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Editorial

Arable Land Quality in Developing China: An Integrated Exploration from Global Challenges to Localized Solutions

Sijing Ye [1,2], Changqing Song [1,2,*], Yakov Kuzyakov [3,4,5], Feng Cheng [6], Xiangbin Kong [7], Zhe Feng [8] and Peichao Gao [1,2]

1 State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing 100875, China; yesj@bnu.edu.cn (S.Y.); gaopc@bnu.edu.cn (P.G.)
2 Faculty of Geographical Science, Beijing Normal University, Beijing 100875, China
3 Department of Soil Science of Temperate Ecosystems, University of Göttingen, 37077 Göttingen, Germany; ykuzyakov@yandex.com
4 Agro-Technological Institute, Peoples Friendship University of Russia (RUDN University), 117198 Moscow, Russia
5 Institute of Environmental Sciences, Kazan Federal University, 420049 Kazan, Russia
6 China Land Surveying and Planning Institute, Beijing 100035, China; chengfeng@mail.clspi.org.cn
7 College of Land Science and Technology, China Agricultural University, Beijing 100193, China; kxb@cau.edu.cn
8 School of Land Science and Technology, China University of Geosciences, Beijing 100083, China; zhefeng@cugb.edu.cn
* Correspondence: songcq@bnu.edu.cn; Tel.: +86-010-5880-5820

1. Introduction

Ensuring global food security and sustainable development remains a top priority at present [1–4]. However, the rising world population and increasing food demands create pressure to intensify arable land use [5–8]. Damaging practices such as excessive land reclamation, over-cultivation, and urban encroachment not only degrade soil but also threaten ecosystems and diminish water resources, negatively impacting human well-being [9–11]. Balancing food needs while preserving arable land stability is a crucial challenge [12,13]. The key lies in advancing sustainable land use, essential to addressing hunger, combating soil erosion, mitigating climate change, and achieving the UN's Sustainable Development Goals [14–17].

Arable land quality is a comprehensive expression of the degree to which various functions of arable land meet human needs, and it has the characteristics of non-direct observation and multi-perspective, multi-scale, and dynamic change (Figure 1) [18–21]. Understanding arable land quality and exploring ways to improve it are of great importance to governments around the world, as they are related to filling the gap in future food demand and coping with climate change and alleviating the contradiction between man and nature [22,23]. China, for instance, focuses on fortifying land protection, integrating it into their natural resource strategy [24–26]. Similarly, the European Union's Common Agricultural Policy (CAP) emphasizes agricultural production, global food security, and environmental concerns [27–29]. Along with this, a noticeable shift in policy evolution is discernible. Policies now prioritize soil health, environmental protection, water management, climate adaptation, and regional economic development over solely maximizing yields and production from high-quality arable land [30–33].

A multitude of national-level initiatives are also propelling transformation, as exemplified in 2019 by China's Ministry of Natural Resources conducting an assessment of arable land quality using diverse metrics, emphasizing the role of agroclimatic resources and soil health and management. Concurrently, the Nature Conservancy in the United States devised a soil health roadmap, aiming to bolster a comprehensive understanding of the

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climate–soil–cropping system to address soil degradation issues [34]. These transformations underscore a pivotal reality: high-quality arable land not only serves the purpose of productive capacity but also underpins multifaceted systemic developments in agriculture, ecology, society, and the economy [35–39].

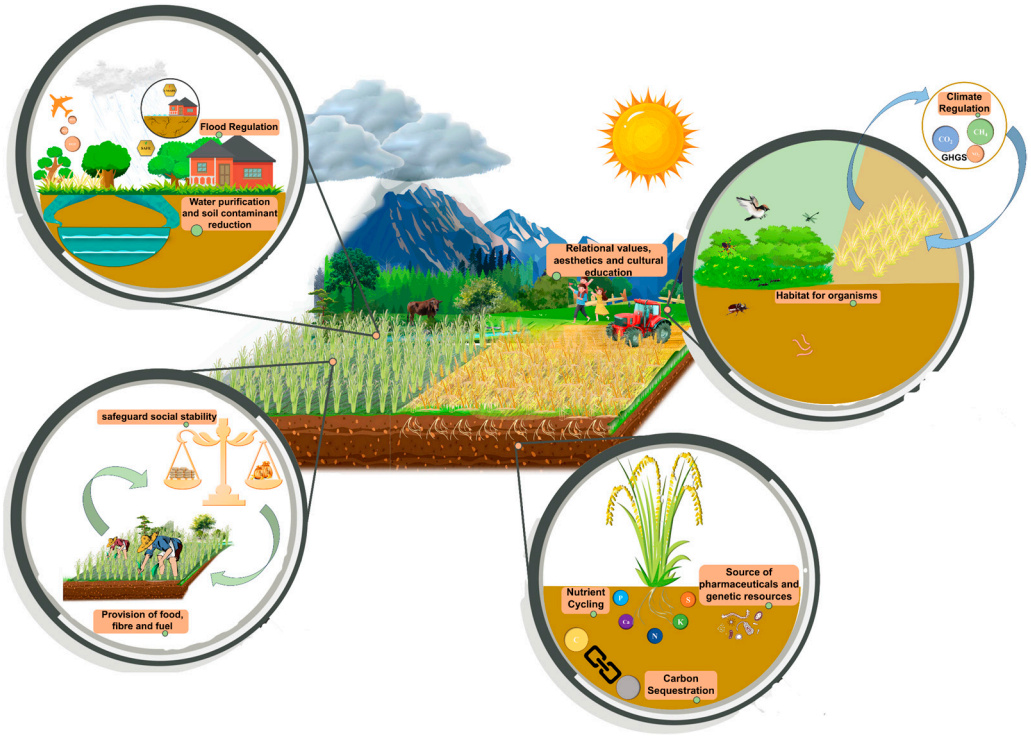

Figure 1. The diversification of arable land functions determines the multi-dimensional characteristics of arable land quality.

To meet the growing demand for research on croplands, studies related to arable land quality have evolved from an initial focus on productivity and suitability for cultivation to a progressive alignment with the coupling of intensified utilization and healthy development. This puts forward higher requirements for the processing technology and analysis models of arable land quality big data. For instance, Ye et al. [40] proposes a new method combining K-means algorithm and sliding window-based partial correlation index method to assess agricultural sustainable intensification and finds that overuse of fertilizer and pesticides remains a major issue to be addressed. Ren et al. [41] assessed the land use and sustainable production potential in the black soil region of the northeast by considering agricultural infrastructure, cultivation conditions, and soil properties.

This Special Issue is dedicated to the observation, estimation, optimization, and application of arable land quality from a comprehensive perspective. Building upon enriched foundational aspects of arable land quality, including its connotations, observational data technologies, computational models, and practical experiences, the aim of this Special Issue is to tackle challenges in understanding regional dominant factors, indicators, simulation technologies, comprehensive theories, and methodologies. It aspires to offer sustainable solutions for arable land use based on scientific discoveries.

Comprising eleven peer-reviewed articles, including one review article and ten research articles (List of Contributions), the organization of this Special Issue unfolds as follows: following the introductory review article, the subsequent papers are categorized into three main themes—(a) soil degradation, (b) arable land quality assessment and management, and (c) arable land utilization and spatiotemporal changes.

2. Arable Land Quality: A Review

In their review article, Ye et al. (2023) introduce the Special Issue with a study on arable land quality, emphasizing the global challenges of food security and the pivotal role of sustainable arable land use in mitigating soil erosion, addressing hunger, and combating climate change. The study delves into the conceptual evolution of "arable land quality" over the past 30 years, transiting from an emphasis solely on crop productivity to a holistic consideration of the intensive use of arable land alongside the healthy development of farmland ecosystems.

Acknowledging the spatial heterogeneity of arable land quality and its regional factors, the article underscores the importance of recognizing these sustainable land use strategies. It highlights the importance of protecting high-quality arable land for national food security, emphasizing that certain regions contribute significantly to overall arable land productivity. The high-quality arable land is used to conduct agricultural intensification and consolidation, essential for enhancing output–input ratios. It stresses that guaranteeing and developing high-quality arable land is crucial to maintaining farmland ecosystem health, improving carbon sequestration, and preventing land degradation.

The challenges in studying arable land quality are discussed extensively, focusing on various aspects from the cognition of regional leading factors to data acquisition challenges, standardization, and evaluation techniques. The article highlights the difficulties in estimating the complex non-linear characteristics of arable land quality and proposes exploring methods from complex systems science and machine learning models. It also emphasizes the need to understand the influence of arable land quality on farmland ecosystem functions and land use transitions and the necessity of effective policies tailored to local contexts for arable land quality protection.

In conclusion, the article emphasizes the need for continued research and policy development addressing the multifaceted challenges associated with understanding, assessing, and preserving arable land quality to ensure sustainable development.

3. Soil Degradation

Ma et al. (2023) focus on assessing the current status of heavy metal(loid) inputs in agricultural soils across China, crucial to understanding the ecological environment in farming areas. Prior studies were limited in scope, often confined to small regions with few sampling sites, providing incomplete national insights. This study conducted a comprehensive review spanning 20 years of publications and utilized meta-analysis, considering spatiotemporal variability to calculate heavy metal(loid) input fluxes via atmospheric deposition, fertilizers, manure, and irrigation. The results revealed that atmospheric deposition contributes considerably to heavy metal(loid) inputs, surpassing those from fertilizer and manure, unlike in Europe. Elements such as As, Cd, Cr, Ni, and Pb mainly enter the soil through atmospheric deposition, constituting 12% to 92% of the total input. Manure accounted for 19% to 75% of Cu and Zn inputs. Cd emerged as the most critical environmental risk element in Chinese agricultural soils, with safety thresholds likely to be exceeded within 100 years in many regions. The Huang-Huai-Hai region requires particular attention due to its overall pollution levels.

Kang et al. (2023) investigate the relationship between soil biodiversity and soil-based ecosystem services by examining key biological indicators across farmland use types in three agricultural regions of China. Using 72 fields, the study explores the distribution and factors based on six indicators: the carbon and nitrogen contents of microbial biomass, soil respiration, soil catalase activity, acid phosphomonoesterase activity (APA), and earthworms. Significant differences were observed among the regions for microbial biomass carbon, soil respiration, catalase activity, and APA. Factors such as cation exchange capacity, total nitrogen, organic matter, hydrolytic nitrogen, and soil bulk density influenced microbial biomass carbon, nitrogen, and soil respiration. APA and earthworm populations were notably affected by total phosphorus, available phosphorus, and available potassium. Climatic conditions, soil types, and farming practices collectively influence soil biodiversity.

The findings highlight the importance of improving soil physical conditions and enhancing fertility levels to establish sustainable farm management.

Liao et al. (2023) discuss the importance of sustainable agricultural production systems due to threats posed by soil degradation and carbon emissions from traditional farming. The study focuses on a cooperative–dominated conservation tillage (CDCT) model implemented in Lishu County, China, examining its practical effectiveness. Unlike traditional methods, the CDCT model involves cooperatives managing cultivated land by employing standardized conservation tillage technology with support from research institutes, governments, and enterprises. The results from a 9-year application of this model show a 6.2% increase in topsoil organic carbon content, indicating improved soil quality compared to traditional methods. The model also increased operational and fertilizer use efficiency, reducing the carbon footprint of maize production by 16%. Additionally, it lowered production costs by 1450 CNY/ha, while increasing profits by 2600 CNY/ha on average, benefiting farmers economically. The farmers who transferred their farmland improved their living conditions by gaining income from land revenue and labor wages. The CDCT model showcased multifaceted benefits and potential for wider application, offering valuable lessons for sustainable land use, thereby contributing to agricultural development with reduced environmental impact.

4. Arable Land Quality Evaluation and Management

Liu et al. (2023) introduce a method to assess both quantity and quality changes in cropland using multi-source remote sensing data, specifically applied in the black soil region of northeast China. Unlike traditional time-consuming field surveys, this method offers a more efficient approach to monitor large-scale cropland changes. The study reveals that between 2010 and 2018, the cropland area increased by 1.2%. Cropland patches grew larger, improving landscape connectivity, and the center of cropland gravity shifted towards the northeast due to concentrated expansion. Conversion sources into cropland were predominantly unused land (36%), grassland (31%), and forest (17%). Overall, cropland quality improved: low-quality land decreased by 7.2%, while high- and medium-quality areas increased by 5.7% and 5.2%, respectively. Quality improvement was prominent in the east and slight in the southwest but declined in the north. Key factors influencing cropland quality were production capacity and soil fertility, affecting 36.22% and 15.64% of the observed changes, respectively. These findings provide a comprehensive understanding of cropland changes and their drivers, offering insights for effective cropland protection and management. The proposed method demonstrates reliability and applicability, serving as a valuable reference for similar cropland evaluation studies.

Tang et al. (2023) address the challenges of investigating and evaluating regional cultivated land quality due to its broad definition and cognitive biases. To tackle this, the study establishes a comprehensive conceptual framework to analyze cultivated land quality from a data perspective. The framework encompasses cultivated land quality ontology, mapping, correlation, and decision models, supported by technologies like collaborative perception, intelligent treatment, diagnostic evaluation, and simulation prediction. Applying this framework, the study outlines the cognitive system of cultivated land quality in the black soil region, centered on production capacity and comprising foundational, guarantee, and consequential components. The evaluation system involves 20–31 key indicators across seven purposes: production supply, threat control, infrastructure regulation, ecological maintenance, economics, social culture, and environmental protection. The framework exhibits adaptability, efficiency, and scalability, serving as a theoretical guide for further studies on cultivated land quality evaluation. It leverages big data to optimize evaluation results under various scenarios and objectives, aiding farmland management and engineering improvements across scales and objectives, bridging theory and practice. Ultimately, it offers a comprehensive understanding of cultivated land quality systems through a big data lens and facilitates practical applications in farmland management.

Miao et al. (2023) propose a novel approach for managing cropland big data, specifically designed to analyze cropland quality evaluations and other geographic data analyses. This method integrates various sources of data by mapping their spatial, temporal, and attribute features into grid cells, thereby achieving structural coherence and organized management of diverse data types with format differences and semantic ambiguities. The paper outlines a dissected cropland big data fusion model, devises conceptual and logic models, and establishes a cropland data organization model using a DGGS (discrete global grid system) and hash coding. It achieves unified management of vector, raster, and text data through multilevel grids. The paper explores grid-scale adaptability evaluation methods, generating distributed multilevel grid datasets for cropland area quality assessments. The experiment conducted in Da'an County, using various datasets (covering the soil organic matter, road network, cropland area, and statistical data) confirms the method's efficacy in unifying and efficiently managing diverse cultivated land data while supporting cropland quality evaluations.

5. Arable Land Utilization and Spatiotemporal Changes

Dong et al. (2023) address the impact of spatiotemporal changes in cultivated land on food security and sustainable development. Existing studies have often focused on single factors such as quantity, quality, and ecology but fail to comprehensively represent total production capacity and land sustainability. Their study constructs an analytical approach to comprehensively assess changes in cultivated land food-production capacity and inform land conservation policies. The method considers three dimensions: quantity, production capacity, and ecology, providing a comprehensive view of changes in cultivated land. Applied to Long'an County, the findings reveal several key points: a strong 31% decrease in cultivated land area from 2010 to 2020, with the land mainly converted to orchards and forest land; a 2.7% improvement in land quality due to natural factors; a 29% decline in total food-production capacity primarily linked to reduced cultivated land area; slight decreases in ecological grade and sustainability; a shift of cultivated land towards ecologically sensitive areas; increased fragmentation and decreased patch size of cultivated land, implying reduced continuity and increased fragmentation; and improved patch regularity, indicating slight adaptation to mechanization. The lower total food production capacity in Long'an County was attributed to low grain cultivation income, leading farmers to prioritize high-return crops, and a lack of targeted government land protection policies. The comprehensive analysis demonstrated its potential applicability to other regions for understanding changes in food production capacity and guiding land protection policies.

Zhou et al. (2022) focus on land consolidation (LC) in China, specifically addressing its role in increasing cultivated land area and increasing quality, particularly in mountainous regions. Data from 64 completed land consolidation zones in the Qinba Mountain Area were analyzed. LC primarily increased terrace cultivation, constituting 92% of the expanded cultivated land. This expansion is concentrated in the Qinba Mountain Area, with terrace farming predominant in both the Hanzhong Basin and Qinba Mountain regions. The conversion rate of cultivated land from LC, especially terraces, is minimal, measuring 0.36% in the Hanzhong Basin and 0.09% in the Qinba Mountain Area. Despite lagging socioeconomic development in these mountainous areas, farmers rely on agriculture for basic income, indicating the sustainable use of high-quality cultivated land with good accessibility. The study concludes that LC remains vital for increasing cultivated land, improving agricultural productivity, boosting farmers' income, and fostering rural development in mountainous regions.

Du et al. (2023) focus on Chongqing, a mountainous region in southwest China, and nearby areas to analyze the spatial differences in farmland transfer rents. The goal is to offer insights into understanding farmland value, ensuring food security, and fostering stable development in the farmland transfer market. Using GIS spatial analysis, the research identifies distinct patterns in farmland transfer rents, with high-value regions clustered around downtown Chongqing and the western area, while lower-value areas are found

in the Daba and Wuling Mountains, known for poverty conditions. Location and terrain are the primary factors influencing these differences. Specifically, the raised slope and supply–demand ratio led to decreased transfer rents (of 0.13% and 0.15%, respectively), while higher GDP elevated rents by 0.09%. Policy factors showed no impact. The study emphasizes that local governments should avoid simplistic comparisons of transfer rents between regions. Regions with lower rents should focus on increasing farmland value by stimulating demand and improving farming conditions, whereas areas with higher rents, especially in crucial grain-producing zones, should ensure that these rents do not jeopardize regional food security.

Wu et al. (2023) address the increasing demand for disaster risk management in land production due to rural economic reforms. Their study emphasizes the urgency of developing agricultural insurance to bolster land production recovery and ensure national food security. The study introduces a quantitative model to determine agricultural premium rates for each county in China based on its disaster risk level, aiming to refine agricultural insurance strategies. The results highlight the fact that (a) the northeast and central parts of southwest, north, and northwest China are severely affected by natural disasters; (b) 129 counties are at an extremely high disaster risk based on an integrated natural disaster risk assessment; and (c) some counties in Inner Mongolia, Shanxi, Liaoning, Jilin, Shandong, Anhui, Jiangxi, Zhejiang, Guangdong, Hubei, and Hunan have notably high agricultural premium rates among a total of 63 counties. These findings underscore regional disparities in disaster risk levels and premium rates among counties, offering guidance to increase the precision of agricultural premium rates.

6. Concluding Comments

This Special Issue entitled "Arable Land Quality: Observation, Estimation, Optimization, and Application" presents a comprehensive exploration of the complexities of arable land management and sustainability in the face of escalating global demands. By delving into multifaceted soil degradation, quality assessment, and spatiotemporal changes, this collection of peer-reviewed articles, comprising review and research contributions, converges on sustainable arable land use.

This introductory discourse underscores the crucial balance required between burgeoning food requirements and the conservation of arable land systems. It illuminates the evolving perspective on arable land quality, transitioning from a productivity-centered approach towards a holistic consideration of ecosystem health. This introduction underscores the evolving global policy landscape, steering away from a sole emphasis on high-yield cultivation towards a more comprehensive approach considering soil health, water resource management, and environmental sustainability.

The thematic sections of this Special Issue meticulously dissect soil degradation, evaluation, and management paradigms, culminating in a nuanced understanding of the challenges and potential solutions. Studies examining heavy metal inputs, soil biodiversity, and innovative agricultural models unveil insights into the delicate interplay between agricultural practices and ecological well-being. Additionally, innovative methodologies for evaluating arable land quality and spatiotemporal changes, using remote sensing, big data integration, and geographic information systems, herald a promising era for data-driven precision in arable land management.

Crucially, this Special Issue highlights regional disparities and the profound impact of the local context on arable land quality, emphasizing the need for tailored, context-specific policies. Insights gleaned from studies analyzing farmland transfer rents, disaster risk management, and the role of land consolidation in mountainous regions underscore the necessity of nuanced policy interventions aligned with local dynamics to guarantee food security and sustainable development.

This compilation of research endeavors not only underscores the multifaceted nature of arable land quality but is also dedicated to addressing the urgent need for a broad range of approaches integrating scientific advancements, policy formulations, and localized

interventions. As the world grapples with burgeoning food demands and environmental sustainability imperatives, this Special Issue looks forward to providing insights for policymakers, researchers, and practitioners involved in arable land utilization and management.

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