management [4], ensuring not only higher outputs but also safeguarding the interests of farmers and ensuring the sustainability of the ecosystem and environment, presents a formidable task [5].

2. Research on Cultivated Land Resource Security

In recent years, numerous scholars have conducted research on the security of cultivated land resources in China, drawing conclusions on the main issues it faces. These include a reduction in the quantity of cultivated land [6], the degradation of its quality [3], an increase in ecological risks [7][8], a decrease in spatial stability [6], and poor enthusiasm for cultivated land protection [9].

First, there has been a rapid loss of high-quality cultivated land. According to surveys, in the past decade, cultivated land has decreased by 113 million mu (approximately 7.53 million hectares), with the lost production capacity being 1.53 times higher than the national average [6]. Second, the quality of cultivated land has degraded, and the agricultural ecosystem and the services provided by cultivated land are under constant pressure. In recent years, cultivated land has shifted toward the north and contracted in the south, leading to a 2.6% decrease in the spatial suitability of cultivated land. Additionally, natural constraints have increased by 19.9%, resulting in prominent obstacles for cultivated land. Issues such as soil acidification and thinning of the cultivated layer have become more pronounced, contributing to the degradation of cultivated land quality [3]. Third, the ecological risk associated with cultivated land utilization has increased, and the stability of its spatial distribution has decreased. From 1990 to 2015, there was rapid cultivated land loss in the eastern regions, with most compensatory cultivated land being in the northeast and northwest regions. Among the newly added cultivated land, 73.6% is categorized as moderate- or inferior-quality cultivated land. This indicates an imbalanced distribution of cultivated land quality across different regions. The utilization of this portion of cultivated land for agricultural production has resulted in a 3.47% increase in wind erosion, a 34.42% increase in irrigation water usage, and a 3.11% decrease in natural habitats. Furthermore, the high-intensity utilization of cultivated land has led to an increase in nitrogen and phosphorus emissions. Unsustainable practices such as the overexploitation of groundwater and soil erosion further exacerbate the ecological risks associated with cultivated land utilization. Fourth, there is insufficient motivation for cultivated land protection. Factors such as rising prices of agricultural production inputs and small-scale operations have led to a continuous decrease in farmers' income from grain production. The significant disparity in the marginal outputs between cultivated land and other land uses results in low comparative benefits, which greatly impacts farmers' motivation to protect cultivated land. As a result, there is a lack of drive to protect cultivated land, leading to issues such as nonagricultural development, diversification away from grain production, and the abandonment of cultivated land [10].

3. Research on Cultivated Land Conservation and the Protection Responsibilities of Local Governments in China

Research on the protection of cultivated land by local governments has regularly been a focus of scholars. They have conducted studies on government responsibilities from different perspectives, including issues related to cultivated land protection by local governments in different periods [11], the actions of governments in protecting cultivated land, and the value orientations of local governments in cultivated land protection issues [12]. Studies have revealed that incentivizing government officials to prioritize economic development often results in a skewed distribution of government public expenditures, with a focus on economic growth rather than investment in public services and human capital [13]. Local governments are often tempted to prioritize economic development instead of protecting cultivated land [5]. As a result, they may prioritize increasing the allocation of construction land in urban planning, disregarding the quality of cultivated land when balancing land occupation and compensation. They may focus solely on supplementing the quantity of cultivated land without considering the potential consequences. Additionally, tendencies to make arbitrary changes to land use can create unhealthy mechanisms where "wealth is generated from land". A series of actions, such as the illegal occupation and construction of the Annan Wetland Environmental Theme Park by the Water Bureau of Daxing District, Beijing, and the unauthorized occupation and construction of the Weiliu Wetland Park by the Construction Management Bureau of the Weihe River Ecological Zone in Weicheng District, Xianyang City, Shaanxi Province, have caused damage to cultivated land.

An equitable determination of the responsibilities and obligations among local governments regarding cultivated land protection is still in the exploratory stage, and the corresponding regional compensation mechanisms need further improvement. The imbalance in responsibility for cultivated land protection and the lack of rigor in implementing cultivated land protection measures contribute to a mutually reinforcing detrimental cycle that perpetually exacerbates the cultivated land protection crisis [14]. The inequitable protection of cultivated land across different regions manifests in the discrepancy between how certain local governments exploit information asymmetry shared with the central government and the costs associated with central government supervision. This distortion of the cultivated land protection system leads to attempts to transfer responsibilities and obligations to other regions. Local governments that prioritize cultivated land protection make significant contributions to food security and ecological stability, incurring high local costs. However, certain local governments benefit from the food security and ecological advantages resulting from cultivated land protection policies implemented by other regions while shouldering comparatively lower local costs [15]. Economic compensation has become an important means and guarantee to achieve fairness. It is an inevitable approach to addressing unequal distributions of regional cultivated land protection responsibilities. For regions unable to fulfill their obligations to ensure food security and ecological stability, appropriate economic compensation should be provided based on their circumstances. This will promote the enhancement of food security and the value of ecological services on cultivated land, thereby highlighting the principle of equal rights and responsibilities among different regions. This approach will foster the sustainable development of regions burdened by excessive cultivated land protection tasks.

4. Research and Application of AI Technology in Cultivated Land Protection

Research on AI technology in the agricultural sector highlights substantial global contributions, concentrating on the development of AI algorithms and models to address challenges spanning yield prediction [16], soil fertility analysis [17], water resource management [18], pest control [19], and crop disease detection [20].

First, the practical application of AI-driven analytical methodologies in cultivated land protection underscores the utilization of technologies such as machine learning, big data analytics, and remote sensing [21]. These advancements enable the collection and analysis of extensive agricultural data, facilitating more precise decision making in land management practices [20]. Second, the utilization of AI for yield prediction is explored [19]. Researchers have successfully employed machine-learning algorithms to develop predictive models, estimating crop production based on historical data, climate conditions, soil quality, and other relevant variables. Renowned for their high accuracy, these models serve as valuable tools for farmers and policymakers to optimize crop planning, resource allocation, and market forecasting. Third, another critical domain where AI demonstrates potential is soil fertility analysis [17]. Deep-learning algorithms are applied to analyze large-scale soil data and identify patterns crucial to soil health and nutrient management. This approach assists in determining optimal fertilizer application rates, enhancing soil productivity, and preventing nutrient deficiencies or excesses. Furthermore, AI-based remote-sensing techniques have transformed land management practices, so they can provide real-time, high-resolution monitoring of cultivated areas [22]. Combining satellite imagery with AI algorithms enables the detection of changes in crop growth, allows the identification of areas susceptible to pest infestation or disease outbreaks, and facilitates timely interventions to mitigate potential losses.

While the integration of AI with cultivated land protection holds immense potential, challenges such as data privacy concerns, the need for extensive databases, and the adoption of AI by farmers, particularly in developing regions, must be addressed. In conclusion, significant strides have been made by AI technology in revolutionizing cultivated land protection. Current efforts must focus on overcoming existing challenges to ensure the widespread adoption of AI in agricultural practices.

5. Research on Compensation for Cultivated Land Protection

Research related to compensation for cultivated land protection mainly focuses on aspects such as the compensation basis [23], compensation standards, and compensation models [24][25]. The compensation basis for cultivated land protection includes universal compensation based on food security, compensation based on the comprehensive value of cultivated land (including food security, ecological value, etc.) [23], compensation based on the input cost of cultivated land protection and the development rights price [2], and compensation based on external benefits. However, research that systematically elucidates the relationship between the ecological protection of cultivated land and the loss of development opportunities is lacking and urgently needs to be supplemented. In terms of compensation standards, more mature methods include contingent valuation, replacement cost, equivalent factor, and opportunity cost. The first two methods rely on data surveys and are suitable for small-scale studies, while the latter two are more suitable for large-scale and macro-level research. Compensation models for cultivated land protection include economic compensation, “economic subsidy + technological compensation”, and “economic subsidy + policy support + technological support”. While some scholars have studied the bottom line of cultivated land protection from the perspective of food security or ecological security, research that considers both aspects of security is relatively rare. Furthermore, the contradiction between economic development and cultivated land protection among different provinces has not been resolved, especially in determining the responsibilities for maintaining cultivated land stocks at the provincial level by considering spatial differences in land quality.

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