# The "Five Modernizations"Trend and Governance Countermeasures for China' s Cultivated Land Resource Utilization (Postprint)

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## Abstract

Understanding the trends in cultivated land resource utilization, analyzing governance countermeasures, and exploring regionally appropriate cultivated land use patterns constitute important prerequisites for implementing the new strategy of "strictest cultivated land protection" with Chinese characteristics. Currently, China' s cultivated land resource utilization is facing intensifying problems of "non-agriculturalization," "non-grainization," "fragmentation," "marginalization," and "ecological degradation" (hereinafter referred to as the "Five Transformations" ). Based on an assessment of the spatiotemporal dynamics of the "Five Transformations" of China' s cultivated land, this article analyzes the challenges in governing these transformations from perspectives including complex causation, phase characteristics, cognitive differences among responsible entities, and dynamic changes in external factors, and derives corresponding insights, aiming to provide perspectives for accelerating the construction of a Beautiful China characterized by harmonious development between humanity and nature.

## Full Text

## Preamble

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## Abstract

Understanding the trends in cropland resource utilization, analyzing governance countermeasures, and exploring regionally appropriate cropland use patterns are important prerequisites for implementing China' s new strategy of "the strictest cropland protection" with distinctive Chinese characteristics. Currently, China' s cropland resource utilization faces intensifying challenges of "non-agricultural conversion," "non-grain cultivation," "fragmentation," "marginalization," and "ecological degradation" (hereinafter referred to as the "five issues" ). This paper evaluates the spatiotemporal changes of these five issues in China, analyzes the governance challenges from perspectives including complex causation mechanisms, phase characteristics, cognitive differences among responsible parties, and dynamic changes in external factors, and derives corresponding insights. The aim is to provide valuable perspectives for accelerating the construction of a Beautiful China featuring harmonious development between humans and nature.

**Keywords:** cropland health, non-agricultural conversion, non-grain cultivation, fragmentation, marginalization, ecological degradation

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Food security represents a global challenge that concerns the fundamental needs of sustainable human development. As the most basic resource for human survival, cropland is a complex system formed through the interaction of natural elements and human activities, with food production as its core function while also serving living, ecological, and cultural purposes. Cropland constitutes the foundation of food security and provides crucial ecological functions including climate regulation, water purification, and biological control, playing an important role in protecting surface water, food chains, biodiversity, and the atmosphere. Protecting cropland resources requires attention not only to the natural attributes of cropland under multi-layer interactions in vertical space but also to sustainable utilization patterns that do not exceed resource-environment carrying capacity limits, balancing food demand assurance with the stability of farmland and other ecosystems.

China has established "cherishing and rationally utilizing every inch of land, and earnestly protecting cropland" as a fundamental national policy. President Xi Jinping has repeatedly emphasized that "cropland is the lifeline of grain production and the foundation for the sustainable development of the Chinese nation," advocating to "protect cropland like giant pandas," and insisting that "the 1.8 billion mu of cropland must be genuine—farmland must remain farmland and must be high-quality farmland." Driven by multiple favorable factors including land control policies, high-standard farmland construction, grain subsidies, and agricultural tax reductions, China has managed to feed nearly 20% of the world' s population with only 9% of global cropland, achieving a "nineteen-year consecutive increase" in grain production and making significant contributions to the UN Sustainable Development Goals. However, current production increases do not guarantee perpetual high yields. Over the past 40 years, excessive inputs of chemical fertilizers and pesticides, promotion of heavy agricultural machinery, and intensive multi-cropping practices have continuously degraded farmland ecosystems, causing thinning and compaction of the plow layer, soil acidification, reduced organic matter, physiological disorders in crops, and damage to soil fauna and microbial communities. Soil pollution has also frequently caused toxic and harmful substances to exceed safety standards in grain products in some regions. Understanding cropland utilization trends and analyzing governance countermeasures to explore regionally appropriate patterns are essential prerequisites for implementing China' s distinctive "strictest cropland protection" strategy and achieving coordinated control of the three red lines: ecological conservation, permanent basic farmland, and urban development boundaries.

## 1. The "Five Issues" Trend in China' s Cropland Resource Utilization

Cropland systems are semi-natural ecosystems that can be artificially enhanced, possessing specific structural and functional characteristics in different geographical spaces and forming stable ecological equilibrium states through long-term natural evolution. Human activities are the dominant factor driving functional state changes or stable phase transitions in cropland systems, directly or indirectly affecting cropland production, living, and ecological functions. Based on long-term research in land science, the structural changes threatening China' s cropland resource security can be summarized as five phenomena: "non-agricultural conversion," "non-grain cultivation," "fragmentation," "marginalization," and "ecological degradation." This paper analyzes these five trends in China' s cropland resource utilization and their governance challenges.

### 1.1 Non-Agricultural Conversion Trend: Cropland area decreased by over 5%, with a "increase in the north, decrease in the south" pattern increasing food security risks and exacerbating productivity losses

Cropland "non-agricultural conversion" refers to the process of occupying cropland for non-agricultural activities such as urban, residential, industrial, and transportation construction, afforestation, lake creation for scenic purposes, and expansion of protected natural areas. According to the main data bulletins of the Second and Third National Land Surveys, China' s total cropland area was 1.9179 billion mu in 2019, a decrease of 112.9 million mu compared to 2009. Comparative analysis using GlobalLand30 data for 2000, 2010, and 2020 [Figure 1: see original paper] shows that during 2000–2010, cropland converted to construction land accounted for 21.86% of total cropland loss, with higher proportions concentrated in the North China Plain and middle-lower Yangtze Plain. During 2010–2020, this proportion increased to 38.47%, exceeding 70% in Shanghai, Beijing, Tianjin, Henan, and Shandong, with particularly prominent increases in the southeastern hilly regions and western irrigated agricultural areas [Figure 1d: see original paper]. While the cropland requisition-compensation balance policy has played an important role in controlling construction land encroachment on cropland, some regions have not achieved quantitative balance (for example, during 2010–2020, all provinces in the North China Plain failed to achieve cropland quantity balance) [Figure 1a: see original paper]. Moreover, due to the lack of control policies on cropland conversion to ecological land during this period, returning cropland to forest and grassland became the main form of cropland loss in southern hilly and western irrigated areas.

Spatially, China' s cropland exhibits a "increase in the north, decrease in the south" pattern [Figure 1b: see original paper], shifting from eastern plains and southeastern coastal provinces with rich agricultural climate resources and favorable farming conditions to northern regions with poorer hydrothermal conditions. This redistribution has reversed China' s traditional "south grain to north" pattern to "north grain to south," exacerbating water resource pressure in the north, causing overutilization of local cropland resources, and increasing uncertainty in food security. The spatial redistribution has also intensified cropland productivity losses [Figure 1c: see original paper]. Research indicates that during 2010–2020, China's total cropland productivity decreased by 31.2546 million tons, 3.25 times that of 2000–2010. The phenomenon of "occupying good land and compensating with poor land" is widespread, with compensated cropland averaging only 62.6% of the potential yield of lost cropland. Furthermore, compensated cropland from 2000–2010 had a low retention rate as cropland by 2020, with nearly half of provinces having less than 50% retention.

### 1.2 Non-Grain Cultivation Trend: Sharply increasing since 2000, higher in the south than north, higher in mountainous areas than plains, and higher in non-major grain-producing areas than major grain-producing areas

Cropland "non-grain cultivation" refers to the conversion of cropland originally used for grain crops to non-grain crops, aquaculture, or leisure agriculture. Typical manifestations include "pond-ization,""orchard-ization,""seedling-ization,"and "tea plantation-ization." Under given constraints, rational choices by cropland management entities to maximize returns can increase income, reduce abandonment, and promote scaled operations. However, without refined regulation based on specific conditions, non-grain cultivation can easily destroy the plow layer, erode fundamental soil productivity, and cause farmland ecosystem degradation, endangering the material foundation of national food security.

In recent years, government promotion of grain-scale production has seen the profit-seeking nature of "industrial and commercial capital" entering agriculture, combined with high land rents in cropland transfer and lagging grain subsidies, exacerbating the spread of non-grain cultivation. A survey from December 2013 to March 2014 revealed that the non-grain rate of transferred cropland in eastern China reached 72.41% in the form of "industrial and commercial capital," with 32.69% and 57.35% in central and western regions respectively. Data from China' s Statistical Yearbooks (1980–2020) show that the non-grain rate has increased sharply since 2000, being higher in the south than north, higher in mountainous areas than plains, and higher in non-major grain-producing areas than major grain-producing areas. Eastern provinces including Shanghai, Zhejiang, Fujian, Guangdong, and Hainan have long experienced serious non-grain cultivation trends, with non-grain years exceeding 50% being common. Southwestern provinces including Guangxi, Sichuan, Yunnan, Guizhou, and Chongqing have seen continuously increasing non-grain cultivation since 2000, reaching historical peaks in 2020.

### 1.3 Fragmentation Trend: Lower in the north and higher in the south, with continuous cropland in the three major plains being highly fragmented; fragmentation has decreased since 2014

Cropland "fragmentation" refers to a household managing multiple cropland plots that "are interspersed, scattered, and disorderly due to human or natural conditions, making it difficult to achieve contiguous, concentrated, and scaled operations." The impacts of fragmentation vary with regional natural-economic-social characteristics. Some studies suggest that in specific areas with abundant surplus labor and limited cropland area, fragmentation facilitates diversified planting and risk dispersion, maintaining or increasing net income. However, with agricultural mechanization and evolving management models, most scholars argue that fragmentation hinders new agricultural technology adoption, intensifies farmer conflicts over field ridges, impedes scaled operations, and negatively affects cropland use efficiency, agricultural input-output ratios, and multiple cropping indices.

Based on upscaled calculations from the Second National Land Survey data [Figure 2: see original paper], China' s fragmentation pattern shows lower levels in the north and higher in the south, with fragmented plots of low contiguity mainly distributed in mountainous and hilly areas. The North China Plain, Guanzhong Plain, Chengdu Plain, and Jiangsu and Anhui in the middle-lower Yangtze Plain exhibit low mean patch area-high spatial density clustering patterns, indicating high potential for scaled operations but fragmented utilization due to artificial division and diversified planting. Wang and Xu demonstrated that over 70% of counties in China showed significant fragmentation trends in cropland landscape patterns during 2004–2013. During 2014–2020, under the influence of farmland transfer policies, fragmentation decreased, most notably in Guangdong and Guangxi.

### 1.4 Marginalization Trend: Intensifying since 2015, higher in mountainous areas than plains, migrating westward from the middle-lower Yangtze region, with cropland use intensity below 60% in over half of counties

Land "marginalization" refers to the process where the economic benefits of a land use state continuously decrease under the combined effects of natural, social, political, economic, and environmental factors. The essence of cropland marginalization is the "rent disappearance" phenomenon under current use, where agricultural net returns are "less than or equal to zero" (called "low-end marginalization" ) or lower than alternative uses (called "high-end marginalization" ), leading to conversion to more extensive uses or even abandonment. Indicative metrics for cropland marginalization typically include "significant decline in cultivation net returns," "reduction in crop sown area," and "decreased intensity."

Based on the "National Agricultural Product Cost-Benefit Compilation" (2001–2018), since 2015, early indica rice, wheat, and corn cultivation in most provinces have shown significant low-end marginalization characteristics, with dramatic income declines compared to pre-2010 levels. Marginalization is more severe in mountainous provinces, primarily because agricultural mechanization is difficult to develop in mountainous areas, resulting in much higher labor requirements per mu than in plains, with significantly lower labor productivity. According to Zhang et al.' s meta-analysis of 165 county-level abandonment cases across 20+ provinces from 1992–2017, China' s abandonment cases show a counterclockwise 90° rotated "T" pattern spatially. After 2010, the focus of abandonment research shifted westward from the middle-lower Yangtze region to a north-south banded distribution from southeastern Gansu to western Guizhou and northern Yunnan, with continuously increasing abandonment cases and rates. Ye et al.' s county-level study on cropland use intensity in China revealed that 73.1% of counties had average cropland use intensity below 0.7, and 53.6% below 0.6, with spatial clustering of hidden abandonment characteristics in Liaoning, Inner Mongolia, Shanxi, Hunan, Anhui, Sichuan, Yunnan, Chongqing, Hainan, and Xinjiang. High-quality but low-intensity has become the core contradiction in cropland use (covering 52.98% of counties). Additionally, the lack of control over "occupying nearby, compensating distant" in cropland requisition-compensation balance policy implementation has exacerbated marginalization. For example, Liu et al. calculated that during 2010–2020, provincial compensated cropland had average cultivation distances 2–7 times that of occupied cropland, while provincial average cultivation distances decreased by 3.82%–63.88% during the same period. This contradiction arises because distant cropland with high cultivation costs is extensively used or abandoned, being classified as other land use types by remote sensing models, masking the "occupying nearby, compensating distant" process and resulting in reduced provincial average cultivation distances.

### 1.5 Ecological Degradation Trend: Severe biological health conditions, fertilizer and pesticide use efficiency still lags far behind developed countries, and control of mercury and cadmium pollution in farmland requires urgent strengthening

Cropland "ecological degradation" refers to the reduction or disappearance of semi-natural habitats due to overexploitation, plot scaling, and excessive hardening of ditches, roads, and channels, combined with heavy chemical inputs and monoculture planting, leading to soil acidification and compaction, intensified heavy metal pollution, agricultural landscape homogenization, and severely reduced biodiversity. Agricultural chemical inputs and heavy metal pollution are important factors influencing ecological degradation.

Based on emergy analysis of FAOSTAT datasets [Figure 3: see original paper], during 1995–2010, China's crop output intensity improvement was accompanied by substantial increases in pesticide and fertilizer input intensity. After 2010, China' s crop production model shifted to "reducing inputs while increasing output," with pesticide input intensity also showing fluctuating decreases. By 2019, China' s crop output intensity only approached the US level in 2000, indicating significant potential for improvement, while pesticide and fertilizer input intensities were 2.32 times and 1.4 times the US 2000 levels, respectively. A meta-analysis of heavy metal (Hg, As, Pb, Cd, Cr, Cu, Zn) content in farmland soils across 121 counties in 29 provinces from 1998–2019 showed that Hg, Pb, and Cd pollution are generally severe, with Cd being the most serious—heavy or severe pollution cases detected in Liaoning, Jiangsu, Jilin, Hubei, Fujian, Guangdong, Sichuan, Jiangxi, Gansu, Shaanxi, Hebei, Guangxi, Xinjiang, and Henan. Temporally, Hg and Cd pollution conditions changed little, while Pb pollution improved somewhat after 2016.

### 1.6 Comprehensive Analysis of the "Five Issues"

Overall, over the past 20 years, China' s cropland non-agricultural conversion, non-grain cultivation, fragmentation, marginalization, and ecological degradation have all shown intensifying trends. Non-agricultural conversion and non-grain cultivation have breached the cropland resource security warning line [Figure 4: see original paper], with non-agricultural conversion being particularly severe in the North China Plain and middle-lower Yangtze Plain, and high non-grain rates prevalent in southern provinces. Fragmentation, marginalization, and ecological degradation have also crossed critical warning lines, with risks of further deterioration. While fragmentation in plain areas has been somewhat controlled, it remains a major constraint on agricultural scaled operations. Marginalization continues to intensify, particularly the explicit and hidden abandonment issues requiring urgent attention. Ecological degradation governance has achieved initial results, but fertilizer and pesticide use efficiency still lags behind developed countries, and monitoring and control of Hg and Cd pollution require strengthening. In the long term, priority should be given to transforming non-agricultural and non-grain trends, further governing fragmentation and marginalization, and preventing ecological degradation from worsening. Additionally, all five issues exhibit varying degrees of westward migration, necessitating proactive prevention and control.

## 2. Challenges in Governance of the "Five Issues"

### 2.1 Complex and Intertwined Causes of the "Five Issues" with Limited Mechanistic Understanding

The causes of the "five issues" are complex, resulting from comprehensive natural-economic-social factors with regional differentiation characteristics. Mechanistic understanding must not implement "one-size-fits-all" control policies.

**(1) Natural factors.** China faces the basic national condition of a large country with small-scale farming, with limited per capita cropland area and poor natural resource endowments. Smallholders remain the absolute mainstay of agricultural operations, accounting for 98% of agricultural households and covering about 70% of national cropland, constrained by climate, terrain, soil properties, and engineering conditions, leading to extensive cultivation of unsuitable land.

**(2) Economic factors.** Urbanization and industrial-commercial capital transfer to agriculture have intensified non-agricultural conversion. Low comparative benefits of grain cultivation, where limited grain areas cannot maintain dignified family livelihoods, are the key driver of non-grain cultivation. Rapid economic growth and industrial upgrading, with declining agricultural proportions, increasing opportunity costs of farming, agricultural labor transfer, and rising agricultural input prices, have intensified non-grain and ecological degradation operations on transferred cropland in plains and pushed marginalization in mountainous areas.

**(3) Social factors.** Weakened labor capacity of older farmer generations, low medical, educational, and living conditions in rural areas, and the reality that farming cannot sustain livelihoods in some regions result in low willingness among the "second farming generation" to continue farming, leading to absence of farming entities and increasing risks of non-grain cultivation and marginalization. Low education levels among farming groups also limit the promotion and application of new agricultural technologies. Meanwhile, inadequate development of agricultural product quality supervision systems and market standardization leads to lack of consumer-side constraints on ecological degradation.

### 2.2 The "Five Issues" Are Systemic Problems with Diverse Forms and Phase Interactions, Complicating Policy Control

The root of the "five issues" lies in the opposition between agricultural management entities and land regulatory bodies regarding expectations of cropland use patterns and output benefits. On one hand, different types of agricultural management entities, aiming to enhance cropland economic benefits, tend toward higher comparative-benefit use patterns under regional natural conditions and capital-technology constraints. On the other hand, different land regulatory bodies impose requirements on cropland use from perspectives of regional development, food security, and resource-ecological health, constraining agricultural management entities' profit-seeking behaviors through administrative regulations. In some regions, this opposition incorporates additional contradictions within agricultural management entities regarding benefit distribution of transferred cropland and environmental safety, and within land regulatory bodies regarding urban development versus cropland protection, becoming more complex.

The "five issues" are systemic problems with multi-phase interactions. Control strategies designed for a single issue may intensify opposition between agricultural management and regulatory entities, pushing one phase to transform into another or even generating new phases. For example, policies like cropland requisition-compensation balance and construction land increase-decrease linkage have effectively controlled non-agricultural conversion, but compensation methods of "occupying nearby, compensating distant" have exacerbated fragmentation and marginalization. Converting forest and grassland to cropland not only damages original ecosystem stability but also demands higher chemical inputs, intensifying ecological degradation. Similarly, farmland transfer policies have effectively improved fragmentation, but scaled operation entities tend to enhance economic returns through non-grain cultivation. Strict control of non-grain cultivation may intensify abandonment in mountainous areas and push plains agricultural entities to increase chemical inputs to boost grain yields.

In summary, governing the "five issues" requires addressing root problems holistically, aiming to resolve opposition between agricultural management and regulatory entities, and fully considering the willingness of agricultural management entities.

### 2.3 Cognitive Differences Among Responsible Parties for the "Five Issues" Lead to Divergent Goals

The "use-endowment-benefit" relationship of cropland resources involves intrinsic linkages and feedback: cropland use behaviors change resource endowment states to support benefit realization; cropland benefits indicate the quality and health of resource endowment, thereby guiding or constraining cropland use behaviors. The "five issues" manifest externally as inappropriate cropland use behaviors while internally damaging resource endowment and affecting farmland ecosystem health. Exploring governance paths requires joint efforts from multiple responsible parties including agriculture, natural resources, ecology-environment, and soil-water conservation to form consensus around the "use-endowment-benefit" cascade process, clarify regional cropland use boundaries, and collaboratively regulate inappropriate behaviors from the source.

Current cropland protection responsibilities are segmented by function, leading to cognitive differences that emphasize local aspects like yield improvement, pollution control, and quality protection over holistic perspectives. These differences result in difficulty coordinating "five issues" governance goals, with shortcomings in policy design and measure specificity, and some issues lacking responsible entities and thus supervision. For example, farmland ecological degradation from long-term monoculture planting. These cognitive differences also cause problems at different levels: some economically underdeveloped regions one-sidedly understand "agricultural structure adjustment," allowing non-grain operations to develop rural economies; some economically developed regions, due to one-sided pursuit of economic development, inadequate institutional construction, and insufficient understanding of the "five issues" hazards, fail to reasonably regulate phenomena such as industrial/mining/urban construction occupying basic farmland, non-grain cultivation on transferred cropland, abandonment, or high chemical inputs.

### 2.4 Dynamic Changes in Natural-Economic-Social Factors Increase Uncertainty in "Five Issues" Governance

The "five issues" process occurs in open farmland ecosystems, where regional evolution mechanisms and governance resilience may be affected by dynamic changes in external natural and economic-social factors, creating great uncertainty for governance.

**(1) Climate factors are the main natural factors increasing uncertainty.** China is a sensitive and significantly affected region of global climate change. Climate change has caused China's average annual surface temperature to rise by 0.26°C per decade during 1951–2021. Since 2012, annual precipitation has been continuously above average, increasing the frequency and intensity of most extreme climate events, negatively affecting crop dry matter accumulation and intensifying agricultural production risks. Without measures, by the late 21st century, maximum declines of China's major crops (wheat, rice, corn) could reach 37%. Climate change alters regional land suitability and resource carrying capacity by changing hydrothermal distribution, exacerbates water supply differences, increases agricultural water demand, and raises agricultural costs and investment needs. These impacts may drive smallholders in different regions to expand economic crop planting, diversify, or seek off-farm work to avoid risks, intensifying "five issues" risks. Climate change impacts on forest and grassland ecosystems may also increase governance difficulty through telecoupling effects. For example, temperature rise-induced soil organic carbon decline and biodiversity loss in forest-grassland ecosystems further increase cropland protection pressure and threaten farmland ecosystem resilience.

**(2) China is in an important stage of economic and social development.** According to the National Bureau of Statistics, the national permanent resident urbanization rate reached 65.22% by the end of 2022, with major grain-producing provinces like Henan, Hebei, Shandong, Anhui, Jiangsu, and Sichuan still having significant urbanization potential, facing continuous challenges of growing construction land demand in the coming period. Meanwhile, income growth and population increase drive diversified dietary structures and grain demand, increasing cropland use pressure. Population aging, agricultural labor outflow, and turbulent international political and economic situations further intensify "five issues" governance challenges.

Therefore, governing the "five issues" must not only address current conditions but also consider impacts of dynamic climate and economic-social factors, reserving flexible response space as much as possible.

## 3. Policy Recommendations

### 3.1 Deepen Cropland System Research and Improve Long-Term Scientific Support for Comprehensive "Five Issues" Governance

Deepen systematic research on "good land, good seeds, and good methods" to provide scientific support for comprehensive "five issues" governance.

**(1) Good land aspect.** Promote research and application of resource carrying capacity, land suitability, and diversified food demand assessments considering dynamic changes in future climate, economic, and social scenarios. Accelerate the formation of a national grain production core area layout with resource endowment advantages, coordinate planning of minimum cropland retention by region, and answer questions such as "what is the upper limit of cropland area a region can support," "which areas are unsuitable for grain but suitable for cash crops," "which areas have high marginalization or ecological degradation that is difficult to reverse and unsuitable for cropland use," and "which areas need fallow rotation and how to implement it." Explore mechanisms and tipping points of how climate, terrain, soil, engineering, use patterns, and soil microorganisms affect regional cropland yield, farmland ecosystem health, and the "five issues," providing theoretical foundations for comprehensive high-standard farmland construction.

**(2) Good seeds aspect.** Construct large-scale biological breeding industry infrastructure and scientific innovation platforms, concentrate efforts on breaking through key crop breeding technologies, encourage and support seed enterprises, improve cooperation models between seed enterprises and research institutions, accelerate breeding industrialization, and promote application of research achievements by popularizing suitable crop breeding results based on regional natural-social-economic conditions and extreme climate risks.

**(3) Good methods aspect.** Encourage and support research exploration centered on sustainable productivity protection of cropland, study sustainable and efficient utilization models for single-season grain cultivation, and research multi-year grain-fruit rotation models beneficial for cropland health maintenance and conservation. Break through key technologies and equipment for cropland resource survey, monitoring, evaluation, prediction, and warning. Promote advanced experiences from agricultural technology extension centers, strengthen cultivation technology training for smallholders, increase financial support and establish assessment standards. Promote high-standard farmland construction to improve cropland use efficiency and disaster resistance, strengthen promotion and application of high-tech solutions like water-saving irrigation, saline-alkali land treatment, and microbial remediation of polluted soils, and break through key technologies for small agricultural machinery suitable for mountainous and hilly areas.

### 3.2 Increase Farmer Grain Cultivation Income, Improve Main Grain Production-Supply-Marketing Chain, and Reduce Farming Risks

**(1) Strengthen agricultural support and protection subsidies.** Fill benefit gaps between grain and cash crops through incentive mechanisms, including establishing regional agricultural carbon sink accounting standards and subsidy standards, prioritizing carbon sink subsidies for grain cropland pilots; establishing carbon tax systems with defined collection entities, tax rates, and subsidy standards, uniformly collecting carbon taxes on chemical fertilizer and pesticide production and subsidizing agricultural departments and management entities practicing conservation tillage.

**(2) Encourage development of villager cooperatives.** Strengthen smallholders' supervisory capacity over scaled operation entities, require participation and profit-sharing by villager cooperatives in requisition-compensation balance, increase-decrease linkage, dry-to-wet conversion, and balance indicator transactions, with corresponding long-term management responsibilities.

**(3) Improve the main grain production-supply-marketing chain.** Reduce grain losses during transportation and sales; standardize agricultural product markets, implement agricultural product health grading, promote open health information and origin traceability, strengthen food safety publicity and education to ensure healthy agricultural products command higher prices.

**(4) Expand main grain policy insurance.** Subsidize farmers' agricultural insurance purchases appropriately to reduce main grain cultivation risks.

### 3.3 Improve Legal Construction, Implement Principal Responsibilities, and Strengthen Regulatory Assessment

**(1) Improve legal and policy construction.** Provide legal and policy guarantees for quantity, quality, and ecological elements involved in cropland protection, strengthen penalties for illegal occupation and pollution damage to cropland. Coordinate and improve requisition-compensation balance, conversion-compensation balance, and increase-decrease linkage policies, set thresholds for contiguous scale and cultivation distance of transferred cropland, carefully transfer construction land, orchard, forest, grassland, and pond surfaces with degradation risks such as water-soil erosion, flooding, or pollution; unify assessment systems and acceptance standards for transferred cropland, clarify later-stage management responsibilities and requirements. Promote establishment of cropland transfer indicator banks at county level to coordinate intra-provincial cropland transfer indicators.

**(2) Gradually restore non-agricultural and non-grain cropland.** Optimize national cropland strategic layout through "south increase, north stability." Establish expert groups to formulate quantitative restoration targets for "restorable cropland" (i.e., current orchards, forests, grasslands, and pond surfaces marked as "immediately restorable" or "engineering-restorable" in the Third National Land Survey). Focus on restoring cropland in southern high-productivity regions and control extensive expansion in northern regions. Establish inter-provincial cropland protection incentive mechanisms, requiring regions unable to meet quantitative restoration targets to pay "high-price"cropland protection compensation fees.

**(3) Improve multi-party principal responsibilities.** Accelerate implementation of the "Field Chief System" and "military order" signing. Strengthen monitoring and assessment of "five issues" remediation, promote a five-level "Field Chief System," map responsibilities at all levels, clarify boundaries, and sign responsibility agreements. Develop comprehensive assessment indicator systems for "Field Chiefs" incorporating "five issues" governance. Integrate existing violation investigation mechanisms from national natural resources supervision and local land law enforcement, and establish and improve rapid verification and early warning monitoring mechanisms for the "five issues" using satellite and low-altitude remote sensing technologies.

### 3.4 Strengthen Publicity and Education to Promote Public Awareness of Cropland Resource Security

**(1) Conduct thematic education around "food security" and "healthy land—healthy food—healthy body."** Link "five issues" governance with public welfare to guide objective public understanding of the "five issues" trends and their hazards, building a mass foundation for cropland resource protection.

**(2) Advocate and implement grain saving and loss reduction actions.** Deepen grain conservation education and public welfare publicity in schools and communities; leverage exemplary roles of government agencies and enterprises, improve dining systems, and establish grain waste monitoring systems.

**(3) Strengthen education on cropland protection laws and favorable national policies for agricultural management entities.** Guide smallholders to understand "five issues" hazards while helping them understand connections between villager cooperatives, various agricultural trusteeship service organizations, agricultural technology extension centers, and their own interests.

## References


1. Godfray H C J, Beddington J R, Crute I R, et al. Food security: The challenge of feeding 9 billion people. *Science*, 2010, 327: 812-818.
2. Foley J A, Ramankutty N, Brauman K A, et al. Solutions for a cultivated planet. *Nature*, 2011, 478: 337-342.
3. Power A G. Ecosystem services and agriculture: Tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 2010, 365: 2959-2971.
4. Zhang X Y, Sui Y Y, Song C Y. Degradation process of arable mollisols. *Soils and Crops*, 2013, 2(1): 1-6.
5. Pretty J. Agricultural sustainability: Concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 2008, 363: 447-465.
6. Schulte R P O, Creamer R E, Donnellan T, et al. Functional land management: A framework for managing soil-based ecosystem services for the sustainable intensification of agriculture. *Environmental Science & Policy*, 2014, 38: 45-58.
7. Deng X Z, Huang J K, Rozelle S, et al. Impact of urbanization on cultivated land changes in China. *Land Use Policy*, 2015, 45: 1-7.
8. Ye S J, Song C Q, Kuzyakov Y, et al. Preface: Arable land quality: Observation, estimation, optimization, application. *Land*, 2022, 11(6): 947.
9. Wan C J, Kuzyakov Y, Cheng C X, et al. A soil sampling design for arable land quality observation by using SPCOSA–CLHS hybrid approach. *Land Degradation & Development*, 2021, 32(17): 4889-4906.
10. Ye S J, Song C Q, Cheng F, et al. Cultivated land health-productivity comprehensive evaluation and its pilot evaluation in China. *Transactions of the Chinese Society of Agricultural Engineering*, 2019, 35(22): 66-78.
11. Xu J M, Meng J, Liu X M, et al. Control of heavy metal pollution in farmland of China in terms of food security. *Bulletin of Chinese Academy of Sciences*, 2018, 33(2): 153-159.
12. Yun W J, Yu Z R. Ecological landscaping strategy of rural land consolidation in China. *Transactions of the Chinese Society of Agricultural Engineering*, 2011, 27(4): 1-6.
13. Ye S J, Song C Q, Gao P C, et al. Construction of the new cognitive system for arable land resources from geospatial perspective. *Transactions of the Chinese Society of Agricultural Engineering*, 2023, 39(9): 225-240.
14. Cai Y L, Huo Y Q. Supply-driven farmland conversion. *China Land*, 2002, (7): 20-22.

15. Qu F T, Chen J L, Chen W. Theoretical and empirical study on the land conversion economic driving forces. *Journal of Natural Resources*, 2005, 20(2): 231-241.

16. Yi X Y, Chen Y J. Analysis on the influencing factors of farmers' transfer to cultivated land and their non-grain planting behavior and scale—Based on the survey data of farmers in Zhejiang and Hebei provinces. *China Rural Survey*, 2010, (6): 2-10.

17. Tan S H, Qu F T, Nike H. The causes of land fragmentation and its influencing factors. *China Rural Survey*, 2003, (6): 24-30.

18. Lü X, Huang X J, Zhong T Y, et al. Review on the research of farmland fragmentation in China. *Journal of Natural Resources*, 2011, 26(3): 530-540.

19. Li X B, Zhao Y L. Forest transition, agricultural land marginalisation and ecological restoration. *China Population, Resources and Environment*, 2011, 21(10): 91-95.

20. Liu C W, Li X B. Diagnosis on the marginalization of arable land use in China. *Geographical Research*, 2006, 25(5): 895-904.

21. Liu C Y, Song C Q, Ye S J, et al. Estimate provincial-level arable land productive-capacity and its coordination with land-use intensity in the mainland of China. *Agriculture, Ecosystems & Environment*, 2022, 326: 107757.

22. Tang H Z, Sang L L, Yun W J. China' s cultivated land balance policy implementation dilemma and direction of scientific and technological innovation. *Bulletin of Chinese Academy of Sciences*, 2020, 35(5): 637-644.

23. Ministry of Land and Resources, State Statistics Bureau, Office of the Second National Land Survey Leading Group of the State Council. Major data bulletin of the second National Land Survey. *National Land & Resources Information*, 2014, (1): 29-31.

24. Office of the Third National Land Survey Leading Group of the State Council, Ministry of Natural Resources, State Statistics Bureau. Major data bulletin of the third National Land Survey. *National Land & Resources Information*, 2021, (17): 7-8.

25. Zuo L J, Zhang Z X, Carlson K M, et al. Progress towards sustainable intensification in China challenged by land-use change. *Nature Sustainability*, 2018, 1(6): 304-313.

26. Liu C Y, Song C Q, Ye S J, et al. Estimate provincial-level effectiveness of the arable land requisition-compensation balance policy in mainland China in the last 20 years. *Land Use Policy*, 2023, 131: 106733.

27. Zhang O X, Jiang C Y. Analysis on differences of "non-grain" of different types farmers in transfer-in farmland. *Finance and Trade Research*, 2016,

27(4): 24-31.

28. Manjunatha A V, Anik A R, Speelman S, et al. Impact of land fragmentation, farm size, land ownership and crop diversity on profit and efficiency of irrigated farms in India. *Land Use Policy*, 2013, 31: 397-405.

29. Liu J, Jin X B, Xu W Y, et al. Influential factors and classification of cultivated fragmentation, implications for future land consolidation: A case study of Jiangsu Province in Eastern China. *Land Use Policy*, 2019, 88: 104185.

30. Wang X, Xu X F. Spatiotemporal characteristics and influencing factors of landscape fragmentation of cultivated land in China. *Transactions of the Chinese Society of Agricultural Engineering*, 2022, 38(16): 11-20.

31. Song X Q, Ouyang Z. Connotation of multifunctional cultivated land and its implications for cultivated land protection. *Progress in Geography*, 2012, 31(7): 859-868.

32. Li S F, Li X B. Economic characteristics and the mechanism of farmland marginalization in mountainous areas of China. *Acta Geographica Sinica*, 2018, 73(5): 803-817.

33. Zhang X Z, Zhao C S, Dong J W, et al. Spatio-temporal pattern of cropland abandonment in China from 1992 to 2017: A Meta-analysis. *Acta Geographica Sinica*, 2019, 74(3): 411-420.

34. Ye S J, Song C Q, Shen S, et al. Spatial pattern of arable land-use intensity in China. *Land Use Policy*, 2020, 99: 105027.

35. Ren S Y, Song C Q, Ye S J, et al. The spatiotemporal variation in heavy metals in China' s farmland soil over the past 20 years: A meta-analysis. *Science of the Total Environment*, 2022, 806: 150322.

36. Zhang J Z, Zheng W W, Xia X L. Cropland "non-grain" : Policy backtracking, formation mechanism and control strategy. *Tudi Kexue Dongtai*, 2022, (2): 16-20.

37. Yang C H, Lin K, Gao X, et al. Analysis on development and risks of China' s food production during 14th Five-year Plan period. *Bulletin of Chinese Academy of Sciences*, 2022, 37(8): 1088-1098.

38. Lin E D, Xu Y L, Jiang J H, et al. National Assessment Report of Climate Change ( ): Climate change impacts and adaptation. *Advances in Climate Change Research*, 2006, 2(2): 51-56.

39. Ye S J, Zhu D H, Yao X C, et al. Development of a highly flexible mobile GIS-based system for collecting arable land quality data. *IEEE J-STARS*, 2014, 7(11): 4432-4441.

40. Ye S J, Liu D Y, Yao X C, et al. RDCRMG: A raster dataset clean & reconstitution multi-grid architecture for remote sensing monitoring of

vegetation dryness. *Remote Sensing*, 2018, 10(9): 1376.

41. Ye S J, Zhang C, Wang Y, et al. Design and implementation of automatic orthorectification system based on GF-1 big data. *Transactions of the Chinese Society of Agricultural Engineering*, 2017, 33(S1): 266-273.

42. China Meteorological Administration Climate Change Center. *Blue Book on Climate Change in China (2022)*. Beijing: Science Press, 2022.

43. Xu R K, Li J Y, Zhou S W, et al. Scientific issues and controlling strategies of soil acidification of croplands in China. *Bulletin of Chinese Academy of Sciences*, 2018, 33(2): 160-167.

44. Sun Y F, Li X, Zhang H B, et al. Functions and countermeasures of biodiversity conservation in agricultural landscapes: A review. *Chinese Journal of Eco-Agriculture*, 2017, 25(7): 993-1001.

45. Liu W E, Zhang X, Zhang J, et al. Farmland buffer strip planning, construction and protective effect on related natural enemy. *Chinese Journal of Eco-Agriculture*, 2017, 25(2): 172-179.

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*Note: Figure translations are in progress. See original paper for figures.*