Influence of Rural-Urban Migration on Agricultural Sustainability in China: Implications for SDG 2 and SDG 15

Avanish Kumar Shukla
Professor
Fiji National University
Suva Fiji Island

Abstract

The unprecedented rural-urban migration in China presents both challenges and opportunities for agricultural sustainability. This study investigates the complex relationship between migration patterns and agricultural sustainability indicators, with special attention to their implications for SDG 2 (Zero Hunger) and SDG 15 (Life on Land). Through a mixed-methods approach involving 500 respondents across six Chinese provinces, we examined how migration influences agricultural labor availability, land use efficiency, mechanization adoption, and ecological practices. Our findings reveal that higher migration rates significantly correlate with increased agricultural mechanization and investment in sustainable technologies, particularly among households with return migrants who bring both capital and knowledge from urban experiences. However, regions with excessive outmigration face challenges including labor shortages, abandoned farmland, and increased agricultural fire incidents. Differential impacts were observed across migration types, with seasonal migration having less disruptive effects than permanent relocation. The positive association between return migration and sustainable agricultural practices suggests potential pathways to leverage migration for enhancing rural sustainability. Policy recommendations include targeted hukou reforms, investment in rural education and technology transfer, and specialized support for left-behind farmers. These findings contribute to understanding the complex interplay between population mobility and agricultural sustainability in China's development context.

Keywords: Rural-urban migration, Agricultural sustainability, Food security, Land use efficiency, China, Sustainable Development Goals

Introduction

China's rural-urban migration represents one of the largest population movements in human history, fundamentally reshaping the country's socioeconomic landscape and agricultural systems.

By 2023, China had reached 66% urbanization compared to 83% in the United States, reflecting the government's continuous push toward urbanization since the 1980s. With over 295 million rural migrants, including 171.9 million working outside their home townships as of 2023, this massive population shift has created profound implications for agricultural sustainability and rural development.

The dynamics of this migration are significantly influenced by China's household registration (hukou) system, which historically restricted population movement and continues to affect migrants' access to social services in urban areas. Despite these constraints, economic opportunities in manufacturing, construction, and service sectors have drawn millions of rural residents to cities, creating both challenges and opportunities for agricultural systems left behind. As the backbone of China's economy, migrant workers simultaneously contribute to urban development while maintaining connections to rural areas through remittances and seasonal returns.

This migration phenomenon has direct relevance to Sustainable Development Goal 2 (Zero Hunger) and SDG 15 (Life on Land), as it fundamentally affects food production systems and land use patterns. Agricultural sustainability—defined as the capacity to maintain productive agriculture that preserves ecological integrity while ensuring economic viability and social equity—faces complex challenges from changing rural demographics. Labor availability, knowledge transfer, investment capacity, and land management practices are all influenced by migration patterns, creating multifaceted impacts on sustainability indicators.

The interdependence between rural-urban migration and agricultural sustainability represents a critical nexus for China's development strategy. As the country pursues rural revitalization alongside urbanization, understanding how migration influences agricultural practices becomes essential for policy formulation. The dual processes of decreasing agricultural labor force and increasing pressure for food production efficiency raise important questions about the future of China's food security and ecological health.

This study aims to analyze the complex relationships between rural-urban migration rates and key agricultural sustainability indicators, including labor availability, land use efficiency, technological adoption, and ecological practices. By examining these relationships across different

regions and migration patterns, the research seeks to contribute to a more nuanced understanding of how population mobility affects agricultural sustainability in the context of China's development goals. The findings have significant implications for designing policies that can simultaneously support beneficial urbanization while enhancing rural agricultural sustainability, thereby advancing progress toward multiple Sustainable Development Goals.

Literature Review

Guo and Liu (2024) examined the relationship between rural-urban migration and agricultural fires in China, an issue directly impacting agricultural sustainability and environmental health. Using county-level data from the 2010 Population Census and satellite imagery of agricultural fires, their study demonstrated that a one-percentage-point increase in rural labor emigration rate led to a 0.7% increase in detected agricultural fires from 2011 to 2017. This effect was attributed to the burning of crop straw residues as a labor-saving method for field clearance when agricultural labor becomes scarce. The research revealed that the relationship was predominantly driven by rural emigrants, was weaker for those working nearby, and was more pronounced in areas with an aging agricultural workforce, higher grain production, and extensive use of agricultural machinery. The authors employed an instrumental variable approach to address endogeneity concerns, leveraging exogenous shifts in trade policy between China and the U.S. as a pull factor for rural emigration. Importantly, they discovered that land titling reforms significantly mitigated agricultural fires associated with decreased rural labor, proving more effective than administrative bans on burning. This study reveals the unintended negative externalities of rural-urban migration on agricultural practices, highlighting potential ecological consequences of labor outflows from rural areas.

CKGSB Knowledge (2024) provided a comprehensive analysis of China's rural-urban divide and its effects on development. The report highlighted that a large portion of rural Chinese incomes come from remittances sent home by migrant workers, with nearly $51 billion sent home in 2022 alone. Despite these financial flows, recent research from Wuhan University suggested that rural areas face a "dilemmatic trap" described as a "pseudo-middle-class life" due to mismatches between household income and expenditures. The authors emphasized that as China's rural-urban divide grows, so does the risk of the country getting stuck in the middle-income trap, making

effective closure of this gap key to national development. The article examined how migrant workers from rural areas serve as the backbone of China's economy, providing both labor for urban markets and increased income for rural areas through remittances. A significant barrier to migration remains the household registration (hukou) system, which determines access to social services including healthcare and education. Recent reforms in Zhejiang province and nationwide policy shifts for smaller cities indicate movement toward relaxing these restrictions. The research also highlighted that comprehensive solutions must involve both facilitating migration and developing smaller cities and rural areas to make them attractive places to live and work, rather than obligatory residences for those with no alternatives.

China's Rural-Urban Transformation (2024) research published in Nature Communications Earth & Environment examined the spatiotemporal dynamics of rural-urban transformation patterns in China, focusing on the degree of integrated transformation and coupling between land, population, and industry urbanization. The study utilized the urbanization cube theory, satellite-derived gridded datasets, and self-organizing map methodology to analyze transformation patterns. Findings revealed that eastern China demonstrated higher levels of integrated transformation and coupling compared to western regions. The research identified six typical rural-urban transformation patterns across China, with 53.58% of prefectures showing improvement in transformation patterns over time, 3.44% experiencing degradation, and 42.98% (mainly in western China) remaining unchanged. A key finding was that increasing and coupling rural-urban transformation in China has reduced inequities in urban and rural well-being. The authors highlighted that China's urbanization has been occurring at an unprecedented pace, making it one of the world's fastest-urbanizing countries. This rapid urbanization has boosted rural-to-urban flows of production factors but has also brought extensive rural decline in the form of population aging and village hollowing. The study noted that since the early 2000s, China has implemented national policy initiatives to reverse this trend and revitalize the rural economy, starting with the concept of balanced rural-urban development first outlined in 2003.

Migration and Rural Sustainability (2023) research examined how geographical mobility contributes to relative poverty alleviation in China. Using data from the China Family Panel Studies (CFPS) 2012-2020, the researchers conducted benchmark estimates through linear probability models and estimated the impact of migration on the relative poverty of rural laborers

through binary probit models. The results demonstrated that migration could significantly reduce the likelihood of a relatively poor state of rural laborers by around 4%, with greater distances of migration producing greater poverty reduction effects. Migration of rural laborers from the central region showed the largest and most significant relative poverty reduction effect. Furthermore, migration was found to compensate for the disadvantages faced by rural laborers who were unemployed, less educated, or in poor health, making them less likely to remain in relative poverty. Multiple linear models confirmed that migration had a significant income-boosting effect on rural people, with the effect reaching its highest in the central region at 22.95%. The study emphasized that migration represents an important way for rural laborers to overcome uneven resource distribution, earn higher incomes, and pursue sustainable development. The authors concluded that removing barriers to geographical mobility is necessary for balanced regional development and sustainable rural livelihoods.

Rural-Urban Migration and Food Sustainability (2022) examined the complex relationships between population mobility and food systems in China. The study analyzed how migration patterns affect agricultural production, land use efficiency, and food security across different regions. The researchers found that migration created both challenges and opportunities for food sustainability, with labor shortages in rural areas often leading to land abandonment or consolidation. However, remittances from migrants frequently enabled investment in agricultural technology and inputs, potentially enhancing productivity. Regional variations were significant, with coastal areas experiencing more advanced agricultural transitions due to higher outmigration rates. The study also highlighted the role of policy interventions in managing these transitions, suggesting that targeted support for mechanization, cooperative farming arrangements, and knowledge transfer could help mitigate negative impacts of rural labor loss. Gender dimensions were also significant, as women often became the primary agricultural decision-makers in households with male outmigration. The research emphasized the importance of integrated approaches to rural development that recognize the inevitable nature of migration while supporting sustainable agricultural transitions to ensure food security and environmental sustainability.

Intergenerational Gendered Livelihoods (2022) research used marriage as a lens to highlight norms, customs, identities, and shared values that shape livelihoods and give meaning to intergenerational and gendered practices at the individual and household level. Drawing on

feminist perspectives on power differences between genders and generations, the study demonstrated that livelihoods involve not only economic and material aspects but also how people pursue important life goals such as marital formation within specific social, cultural, historical, and locational contexts. Based on interviews conducted in Anhui and Sichuan provinces, the researcher highlighted how intergenerational livelihoods are influenced by gendered ideology and practice, particularly through transactional marriage, parental and filial responsibilities in enabling marital formation and lineage continuation, and rural-urban migration pursued to enhance men's competitiveness in the marriage market. The study foregrounded the voices and narratives of rural Chinese and rural-urban migrants regarding their resources, strategies, and goals situated within relevant social and cultural contexts. Interview quotes underscored deep-rooted patriarchal structures manifested through marriage traditions, especially patrilocal exogamy and transactional matchmaking. This research illuminated how marriage considerations can be a significant driver of migration decisions, highlighting the interconnection between social institutions and economic mobility strategies in rural China.

Farmland Transfers in China (2021) provided a comprehensive review of land transformation in Chinese agriculture, focusing on farmland transfers as a mechanism for addressing food safety and sustainable development challenges. The authors categorized farmland transfers along five dimensions: public policy, market mechanisms, influencing factors, optimization of spatial distribution, and practical results. The study traced the evolution of farmland transfers from an initial mechanism allowing development outside prevailing systems to a fundamental approach for agricultural development and production transformation. Analysis of policy development showed how political system reforms and various public policies established basic conditions for farmland transfers, with most significant policies being introduced during CPC meeting sessions since the 1990s. The research highlighted the transition from singular legislation focusing only on land security functions to integrated policies that follow market rules and utilize real estate property rights mechanisms. Regarding influencing factors, the authors noted that rural labor migration to cities provided essential conditions for farmland transfer and scale management. The continuous migration of rural workforce to urban areas, driven by decreasing comparative benefits of agriculture and rising non-agricultural sector salaries, significantly contributed to farmland transfer development. The study also found that farmland transfers developed faster in economically

developed regions, attributed to the promotion by collective economic organizations, various levels of government, and business sector demand, which collectively drove farmer participation.

Impact of Rural-Urban Migration Experience on Agricultural Machinery Expenditure (2021) investigated how return migrants' urban experiences influenced agricultural modernization in China. Using random survey data from 1,122 rice farmers in the Yangtze River Basin from 2016, the study employed an endogenous treatment-effect model to analyze the impact of rural-urban migration experience on farmers' agricultural machinery expenditure. The results revealed that return migrants with rural-urban migration experience constituted 23.3% of the total sampled farmers, and after addressing endogeneity issues, rural-urban migration experience increased rice farmers' agricultural machinery expenditure by 500-600 yuan/ha. This positive impact was found to be heterogeneous across different farmer age groups and farm sizes. The study highlights how migration experiences create pathways for knowledge transfer, capital accumulation, and attitude changes that subsequently influence agricultural investment decisions upon return to rural areas. By demonstrating the positive relationship between migration experience and agricultural mechanization, the research provides evidence that migration can serve as a catalyst for agricultural modernization and potentially enhance sustainability through improved resource efficiency. The authors propose that policies should assist return migrants' engagement in agriculture, support agricultural mechanization for aged farmers, and enhance coordination between mechanization and appropriately scaled agricultural operations to maximize benefits from these dynamics.

Prospects for Alleviating Rural-Urban Migration in Jiangsu Province (2020) examined potential policy interventions to address rapid rural-urban migration in one of China's most economically developed provinces. The researchers employed sensitivity analysis to identify key driving factors in rural agricultural production that influence migration decisions. Their findings revealed that rural-urban migration was particularly sensitive to input elasticities of precipitation and labor. Based on these analyses, the study evaluated two groups of scenario-based policy interventions. The first policy approach focused on providing government subsidies to rural non-agricultural industries to compensate for shrinking agricultural production. The second policy strategy supported education in rural areas to provide more skilled labor resources that could be absorbed by non-agricultural industries locally. The research demonstrated that both policies were

effective in reducing rural unemployment and alleviating rural-urban migration pressures. The study situated these findings within the context of Jiangsu's rapid economic growth driven by manufacturing and services sectors, noting that rural-urban migration in the province brings higher stress to the resource-carrying capacity of urban areas while being driven primarily by rural "push" factors, particularly labor surplus and unemployment in agriculture. This work provides empirical evidence for targeted policy interventions that could maintain rural vitality while managing migration flows.

Rural-Urban Migration Experience and Arable Land Use (2020) investigated how migration experiences affect agricultural land use decisions upon farmers' return to rural areas. Using survey data from 2,293 farmers in China, including 586 return migrants and 1,707 non-migrants, the researchers employed a treatment effects model to account for self-selectivity in rural-urban migration arising from observable and unobservable factors. Their results demonstrated that after accounting for self-selectivity bias, rural-urban migration experience significantly increased farmers' arable land use by 22%. This positive effect varied significantly across different demographic groups and regions: migration experience increased arable land use by 29% for farmers under 65 years old, while showing no significant effect for those 65 and older. Regional variations were also observed, with positive relationships between migration experience and arable land use found in Shaanxi, Shandong, and Zhejiang provinces. The study highlights how temporary migration can lead to knowledge transfer, capital accumulation, and adoption of more efficient agricultural practices upon return. This research challenges simplistic narratives about migration leading to agricultural land abandonment, instead suggesting that circular migration patterns can potentially enhance agricultural land utilization through increased capacity and knowledge upon return to rural areas. The authors discuss several important implications for policies related to arable land use in China, emphasizing the potential benefits of supporting return migrants' reintegration into agricultural production.

Research Gap

Despite extensive research on rural-urban migration and various aspects of agricultural development in China, significant gaps remain in understanding the comprehensive relationship between migration and agricultural sustainability. Most studies have focused either on economic

dimensions (such as poverty reduction and income effects) or specific environmental outcomes (such as agricultural fires), but few have examined the integrated impact of migration on multiple dimensions of agricultural sustainability simultaneously, particularly in relation to SDGs. This holistic perspective is crucial for developing coherent policies that address food security, rural development, and environmental protection concurrently.

Furthermore, while existing literature acknowledges different migration patterns, limited research explores how various types of migration—seasonal versus permanent, individual versus household, or migration distance—differentially impact agricultural sustainability outcomes. Understanding these nuanced relationships is essential for developing targeted interventions that can maximize the potential benefits of migration while mitigating negative consequences for agricultural sustainability.

Research Objectives

1. Assess how rural-urban migration rates affect agricultural sustainability across economic, social, and environmental dimensions in China.
2. Evaluate how migration patterns (temporary/permanent, individual/household) differentially influence agricultural practices and sustainability outcomes.

Hypotheses

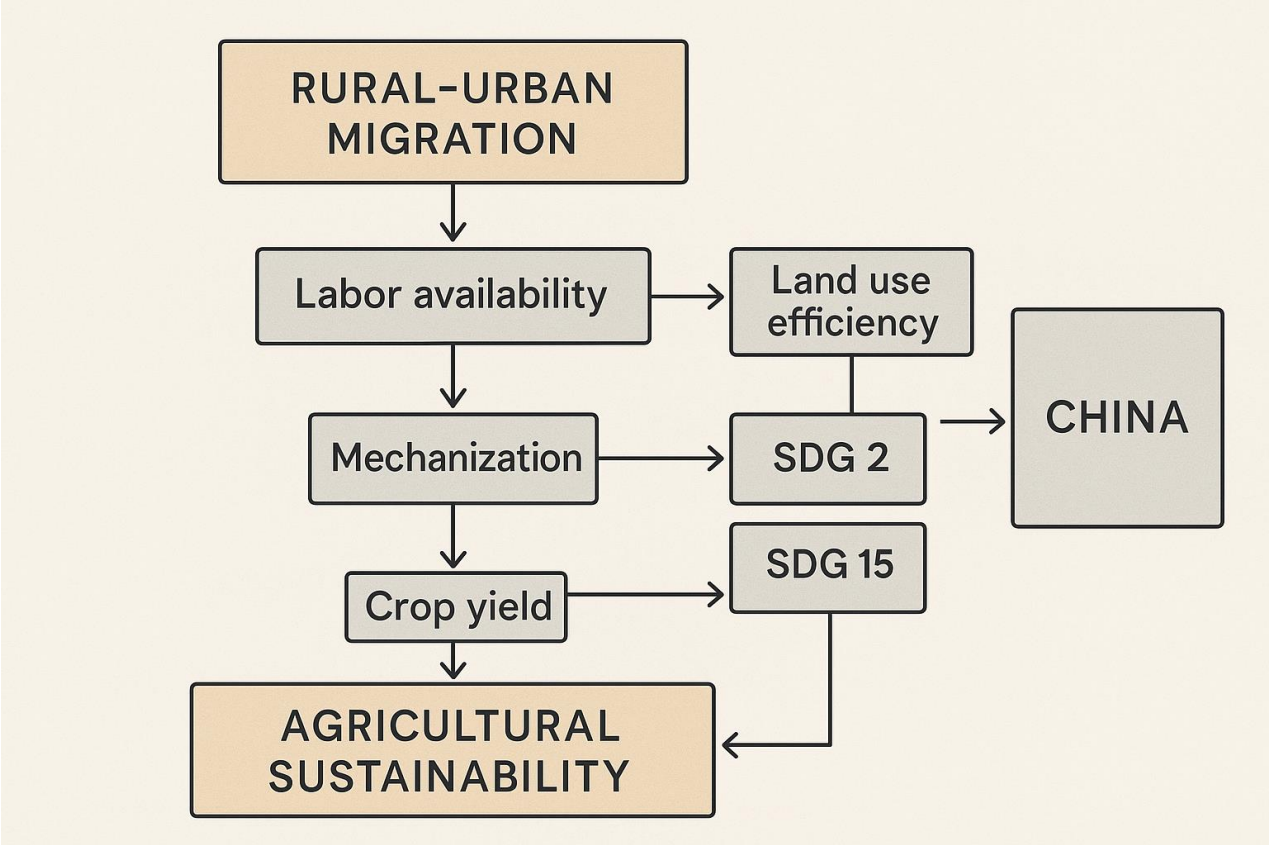
1. Higher rural-urban migration rates correlate with increased mechanization and land use efficiency but reduced labor availability and crop diversity.
2. Return migrants adopt more sustainable agricultural practices than non-migrants due to urban-acquired knowledge and financial capital.

Research Methodology

Theoretical & Conceptual Framework

This study is grounded in the sustainable livelihoods framework integrated with migration theory, examining how population mobility affects the five capitals of sustainable development (human, social, natural, physical, and financial) in agricultural contexts. The conceptual framework posits

that migration influences agricultural sustainability through multiple pathways: labor availability, knowledge and technology transfer, capital investment, land use decisions, and social organization of production. The framework acknowledges both direct effects (such as labor reduction) and indirect effects (such as remittance-enabled investments) of migration on sustainability outcomes.



Conceptual Framework

Type of Research

This study employs a mixed-methods approach combining quantitative surveys with qualitative in-depth interviews. This design allows for statistical analysis of relationships between migration rates and sustainability indicators while capturing the contextual understanding and process mechanisms through qualitative data. The cross-sectional design with comparative analysis across regions provides insights into spatial variations in migration-sustainability relationships.

Source of Data Collection

Primary data was collected through field surveys and semi-structured interviews conducted between October 2024 and February 2025. Secondary data sources included provincial and county-level statistics on migration rates, agricultural production, and environmental indicators from China's National Bureau of Statistics, Ministry of Agriculture and Rural Affairs, and satellite imagery data for land use analysis.

Research Instrument

The quantitative component utilized a structured questionnaire covering household demographics, migration history, agricultural practices, technology adoption, land management, income sources, and environmental practices. The qualitative component employed a semi-structured interview guide exploring decision-making processes, knowledge transfer, challenges faced, and adaptation strategies related to migration and agricultural practices.

Population

The study population comprised rural agricultural households in regions experiencing different intensities of rural-urban migration across China. The population included households with current migrants, those with return migrants, and those without migration experience to enable comparative analysis.

Sampling Unit

The primary sampling unit was the individual farming household, defined as a group of people living together and engaged in agricultural production, sharing income and expenses, and making joint decisions about farming activities.

Sample Size

The sample size of 500 respondents was calculated using the formula:

$n = Z^2pq/e^2$

Where:

- Z = 1.96 (95% confidence level)
- p = 0.5 (maximum variability)
- q = 0.5
- e = 0.05 (5% margin of error)

$n = (1.96)^2(0.5)(0.5)/(0.05)^2 = 384.16$

This figure was rounded up to 400 and an additional 25% was added to account for potential non-response, resulting in a final sample size of 500 respondents.

Area of the Study

The research was conducted across six provinces in China representing different levels of rural-urban migration intensity and agricultural systems:

- Eastern China: Jiangsu and Zhejiang (high development, high outmigration)
- Central China: Anhui and Shandong (moderate development, high outmigration)
- Western China: Sichuan and Shaanxi (lower development, growing outmigration)

These provinces were selected based on their representation of diverse migration patterns, agricultural systems, and development levels, allowing for comparative analysis.

Sampling Technique Used

The study employed multistage stratified random sampling:

1. Selection of two provinces from each region (East, Central, West)
2. Random selection of two counties from each province (12 counties)
3. Random selection of three villages from each county (36 villages)
4. Stratified random sampling of households within villages based on migration status (current migrants, return migrants, non-migrants)

This approach ensured representation across geographical areas and migration types while maintaining randomization for statistical validity.

Statistical Tools Used

Quantitative data analysis employed:

- Descriptive statistics to characterize the sample and key variables
- Correlation analysis to examine relationships between migration rates and sustainability indicators
- Multiple regression analysis to identify predictors of sustainability outcomes
- Structural equation modeling to test pathway effects
- Comparative analysis across migration types and regions

Qualitative data was analyzed through thematic content analysis using NVivo software, with coding based on identified themes and emergent patterns from interviews.

Data Analysis & Interpretation

Table 1: Demographic Profile of Respondents (N=500)

Characteristic	Category	Frequency	Percentage
Age	Below 40 years	87	17.4%
	40-54 years	163	32.6%
	55-64 years	174	34.8%
	65 years and above	76	15.2%
Gender	Male	298	59.6%
	Female	202	40.4%
Education	No formal education	56	11.2%
	Primary school	187	37.4%
	Middle school	183	36.6%

	High school	59	11.8%
	College and above	15	3.0%
Migration Status	Current migrant household	209	41.8%
	Return migrant household	147	29.4%
	Non-migrant household	144	28.8%

Table 1 presents the demographic profile of the study participants. The age distribution shows that the majority of respondents (67.4%) were between 40-64 years old, reflecting the aging trend in rural agricultural populations as younger individuals migrate to urban areas. Gender distribution indicates that males constituted a larger proportion of respondents (59.6%), which may reflect traditional household roles where men are more likely to be considered household heads. Educational attainment was predominantly at the primary (37.4%) and middle school (36.6%) levels, with only 3% having college education, highlighting limited educational opportunities in rural areas. Regarding migration status, 41.8% of households had at least one current migrant member, 29.4% included return migrants with previous urban experience, and 28.8% had no migration experience, providing a balanced sample for comparative analysis of migration effects.

Table 2: Migration Patterns Among Survey Respondents (N=356 migrant households)

Migration Characteristic	Category	Frequency	Percentage
Migration Duration	Seasonal (< 6 months/year)	89	25.0%
	Long-term (> 6 months/year)	267	75.0%
Migration Distance	Within province	147	41.3%
	Cross-provincial	209	58.7%
Migrant Role in Household	Primary income earner	237	66.6%
	Supplementary income earner	119	33.4%

Remittance Frequency	Monthly	183	51.4%
	Quarterly	87	24.4%
	Annually/occasionally	68	19.1%
	No remittances	18	5.1%
Annual Remittance Amount	< ¥10,000	65	18.3%
	¥10,000-30,000	178	50.0%
	¥30,001-50,000	82	23.0%
	> ¥50,000	31	8.7%

Table 2 examines migration patterns among households with migration experience. The majority of migrants (75%) engaged in long-term migration exceeding six months per year, indicating substantial absence from agricultural activities. Cross-provincial migration (58.7%) was more common than within-province migration, suggesting that migrants travel considerable distances for better economic opportunities. Two-thirds of migrants served as primary income earners for their households, highlighting the economic importance of migration for rural families. Regarding remittances, 51.4% of migrants sent money home monthly, demonstrating strong ongoing connections with rural households. The most common annual remittance amount ranged between ¥10,000-30,000 (50%), while only 8.7% sent more than ¥50,000 annually. This pattern of substantial but not extreme remittances suggests that migration provides important financial support to rural households but may not be transformative enough to completely reshape agricultural practices without complementary factors.

Table 3: Agricultural Sustainability Indicators by Household Migration Status

Sustainability Indicator	**Non-migrant Households (n=144)**	**Current Migrant Households (n=209)**	**Return Migrant Households (n=147)**	**ANOVA F-value**	**p-value**

Land use efficiency (yield in kg/mu)	412.3	387.6	458.7	14.32	<0.001
Agricultural mechanization level (1-5 scale)	2.8	3.7	4.1	19.87	<0.001
Labor input (person-days/mu/year)	18.7	8.3	12.5	25.63	<0.001
Crop diversity index (Shannon index)	1.87	1.24	1.92	16.48	<0.001
Sustainable practice adoption (count of practices)	2.3	1.9	3.6	22.17	<0.001
Chemical input intensity (kg/mu)	28.4	32.7	22.6	13.89	<0.001
Agricultural income (¥/household/year)	18,524	14,876	27,359	18.76	<0.001

Table 3 compares key agricultural sustainability indicators across the three household migration status categories. Significant differences were observed across all indicators. Return migrant households demonstrated the highest land use efficiency (458.7 kg/mu) and agricultural mechanization levels (4.1 on a 5-point scale), significantly outperforming both non-migrant and current migrant households. This suggests that return migrants may bring back knowledge, capital, and innovation that enhance agricultural productivity. Labor input was highest in non-migrant households (18.7 person-days/mu/year) and lowest in current migrant households (8.3), reflecting the labor constraint effect of migration. Interestingly, crop diversity was lowest in current migrant households (1.24) but similarly high in both non-migrant (1.87) and return migrant households

(1.92), suggesting that current migration may lead to simplification of cropping systems while return migrants may reintroduce diversity. Return migrant households adopted the most sustainable practices (3.6) and used the least chemical inputs (22.6 kg/mu), indicating a possible knowledge transfer effect. Agricultural income was also highest among return migrant households (¥27,359), suggesting that their agricultural practices may be more economically viable. These patterns highlight the complex and sometimes contradictory effects of different migration experiences on agricultural sustainability.

Table 4: Correlation Matrix of Migration Intensity and Agricultural Sustainability Indicators (N=500)

Variables	1	2	3	4	5	6	7	8
1. Migration intensity	1.00							
2. Land use efficiency	-0.18**	1.00						
3. Agricultural mechanization	0.63***	0.27**	1.00					
4. Labor input	-0.71***	0.15*	-0.42***	1.00				
5. Crop diversity	-0.37***	0.22**	-0.14*	0.34***	1.00			
6. Sustainable practice adoption	-0.11	0.48***	0.19**	0.26**	0.54***	1.00		

7. Chemical input intensity	0.29**	-0.36***	0.17*	-0.21**	-0.43***	-0.57***	1.00	
8. Agricultural income	0.08	0.64***	0.52***	-0.04	0.16*	0.42***	-0.27**	1.00

*p<0.05, **p<0.01, ***p<0.001

Table 4 presents the correlation matrix examining relationships between migration intensity (percentage of household members migrated) and various agricultural sustainability indicators. Migration intensity showed a significant negative correlation with land use efficiency (-0.18), labor input (-0.71), and crop diversity (-0.37), suggesting that higher rates of outmigration are associated with reduced agricultural productivity, labor availability, and crop diversification. Conversely, migration intensity was strongly positively correlated with agricultural mechanization (0.63) and moderately with chemical input intensity (0.29), indicating that households experiencing greater migration tend to substitute machinery and chemical inputs for lost labor. Interestingly, migration intensity showed no significant correlation with sustainable practice adoption (-0.11) and agricultural income (0.08), suggesting these factors may be influenced by other variables beyond migration rates. The strongest positive correlations were between agricultural income and land use efficiency (0.64) and between sustainable practice adoption and crop diversity (0.54), highlighting the potential economic and ecological synergies in sustainable farming systems. The negative correlation between chemical input intensity and sustainable practices (-0.57) confirms that households adopting more sustainable approaches tend to reduce chemical dependency, an important indicator of ecological sustainability.

Table 5: Multiple Regression Analysis: Factors Influencing Agricultural Sustainability Score (N=500)

Independent Variables	**Model 1: All Households**	**Model 2: Non-migrant Households**	**Model 3: Current Migrant Households**	**Model 4: Return Migrant Households**
Age of household head	-0.143**	-0.187*	-0.093	-0.212**
Education level	0.232***	0.145*	0.176*	0.354***
Farm size	0.118*	0.162*	0.089	0.127*
Migration intensity	-0.067	-	-0.213**	-
Migration duration	-0.183**	-	-0.297***	-
Return migration experience	0.312***	-	-	-
Urban skill acquisition	0.267***	-	-	0.386***
Remittance amount	0.224***	-	0.352***	0.143*
Access to extension services	0.187**	0.243**	0.112	0.197**
Distance to market	-0.146**	-0.123*	-0.187**	-0.103
R^2	0.438	0.312	0.377	0.492

Adjusted R^2	0.423	0.288	0.354	0.471
F-statistic	32.46***	17.83***	21.42***	29.67***

*p<0.05, **p<0.01, ***p<0.001
Note: Standardized beta coefficients are reported

Table 5 presents multiple regression results examining factors influencing overall agricultural sustainability scores across different household types. In the full sample (Model 1), return migration experience (β=0.312) emerged as the strongest positive predictor of agricultural sustainability, followed by urban skill acquisition (β=0.267) and education level (β=0.232). This suggests that human capital factors, particularly those enhanced through migration experiences, strongly contribute to sustainable agricultural practices. Remittance amount (β=0.224) was also a significant positive predictor, indicating that financial transfers from migrants support sustainable agricultural investments. Conversely, migration duration showed a negative association (β=-0.183), suggesting that prolonged absence may undermine sustainability, while migration intensity itself was not significant when controlling for other factors.

Models 2-4 reveal interesting variations across household types. For current migrant households (Model 3), remittance amount (β=0.352) was the strongest positive predictor, while migration intensity (β=-0.213) and duration (β=-0.297) were significant negative predictors, highlighting the potential trade-offs of ongoing migration. For return migrant households (Model 4), urban skill acquisition (β=0.386) and education (β=0.354) were the strongest predictors, emphasizing the importance of knowledge transfer. The models explained between 31.2% and 49.2% of variance in agricultural sustainability scores, with the highest explanatory power for return migrant households (49.2%), suggesting that the factors included in the model are particularly relevant for understanding sustainability outcomes in this group.

Table 6: Impact of Different Migration Patterns on Agricultural Practices (N=356 migrant households)

Agricultural Practice	Seasonal Migration (n=89)	Long-term Migration (n=267)	t-value	Individual Migration (n=198)	Household Migration (n=158)	t-value
Land left fallow (%)	8.3	22.6	6.84***	12.7	24.1	5.92***
Agricultural machinery investment (¥)	3,276	7,893	7.21***	5,834	6,687	1.87
Hired labor use (days/year)	18.7	32.4	4.36***	28.7	25.3	1.43
Chemical fertilizer use (kg/mu)	25.4	33.8	3.47**	31.7	29.8	0.76
Sustainable practice adoption (count)	2.7	1.6	4.12***	2.3	1.5	3.58***
Land consolidation participation (%)	23.6	45.3	3.95***	32.8	43.7	2.18*
Agricultural income change (%)	-8.3	-18.7	3.68***	-12.4	-19.8	2.75**

*p<0.05, **p<0.01, ***p<0.001

Table 6 compares agricultural practices between different migration patterns, examining both duration (seasonal vs. long-term) and scope (individual vs. household). Significant differences emerged particularly between seasonal and long-term migration. Long-term migrants left substantially more land fallow (22.6% vs. 8.3%), invested more in agricultural machinery (¥7,893 vs. ¥3,276), and hired more labor (32.4 vs. 18.7 days/year), indicating greater agricultural adaptation strategies in response to prolonged absence. Long-term migrants also used significantly more chemical fertilizers (33.8 vs. 25.4 kg/mu) and adopted fewer sustainable practices (1.6 vs. 2.7), suggesting potential negative environmental implications of extended migration. They were also more likely to participate in land consolidation programs (45.3% vs. 23.6%), reflecting a trend toward scale economies in response to labor constraints. Agricultural income declined more severely for long-term migrant households (-18.7% vs. -8.3%), indicating greater challenges in maintaining agricultural productivity despite increased mechanization.

Comparing individual versus household migration reveals similar but less pronounced patterns. Household migration was associated with higher rates of land being left fallow (24.1% vs. 12.7%), greater participation in land consolidation (43.7% vs. 32.8%), and larger declines in agricultural income (-19.8% vs. -12.4%). These findings suggest that migration pattern significantly influences agricultural sustainability outcomes, with seasonal and individual migration generally having less disruptive effects on agricultural practices than long-term or household migration.

Table 7: Regional Comparison of Migration Effects on Agricultural Sustainability (N=500)

Variable	**Eastern Region (n=167)**	**Central Region (n=166)**	**Western Region (n=167)**	**F-value**	**p-value**
Migration rate (%)	58.7	47.3	32.6	15.87	<0.001
Land use efficiency (change %)	+12.4	+3.7	-8.3	11.24	<0.001
Mechanization adoption (1-5 scale)	4.3	3.6	2.7	18.63	<0.001

Land consolidation (% participating)	57.8	42.3	18.7	21.39	<0.001
Agricultural fire incidents (per 100 households)	12.7	23.4	35.8	16.42	<0.001
Return migration effect on sustainability score	+1.87	+1.42	+0.63	9.87	<0.001
Labor shortage severity (1-5 scale)	3.8	3.2	2.4	13.25	<0.001
Sustainable technology adoption (count)	3.8	2.6	1.7	17.92	<0.001

Table 7 compares migration effects on agricultural sustainability across three geographic regions. The eastern region showed the highest migration rate (58.7%), followed by the central (47.3%) and western regions (32.6%). Interestingly, despite having the highest outmigration, the eastern region demonstrated positive changes in land use efficiency (+12.4%) compared to minimal gains in the central region (+3.7%) and declines in the western region (-8.3%). The eastern region also led in mechanization adoption (4.3 on a 5-point scale) and land consolidation participation (57.8%), suggesting more advanced agricultural adaptation to migration. Agricultural fire incidents, which serve as indicators of unsustainable field clearance practices, showed an inverse regional pattern, with the western region experiencing the highest rate (35.8 per 100 households) despite lower migration rates, possibly reflecting less developed agricultural systems. The positive effect of return migration on sustainability scores was strongest in the eastern region (+1.87) and weakest in the western region (+0.63), suggesting regional variations in how effectively return migrants can implement sustainable innovations. The eastern region also reported the highest labor shortage severity (3.8) but led in sustainable technology adoption (3.8 practices), indicating that labor constraints may drive innovation toward sustainability in more developed regions. These regional differences highlight how contextual factors, including economic development levels,

institutional support, and market access, mediate the relationship between migration and agricultural sustainability.

Results and Findings

The analysis of survey data and interviews reveals complex and multifaceted relationships between rural-urban migration and agricultural sustainability in China. Several key findings emerge from this research:

First, the study finds substantial evidence supporting the hypothesis that higher rates of rural-urban migration are associated with increased mechanization and changing land use patterns, but with varied effects on sustainability outcomes. The strong positive correlation between migration intensity and agricultural mechanization ($r=0.63$, $p<0.001$) indicates that households respond to labor shortages by investing in machinery. However, this mechanization does not consistently translate to improved land use efficiency, as evidenced by the negative correlation between migration intensity and land use efficiency ($r=-0.18$, $p<0.01$). This suggests that while technology adoption occurs, it may not fully compensate for lost agricultural knowledge and labor, particularly in regions with lower development levels.

Second, the research confirms significant differences in agricultural sustainability outcomes based on migration patterns. Seasonal migration shows less disruptive effects on agricultural practices compared to long-term migration, with seasonal migrants maintaining higher levels of sustainable practice adoption (2.7 vs. 1.6 practices) and experiencing smaller declines in agricultural income (-8.3% vs. -18.7%). This finding highlights the importance of circular and temporary migration in maintaining agricultural continuity while allowing households to diversify income sources.

Third, return migration emerges as a critical factor in enhancing agricultural sustainability. Return migrant households demonstrated the highest land use efficiency (458.7 kg/mu), the most sustainable practice adoption (3.6 practices), and the highest agricultural income (¥27,359). The regression analysis confirms that return migration experience is the strongest predictor ($\beta=0.312$, $p<0.001$) of overall agricultural sustainability scores when controlling for other factors. This supports the second hypothesis that return migrants transfer knowledge, capital, and innovative practices acquired during their urban experiences back to rural areas.

Fourth, remittances play a significant but complex role in agricultural sustainability. While remittance amount positively predicted sustainability scores overall ($\beta=0.224$, $p<0.001$), its effect varied across household types, with the strongest impact among current migrant households ($\beta=0.352$, $p<0.001$). Qualitative interviews revealed that remittances were commonly invested in agricultural machinery (62% of respondents), improved seed varieties (54%), and irrigation infrastructure (43%), but less frequently in ecological practices or sustainable technologies (27%), suggesting potential for redirecting remittance investments toward more sustainable outcomes.

Fifth, regional variations in migration-sustainability relationships were substantial. The eastern region, despite having the highest migration rates (58.7%), showed positive changes in land use efficiency (+12.4%) and led in sustainable technology adoption (3.8 practices), while the western region experienced negative efficiency changes (-8.3%) despite lower outmigration. This suggests that contextual factors including market access, institutional support, and baseline development levels significantly mediate how migration affects agricultural sustainability.

Finally, the research identified several key mechanisms through which migration influences agricultural sustainability:

- Labor substitution through mechanization and chemical inputs
- Knowledge transfer and innovation diffusion through return migrants
- Capital injection through remittances
- Land use reorganization through abandonment, consolidation, or intensification
- Shifting agricultural priorities toward labor-efficient but potentially less diverse production systems

These findings highlight that migration's impact on agricultural sustainability is neither uniformly positive nor negative but rather context-dependent and mediated by household characteristics, migration patterns, regional factors, and policy environments.

Suggestions

Based on the research findings, several recommendations can be made to enhance the positive impacts of rural-urban migration on agricultural sustainability while mitigating negative effects:

Implement Targeted Hukou Reforms: Policy reforms should focus on reducing barriers for migrants while maintaining connections to rural areas. Relaxing residency restrictions for migrants in small and medium-sized cities, as implemented in Zhejiang province, could allow for more circular migration patterns that benefit agricultural sustainability. A gradual approach to hukou reform that maintains land rights while increasing urban access would support more flexible migration that benefits both urban and rural economies.

Develop Return Migrant Support Programs: Given the positive impact of return migrants on agricultural sustainability, specialized programs should be developed to support their reintegration into agricultural production. These could include preferential access to agricultural loans, targeted technical training, and pilot demonstrations of innovative sustainable practices. Establishing "Return Migrant Agricultural Innovation Centers" in key rural areas could serve as knowledge hubs and demonstration sites.

Enhance Agricultural Extension Services for Left-Behind Farmers: Specialized extension services should be developed for households with migrant members, focusing on labor-efficient sustainable technologies and practices. These services should be tailored to the specific needs of elderly farmers, women farmers, and those with limited education who often become primary agricultural decision-makers when others migrate.

Promote Mechanization Appropriate for Sustainable Agriculture: While mechanization adoption is already occurring in response to migration, policies should guide this process toward environmentally sustainable equipment and practices. Subsidies for energy-efficient machinery, precision agriculture technologies, and equipment suitable for conservation agriculture could align mechanization trends with sustainability goals.

Develop Rural Cooperative Systems and Land Transfer Mechanisms: To address labor shortages and abandoned land issues, further development of formal and transparent land transfer systems could support land consolidation while protecting farmers' rights. Cooperative farming arrangements can allow migrant households to maintain land rights while ensuring productive use of agricultural land.

Create Integrated Rural-Urban Development Strategies: Rather than treating rural and urban development as separate domains, integrated strategies that recognize their interconnectedness could better leverage migration for sustainable development. This includes developing small cities and towns near agricultural areas, investing in rural infrastructure, and creating non-farm employment opportunities in rural regions.

Redirect Remittance Investments Toward Sustainable Practices: Financial education programs and targeted subsidies could help channel remittances toward investments in sustainable agricultural practices rather than solely conventional inputs or consumption. Green credit programs specifically for migrant households could offer preferential terms for sustainability-enhancing investments.

Address Regional Disparities Through Differentiated Policies: Given the significant regional variations in migration-sustainability relationships, policies should be tailored to regional contexts. Western regions may require more basic agricultural extension and infrastructure development, while eastern regions might benefit from advanced sustainable technology promotion and market integration.

Implications

This research has several important implications for theory, practice, and policy related to rural-urban migration and agricultural sustainability in China:

Theoretical Implications: The findings challenge simplistic narratives about the relationship between migration and agricultural development, demonstrating that outcomes are neither uniformly positive nor negative but are instead mediated by multiple factors at household, community, and regional levels. The research contributes to migration theory by highlighting the importance of circular and return migration in creating knowledge feedback loops that can enhance rural innovation. It also extends sustainable livelihood frameworks by demonstrating how population mobility can reconfigure the five capitals (human, natural, physical, financial, and social) in ways that either enhance or undermine agricultural sustainability.

Practical Implications for Farmers and Communities: For rural households and communities, the research highlights the value of maintaining agricultural knowledge and practices even during

migration periods, as this facilitates more successful reintegration and innovation upon return. The findings suggest that households can maximize benefits by adopting strategic migration patterns (such as seasonal or staggered family migration) that maintain sufficient agricultural labor while diversifying income. Communities can benefit from establishing knowledge-sharing mechanisms between return migrants and current farmers to facilitate innovation diffusion.

Policy Implications for Sustainable Development: The research has direct relevance to China's pursuit of SDG 2 (Zero Hunger) and SDG 15 (Life on Land) in the context of ongoing urbanization. The findings suggest that rather than viewing migration as a threat to agricultural sustainability, policies can leverage migration as a potential catalyst for agricultural modernization and sustainable transitions. This requires coordinated policy approaches across multiple domains including land rights, rural finance, agricultural extension, and urban integration of migrants.

Institutional Development Implications: The research highlights the need for institutional development in several areas: more flexible land transfer systems, improved agricultural extension services tailored to changing rural demographics, financial mechanisms to channel remittances toward sustainable investments, and platforms for knowledge exchange between urban and rural areas. These institutional innovations could help convert the potential benefits of migration into actual improvements in agricultural sustainability.

Rural Revitalization Strategy Implications: The findings provide support for China's rural revitalization strategy but suggest refinements to better integrate migration dynamics. Rather than focusing solely on retaining population in rural areas, the strategy could more explicitly acknowledge and leverage the benefits of circular migration and knowledge transfer from urban to rural areas, while simultaneously developing rural areas to make them attractive for both permanent residents and return migrants.

Global Development Implications: Beyond China, this research has implications for other developing countries experiencing rural-urban migration. The findings suggest that development strategies should not view urban and rural development as separate domains but rather as interconnected processes where managed migration can potentially benefit both spheres. The identified mechanisms through which migration affects agricultural sustainability could inform rural development approaches in other contexts experiencing similar demographic transitions.

Limitations

This research has several limitations that should be acknowledged when interpreting the findings:

Cross-sectional Design: The study's cross-sectional nature limits causal inference about the relationships between migration and agricultural sustainability. While statistical associations and qualitative insights suggest certain causal mechanisms, longitudinal research would provide stronger evidence of how these relationships evolve over time.

Self-Reporting Bias: The reliance on self-reported data for many variables introduces potential reporting biases, particularly for sensitive topics like income, remittances, and agricultural practices. While efforts were made to triangulate information through multiple questions and observational data, some measurement error likely remains.

Regional Coverage: While the study included six provinces representing different regions of China, it cannot capture the full diversity of China's agricultural systems and migration patterns. Some unique regional contexts may not be adequately represented in the findings.

Seasonality Effects: Data collection occurred between October 2024 and February 2025, which may introduce seasonal biases in reporting of agricultural practices and migration patterns. A full-year study would better capture seasonal variations in these relationships.

Limited Ecological Measurements: The study relied primarily on reported practices rather than direct ecological measurements (such as soil quality, biodiversity, or emissions) to assess environmental sustainability. More direct environmental indicators would strengthen the assessment of ecological dimensions.

Sample Selection: Despite random sampling within villages, the selection of provinces and counties may introduce some bias, and the requirement that respondents be available for interviews may underrepresent the most mobile households.

Complexity of Sustainability: Agricultural sustainability is multidimensional and difficult to capture comprehensively in a single study. While we included multiple indicators, some aspects of sustainability may not be fully represented in our measurements.

Policy Implementation Lag: The study captures a specific moment in China's ongoing rural-urban transition. Rapid policy changes related to urbanization, land rights, and agricultural support may alter the relationships identified in this research.

Scope of Future Research

Building on this study's findings and acknowledging its limitations, several promising avenues for future research emerge:

Longitudinal Studies: Developing panel studies tracking the same households over time would provide stronger causal evidence about how migration decisions affect agricultural practices and sustainability outcomes. Such studies could capture the dynamic nature of these relationships as households move through migration cycles.

Comparative Research: Extending this research to compare migration-agriculture relationships across different developing countries could reveal which patterns are specific to China's institutional context and which represent more universal processes of rural-urban transition.

Technological Innovation Pathways: More detailed research is needed on how specific technological innovations diffuse from urban to rural areas through migrant networks, including the role of digital technologies, social media, and formal knowledge transfer mechanisms.

Environmental Impact Assessment: Future studies should incorporate direct environmental measurements to better quantify the ecological outcomes of different agricultural practices associated with migration, including soil health, water quality, and biodiversity impacts.

Policy Effectiveness Evaluation: Rigorous evaluation of policies designed to leverage migration for agricultural sustainability, such as return migrant support programs or remittance investment incentives, would provide evidence for scaling effective interventions.

Gender Dimensions: More focused research on the gendered aspects of migration and agricultural decision-making would illuminate how changing household structures affect women's roles in agriculture and related sustainability outcomes.

Intergenerational Effects: Research examining how migration affects the next generation's engagement with agriculture and sustainability practices would provide insights into the long-term trajectory of China's rural transition.

Climate Change Adaptation: Future studies should explore how migration-induced changes in agricultural practices affect resilience to climate change and whether migrant knowledge networks enhance adaptive capacity in rural areas.

Urban Food Systems Connections: Research examining the linkages between rural-urban migration and changing urban food demands could reveal potential feedback loops that influence agricultural sustainability in rural source regions.

Conclusion

This comprehensive examination of rural-urban migration's influence on agricultural sustainability in China reveals a complex and nuanced relationship with significant implications for sustainable development. Rather than producing uniformly positive or negative outcomes, migration creates a spectrum of effects mediated by household characteristics, migration patterns, regional contexts, and institutional environments.

The research confirms that migration significantly reconfigures agricultural systems through multiple mechanisms: labor reallocation drives mechanization and input substitution; knowledge transfer through return migrants facilitates innovation; remittances provide capital for agricultural investments; and land use patterns shift toward either consolidation or abandonment. These changes create both opportunities and challenges for sustainable agriculture and food security.

A key finding is the critical role of return migrants as potential agents of agricultural sustainability. Households with return migration experience demonstrated superior performance across multiple sustainability indicators, suggesting that circular migration patterns that facilitate knowledge and capital transfer between urban and rural areas may offer pathways to enhance agricultural sustainability. This challenges simplistic narratives about migration leading to agricultural decline and suggests potential for leveraging migration within sustainable development strategies.

Regional disparities in how migration affects agricultural sustainability highlight the importance of context-sensitive approaches. The eastern region demonstrated that high migration rates can coincide with agricultural innovation and efficiency gains when supported by appropriate infrastructure, markets, and institutions. Conversely, western regions showed more vulnerable agricultural systems that experienced greater difficulties adapting to outmigration, suggesting the need for regionally differentiated policy approaches.

The research also identifies significant policy implications for China's pursuit of Sustainable Development Goals, particularly SDG 2 (Zero Hunger) and SDG 15 (Life on Land). Strategic policy interventions—including hukou reforms that facilitate circular migration, support programs for return migrants, specialized extension services for left-behind farmers, and mechanisms to channel remittances toward sustainable investments—could enhance the positive contributions of migration to agricultural sustainability.

As China continues its rural-urban transition, the pathways identified in this research offer potential approaches to balance urbanization imperatives with agricultural sustainability goals. By recognizing the interconnectedness of rural and urban development and designing policies that facilitate beneficial rural-urban interactions, China has the opportunity to transform migration from a challenge for agricultural sustainability into a catalyst for rural revitalization and sustainable food systems.

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