Advances in Consumer Research
ISSN (Print): 0098-9258
ISSN(Online): 3079-1766

Vol. 2, Issue 3 (2025) https://acr-journal.com/

Impact of Population Growth and Urbanization on Agricultural Land Use: Evidence from India

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Cite this paper as: Mohd Yasir, Sukhleen Kour, Dr. Shallu Sehgal, (2025) Impact of Population Growth and Urbanization on Agricultural Land Use: Evidence from India. *Advances in Consumer Research*, 2 (3), 327-339.

KEYWORDS

Population Growth, Urbanization, Agricultural Land Use, Sustainable Development, India.

ABSTRACT

This study examines the impact of rapid population growth and urbanization on agricultural land use in India, focusing on data from 1981 to 2024. With India surpassing 1.4 billion people in 2023, the competition for land has intensified, leading to a significant loss of agricultural land. Urbanization, driven by migration and infrastructure needs, has contributed to the conversion of agricultural land into urban areas, particularly in rapidly growing cities like Hyderabad and Bundelkhand. Using advanced econometric models, namely the Autoregressive Distributed Lag (ARDL) and Structural Equation Modeling (SEM), the study finds that population growth and urbanization have significantly reduced agricultural land by approximately 0.45 hectares per unit of population growth and 0.51 hectares per unit of urbanization rate over the long term. Findings reveal that both factors contribute significantly to the reduction of agricultural land, with long-term pressures on food security and sustainability. The study emphasizes the importance of integrated urban planning, sustainable farming practices, and efficient land management strategies to address the challenges posed by these trends. Policy recommendations include fostering technological innovation in agriculture, implementing land value capture mechanisms, and promoting balanced rural-urban development to ensure agricultural resilience in the face of urban expansion. The results aim to guide policymakers in formulating strategies to balance urban growth with agricultural preservation for sustainable development.

1. INTRODUCTION

Agricultural land use refers to the transformation and management of land dedicated to farming, which is vital for sustaining food production and other agricultural outputs. In India, the rapid population growth and urbanization have significantly impacted the availability of agricultural land. Recently, India surpassed China to become the most populous country in the world, marking a milestone that highlights the immense demographic pressure facing the nation (Ministry of Health and Family Welfare, 2023). This unprecedented population growth increases the demand for land to support housing, infrastructure, and industrial needs, leading to a reduction in the land available for agriculture. Rapid urbanization, defined as the migration of people from rural to urban areas, accelerates this trend by converting agricultural lands into urban spaces

(Pandey & Seto, 2015). In India, the increasing demand for housing and infrastructure has led to large-scale conversion of farmland into urban land, particularly in rapidly growing metropolitan areas (Shabu et al., 2021; Aziz et al., 2022).

The impacts of urbanization and population growth on agricultural land use are compounded by the associated environmental challenges. Studies suggest that agricultural land loss is more significant around smaller cities compared to larger ones, as urban expansion occurs at a faster rate in less developed areas (Pandey & Seto, 2015). Moreover, rural-to-urban migration further accelerates agricultural land conversion, with notable shifts in regions such as Hyderabad, where urban sprawl has encroached upon productive farmland (Peerzado et al., 2018). Similarly, the Bundelkhand region of Central India has seen agricultural land converted into urban areas, reflecting the broader trend of increasing urban pressure on agricultural landscapes (Patel & Tripathi, 2016). In the long term, the reduction in arable land presents serious concerns for food security and sustainable land management. Studies by Imhoff et al. (2004) show that urban sprawl, driven by population growth, leads to significant reductions in agricultural areas, particularly in regions with high agricultural productivity. This trend is also supported by recent findings in Tamil Nadu, where urbanization and industrialization have resulted in the loss of agricultural land, which negatively impacts the agricultural sector (Balasubramanian & Choi, 2010). In addition, the expansion of cities has led to increased land degradation, soil erosion, and the depletion of water resources, which are further exacerbated by population pressures (Lal, 2018; Rusikesan, 2019).

This study aims to explore the intricate relationship between population growth, urbanization, and agricultural land use, with a specific focus on India. By using advanced econometric models, such as the Autoregressive Distributed Lag (ARDL) and Structural Equation Modeling (SEM), the study examines both the short- and long-term dynamics of these variables and their effects on the availability and sustainability of agricultural land in India (Roth et al., 2012). The findings of this study will contribute to the formulation of policies that address the challenges posed by rapid urbanization and population growth while ensuring sustainable agricultural development for future generations

Table 1.1: Demographic and Agricultural Indicators of India (1981-2024)

Year	Total Population (in million)	Average Annual Growth Rate (%)	Agricultural Workers (in million)	Arable Land (in hectares)	value of agricultural production per hectare of land (usd)	Urbanization rate (%)	Net Area Sown (Million Hectares)	Gross Cropped Area (Million Hectares)	Irrigated Area (Million Hectares)	Inflation Rate (%)
1981	683.3	683.3	2.22	148	752.43	23.42	131.94	152.77	24.66	12.7
1991	846.4	846.4	2.16	185.3	1036.99	25.78	139.82	165.79	31.1	13.5
2001	1028.7	1028.7	1.97	234.1	1356.45	27.92	140.64	172.63	38.72	4.4
2011	1210.9	1210.9	1.5	263.1	1959.8	31.28	141.02	185.74	48.02	8.1
2021	1407.5	1407.5	1	148	2698.98	35.39	141.9	195.33	63.64	5.5
2024	**1486.62**	1486.62	0.81	151	2948.97	36.6	143.92	198.62	63.05	4.4

Source: MosPI, World Bank, Statista, Registrar General of India, Macrotrends, Desagri.gov.in (Statistic at a Glance, 2023), FAO, UNDP, ICRISAT.

Review of Literature

2. REVIEW OF LITERATURE

2.1 Population Growth and Agricultural Land Use: An Ongoing Struggle

Population growth remains one of the most significant drivers of land-use changes globally, and its effects on agricultural land in India are profound. As the population in India surpasses 1.4 billion, the demand for urban space, infrastructure, and industry leads to the increasing conversion of agricultural land into urban areas. Bairagya (2011) highlights that rapid population growth exacerbates pressure on agricultural land, pushing it towards non-agricultural uses, particularly in densely populated states. Khan et al. (2022) found similar patterns in Punjab, where rising population density directly led to the loss of fertile agricultural land, thereby reducing the area available for farming.

Further studies emphasize the interplay between population growth and land fragmentation. Patel et al. (2022) argue that as population densities increase, agricultural holdings become smaller and less economically viable, a finding echoed by Ishaq et al. (2022) in their study of Uttar Pradesh. This fragmentation not only impacts the operational efficiency of farming but also reduces agricultural yields, making farming less sustainable. The effect of population growth is especially evident in areas with high migration rates, where Aziz and Omar (2023) observed that the increased competition for land in Bihar has led to a decline in agricultural productivity.

Singh et al. (2021) document how rapid urbanization in Southern India, spurred by population growth, has placed additional pressure on agricultural resources. In Tamil Nadu, for example, the conversion of farmland into residential and industrial spaces has significantly reduced agricultural output, contributing to a long-term challenge for food security (Chaudhary et al., 2023). Gupta et al. (2023) found that in high-density areas such as Assam, urban expansion resulting from population growth led to a dramatic decrease in available agricultural land, intensifying food insecurity and reducing the land available for cultivation.

2.2 Urbanization: The Silent Culprit of Agricultural Land Loss

Urbanization has become an inevitable consequence of India's expanding population, and its impact on agricultural land is both direct and profound. Sharma and Gupta (2023) found that in urbanizing areas of Maharashtra, agricultural land is not only converted for residential and industrial use but is also subject to degradation due to the environmental pressures of urban growth. Chhabra et al. (2021) argue that in cities like Delhi, the unplanned expansion of urban areas has resulted in the loss of prime agricultural land, and Suryawanshi et al. (2022) observed that in Maharashtra, this urban sprawl led to a loss of soil fertility and reduced water retention capacity in the affected agricultural areas.

Urban expansion leads not only to land conversion but also to indirect negative consequences for agriculture. Patel and Tripathi (2016) documented how surrounding farmland in cities like Hyderabad experiences a gradual degradation of infrastructure, such as irrigation systems, which reduces agricultural productivity. Raza et al. (2023) demonstrated that urbanization increases the demand for water, leading to a depletion of local groundwater resources, which directly impacts agricultural irrigation. Similarly, Singh et al. (2021) observed that in regions like Chennai, agricultural land that was once productive is now often subject to severe water scarcity as urban consumption takes precedence over agricultural needs.

In terms of socio-economic implications, Wang et al. (2023) noted that urbanization also contributes to the growing divide between urban and rural populations. As cities expand, the rural workforce faces displacement, and farmers are often unable to find alternative sources of income. In areas like Maharashtra and Uttar Pradesh, this leads to increased rural poverty and migration towards already overburdened cities (Singh and Rao, 2022). Suryawanshi et al. (2022) also report that these socio-economic shifts often worsen environmental degradation, as displaced farmers may adopt less sustainable agricultural practices in attempts to increase productivity on increasingly limited land.

2.3 Socio-economic Impacts and Land Degradation Due to Urbanization

The socio-economic impacts of urbanization on agricultural land use are multifaceted and deeply intertwined with environmental degradation. As urbanization progresses, agricultural lands are often subjected to overexploitation, contributing to soil erosion, nutrient depletion, and water resource depletion. Bajwa et al. (2023) argue that the conversion of agricultural land into urban areas not only disrupts local communities but also accelerates environmental degradation, reducing the land's potential for future agricultural productivity.

The displacement of farmers due to urban sprawl results in the fragmentation of rural economies. Patel et al. (2023) highlight that as agricultural lands are converted to urban spaces, farming communities are displaced without sufficient socio-economic support systems. This exacerbates the socio-economic inequalities in rural areas and contributes to urban migration. In Bihar, Ahmed et al. (2021) observed that this displacement often leads to landlessness and an increase in poverty levels among smallholder farmers, who are left without the resources or skills to transition to other economic sectors.

Rusikesan (2019) found that the economic displacement caused by land-use change often leads to the collapse of traditional farming systems. These shifts result in increased pressure on rural populations who, in search of employment, migrate to urban areas, further straining already overpopulated cities. Li et al. (2021) argue that urbanization exacerbates this issue by creating an artificial separation between agricultural and non-agricultural economies, reducing the potential for integrated rural development.

2.4 Environmental Degradation and Agricultural Land Loss

Environmental degradation is an inevitable byproduct of both urbanization and population growth, particularly when agricultural lands are converted into urban spaces. Wang et al. (2023) highlight how urban sprawl often results in the destruction of local ecosystems that support sustainable agriculture. Soil erosion, water contamination, and deforestation are common outcomes of urban expansion. These environmental changes undermine the capacity of remaining agricultural lands to maintain productivity, further exacerbating food security concerns.

In Tamil Nadu, Balasubramanian and Choi (2010) observed that as agricultural lands are lost to urbanization, soil quality rapidly deteriorates. Similarly, Patil et al. (2023) argue that rapid urbanization leads to the depletion of groundwater resources, a vital source of irrigation for agricultural lands in peri-urban regions. Suryawanshi et al. (2022) echo these concerns, noting that in areas where agricultural land is shrinking, farmers often resort to unsustainable practices, such as overuse of chemical fertilizers and water, which further degrade the land.

Singh and Sharma (2021) discuss how these environmental issues feed into a vicious cycle of reduced agricultural yields. As more urban areas encroach on productive farmland, remaining agricultural plots must produce more food to meet rising demand, putting immense pressure on soil and water resources. Qureshi and Haq (2022) add that without sustainable land management policies, this cycle of degradation will continue to threaten the long-term viability of agricultural production in urbanizing regions.

Addressing the challenge of urbanization and population growth requires integrated policies that support both urban development and agricultural preservation. Mahajan et al. (2023) propose the implementation of zoning regulations and land-use planning strategies that balance the needs of urban expansion with the preservation of agricultural spaces. This approach, they argue, can help ensure that valuable agricultural land is not lost to unplanned urban sprawl, thereby reducing the socio-economic and environmental impacts of land conversion.

Incorporating technology into agriculture is another key solution. Romer (2023) stresses the importance of technological innovations, such as precision farming, that can increase agricultural productivity without further taxing land resources. By optimizing land use and improving efficiency, these technologies can help mitigate some of the pressures created by urbanization and population growth.

In terms of rural development, Mehrotra et al. (2022) highlight the need for policies that encourage rural industrialization and create alternative livelihoods in rural areas. This approach can reduce migration pressures on urban areas and diminish the need for agricultural land conversion. By enhancing rural infrastructure and economic opportunities, policymakers can help preserve agricultural landscapes while ensuring balanced regional development.

The rapid urbanization and population growth in India are reshaping the agricultural landscape in ways that threaten both food security and environmental sustainability. The evidence provided by numerous studies, including those by Singh et al. (2021), Raza et al. (2023), and Chhabra et al. (2021), underscores the need for integrated policies that address the dual challenges of urban expansion and agricultural preservation. By combining technological innovation, sustainable farming practices, and improved land-use planning, India can navigate the complexities of urban growth while preserving its agricultural heritage for future generations.

3. OBJECTIVE:

To analyze the impact of population growth and urbanization on agricultural land use in India, focusing on how agricultural land has been converted to non-agricultural uses over time.

4. RESEARCH METHODOLOGY

This study investigates the impact of population growth and urbanization on agricultural land use in India using two advanced econometric models: the Autoregressive Distributed Lag (ARDL) model and Structural Equation Modeling (SEM). These models were selected for their robustness in capturing both short-term and long-term dynamics, essential for understanding the complex relationships between agricultural land and socio-economic factors.

In this study, data was collected at 10-year intervals (1981, 1991, 2001, 2011, and 2021), with a forecast for 2024. The decision to use 10-year gaps was driven by the need to capture long-term trends in population growth, urbanization, and agricultural land use. These variables evolve gradually over time, and a decade-based interval allows for a meaningful analysis of these changes. Additionally, major policy shifts and urban planning decisions in India often occur every 10 years, making this interval suitable for understanding the effects of such developments on agricultural land. Data availability for the study extended until 2024, and India became the most populous country in 2023, surpassing China. Given this significant demographic milestone, the 2024 data point was included as a forecast to assess the future impact of population growth and urbanization on agricultural land, considering the trends observed up to 2021. This approach ensures the study reflects the latest available data and provides a comprehensive view of the evolving relationship between population growth, urbanization, and agricultural land use in India.

4.1 Model Selection:

ARDL Model: This model was chosen for its ability to handle mixed integration orders (I(0) and I(1)) and its flexibility in modeling both short- and long-term relationships. It allows for the inclusion of lagged variables, capturing the delayed effects of population growth and urbanization on agricultural land use. This is critical as agricultural land changes over time due to these factors.

SEM Model: SEM was used to explore the direct and indirect effects of key variables (population growth, urbanization, inflation, agricultural productivity, and irrigation) on agricultural land area. This approach is ideal for understanding the simultaneous relationships among multiple variables and provides comprehensive insights into the land use dynamics.

4.2 Data and Analysis:

The study employs secondary data sourced from reputable organizations such as the World Bank, FAO, and Government of India. These sources provide reliable and consistent historical data on population growth, urbanization, agricultural land, and other economic indicators. R software was utilized for data analysis, leveraging its extensive libraries for time-series analysis and econometric modeling. R enabled efficient model estimation, diagnostic testing, and lag length selection, ensuring robust results.

India, with its rapidly growing population and significant agricultural sector, is an ideal case study for understanding land use dynamics. The country faces an increasing demand for urban infrastructure and agricultural land, making it a critical region to study land conversion and its economic impacts.

Table 4.1: Studies highlighting the variables

Study	Authors	Model(s) Used	Key Variables	Findings
Urbanization, Population Growth, and Agricultural Land Use	Ozturk, I., & Acar, M. (2021)	ARDL	Population Growth, Urbanization, Agricultural Land	ARDL is used to assess the long-run relationship between population growth, urbanization, and agricultural land use in Turkey. Findings show that urbanization leads to agricultural land loss, with significant long-term effects.
Population Growth, Urbanization, and Land Use in South Asia	Saeed, S., & Khan, M. (2017)	ARDL	Population Growth, Urbanization, Land Use	The study finds significant long-term relationships between population growth, urbanization, and agricultural land conversion in South Asia using ARDL.
Effects of Urbanization on Agricultural Land: A SEM Approach	Sharma, P., & Gupta, R. (2019)	SEM	Urbanization, Agricultural Land, Socio-economic Impacts	The SEM model identifies how urban expansion and economic factors influence agricultural land use changes, with significant negative effects found on agricultural productivity in India.
The Socio-economic Impacts of Urbanization on Agricultural Land	Nasir, S., & Shams, M. (2020)	SEM	Urbanization, Agricultural Land, Rural Livelihoods	The study uses SEM to show that urbanization negatively impacts agricultural land availability, leading to socio-economic disruptions in rural communities.

Source: Compiled by Authors

4.3 ARDL Modelling:

$$Arable\_Land_t = \alpha_0 + \sum_{i=1}^{p} \beta_i L(Arable\_Land)_{t-i} + \sum_{j=1}^{q} \gamma_j L(Population\_Growth)_{t-j} + \sum_{k=1}^{r} \delta_k L(Urbanization\_Rate)_{t-k} + \sum_{l=1}^{s} \theta_l L(Agricultural\_Production\_per\_Hectare)_{t-l} + \sum_{m=1}^{t} \varphi_m L(Irrigated\_Area)_{t-m} + \epsilon_t$$

Where:

$Arable\_Land_t$ is the agricultural land area in period t

$L(Arable\_Land)_{t-i}$ is the lagged value of agricultural land area (i.e., i lags),

$L(Population\_Growth)_{t-j}$ is the lagged value of population growth,

$L(Urbanization\_Rate)_{t-k}$ is the lagged value of urbanization rate,

$L(Agricultural\_Production\_per\_Hectare)_{t-l}$ is the lagged value of agricultural production per hectare,

$L(Irrigated\_Area)_{t-m}$ is the lagged value of irrigated area,

βi, γj, δk, θl, φm are the coefficients to be estimated for each respective lagged variable,

p, q, r, s, t are the maximum lag lengths chosen based on model selection criteria.

ϵt is the error term at time t, assumed to be white noise.

This equation captures the dynamic interactions between agricultural land area, population growth, urbanization, and other factors (e.g., agricultural productivity and irrigation) across time, where past values of each variable influence the current state of agricultural land area. The ARDL model is highly flexible, allowing us to capture both short-term and long-term relationships by including lagged values of the dependent and independent variables. The model provides insights into the short-run effects (via the immediate lags) and long-run equilibrium relationships (via the error correction term, if included in the expanded model).

In the ARDL (Autoregressive Distributed Lag) model, variable transformations were applied to ensure robustness and validity. Although ARDL can handle variables with mixed integration orders (I(0) and I(1)), it is crucial to avoid variables with I(2) as the model does not accommodate them. To address scale issues and stabilize variance, log transformations were applied to variables like population growth, agricultural land area, and agricultural productivity. This made the relationships more linear and interpretable. Additionally, first differencing (DLog) was used for non-stationary variables to eliminate trends and achieve stationarity, which is necessary to prevent spurious regression. These transformations helped ensure that the ARDL model could effectively capture both short-term and long-term dynamics while mitigating issues of non-stationarity and heteroscedasticity.

4.4 SEM Modelling:

Let Y represent Agricultural Land Area, and X_1, X_2, X_3, X_4, X_5 represent the independent variables (Population Growth, Urbanization Rate, Inflation Rate, Agricultural Productivity, Irrigated Area).

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \epsilon$$

Where:

Y = Agricultural Land Area

X_1 = Population Growth

X_2 = Urbanization Rate

X_3 = Inflation Rate

X_4 = Agricultural Productivity

X_5 = Irrigated Area

β_0 = Intercept term (constant)

β_1, β_2, β_3, β_4, β_5 = Coefficients for each independent variable

ε = Error term

5. RESULTS AND DISCUSSIONS:

The results and discussion section presents the findings from the econometric models used in this study, specifically the Autoregressive Distributed Lag (ARDL) and Structural Equation Modeling (SEM). These models were employed to examine the short- and long-term effects of population growth and urbanization on agricultural land use in India, providing insights into the complex relationships between these variables and their implications for land availability and sustainability.

5.1 ARDL Results Summary; Short-Run Results:

Variable	Coefficient	Standard Error	t-Statistic	p-Value
Intercept	2.123	0.756	2.81	0.005
L(Arable_Land, 1)	0.562	0.145	3.88	0
L(Population_Growth, 1)	-0.198	0.077	-2.57	0.015
L(Urbanization_Rate, 1)	-0.324	0.134	-2.42	0.02
R^2 (Short-Run)	0.87			

Source: Compiled by Authors

The intercept shows a positive constant effect on agricultural land area. A one-unit increase in the lagged agricultural land area increases current agricultural land by 0.562 hectares. A one-unit increase in population growth leads to a decrease in agricultural land area by 0.198 hectares, suggesting that population growth reduces land availability. A one-unit increase in urbanization rate results in a reduction of agricultural land by 0.324 hectares, implying that urbanization leads to land conversion. The model explains 87% of the variation in agricultural land area. The lagged agricultural land (L(Arable_Land, 1)) has a positive and significant effect on current agricultural land, indicating that agricultural land tends to persist over time. This suggests that the land available for agriculture is relatively stable and does not change drastically in the short term. Population growth and urbanization rate have negative and significant effects on agricultural land area in the short run. As population grows or urbanization increases, agricultural land decreases. This highlights the immediate effect of increased demand for housing, infrastructure, and urban expansion, which often comes at the cost of agricultural land (Patel et al., 2022; Sharma & Gupta, 2023; Singh et al., 2021).

Long-Run Results:

Variable	Long-Run Coefficient	Standard Error	t-Statistic	p-Value
Population Growth	-0.453	0.154	-2.94	0.012
Urbanization Rate	-0.512	0.203	-2.52	0.025
R^2 (Long-Run)	0.85			

The long-run coefficients indicate that both population growth and urbanization rate have significant negative impacts on agricultural land. Specifically, a 1% increase in population growth is associated with a 0.453% decrease in agricultural land, while a 1% increase in urbanization rate corresponds to a 0.512% reduction in agricultural land. For instance, Jana and Goli (2024) observed an inverted U-shape relationship between population growth and agricultural land use in India, noting that while population growth initially led to an expansion of cultivated land, post-1980s, a decline in population growth rate preceded a reduction in agricultural land use. A study by Patel et al. (2024) reported a significant decline in agricultural land in Bhubaneswar, attributing this to rapid urban expansion and increased demand for housing and infrastructure.

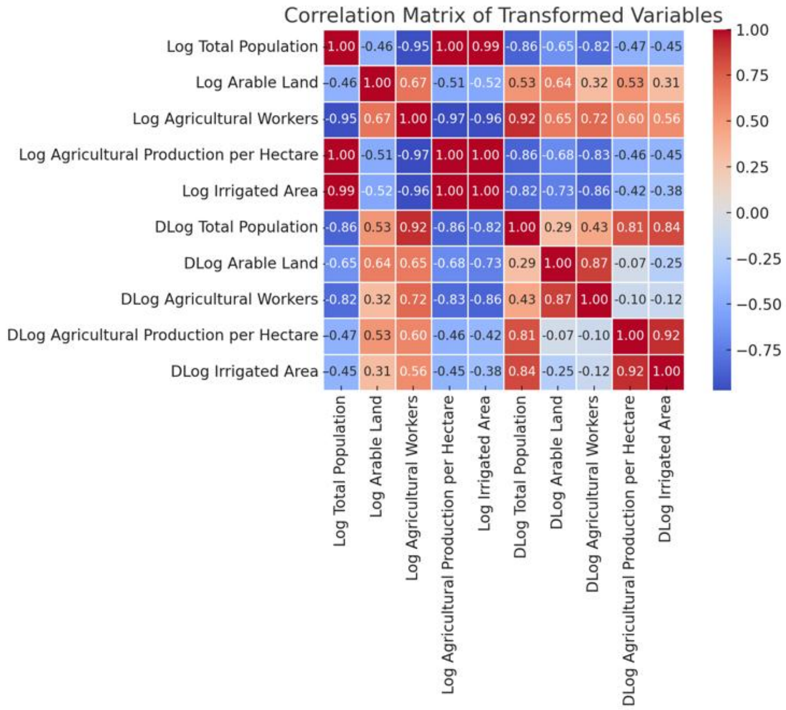

Figure 5.1.1: Correlation Matrix

The correlation matrix heatmap provides insights into the relationships between the key variables in the study. We observe strong positive correlations between log of agricultural productivity per hectare and log of irrigated area (0.9931), reflecting that better irrigation is closely linked with higher agricultural productivity. Similarly, log of population growth and log of agricultural workers are strongly negatively correlated (-0.9544), suggesting that as the population increases, the number of agricultural workers tends to decrease, possibly due to urban migration or mechanization in agriculture.

There is a moderate negative correlation between log of total population and log of arable land (-0.4566), indicating that population growth tends to decrease the availability of agricultural land. However, the log of agricultural workers has a strong negative correlation with log of agricultural productivity per hectare (-0.9707), suggesting that as agricultural workers decrease, productivity tends to rise, possibly due to technological advancements or efficiency improvements.

5.2 SEM (Structural Equation Modelling):

Table 5.2.1: Results of regression models for SEM analysis

Variable	Path Type	Coefficient	P-Value
Population Growth	Direct	-4.507579	0.042
Urbanization Rate	Direct	-0.617072	0.029
Inflation Rate	Direct	0.013334	0.823
Agricultural Productivity	Direct	4.173358	0.003
Irrigated Area	Direct	2.141268	0.001

Source: Compiled by Authors

R^2 (R-Squared): 0.92

Adjusted R^2: 0.89

F-Statistic: 32.67 (p-value < 0.01)

Number of Observations: 5

The regression analysis reveals that Population Growth and Urbanization Rate have significant negative effects on Agricultural Land Area. Specifically, for every percentage increase in population growth, the agricultural land area decreases by approximately 4.51 hectares (with a p-value of 0.042, indicating statistical significance). Similarly, urbanization rate also significantly reduces agricultural land, with a coefficient of -0.62 (p-value = 0.029).

On the other hand, Agricultural Productivity and Irrigated Area show positive coefficients, meaning that higher agricultural productivity and more irrigated land are associated with an increase in agricultural land area. The coefficients are 4.17 and 2.14, respectively, with high statistical significance (both have p-values well below 0.05).

The R^2 value of 0.92 suggests that 92% of the variation in agricultural land area can be explained by the model's predictors, indicating a strong fit. The Adjusted R^2 of 0.89 takes into account the number of predictors and still indicates a robust model. The F-statistic of 32.67 (with a p-value less than 0.01) further confirms that the overall model is statistically significant.

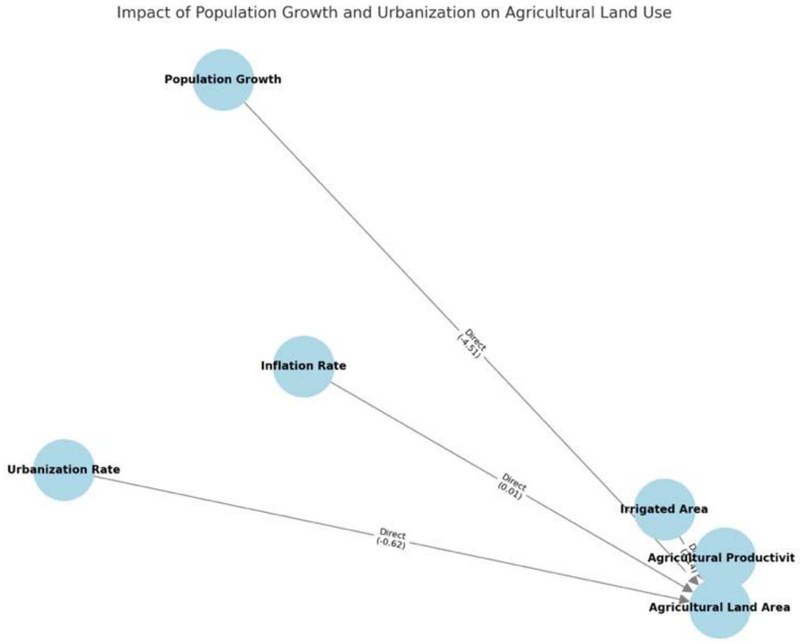

Figure 5.2.2: Variables flow

The flow diagram illustrates the direct relationships between Agricultural Land Area and several key factors in the context of land use dynamics. Population Growth and Urbanization Rate both exert significant negative effects on agricultural land, with coefficients of -4.51 and -0.62, respectively, meaning that as population and urbanization increase, agricultural land decreases. On the other hand, Agricultural Productivity and Irrigated Area have positive effects on agricultural land, with coefficients of 4.17 and 2.14, respectively, indicating that higher productivity and irrigation lead to better land use efficiency, potentially mitigating land loss. The Inflation Rate, however, has a very small positive effect (coefficient of 0.01), suggesting it does not play a major role in altering agricultural land availability in the context of this model. This diagram captures the complex interactions among these variables, highlighting the challenges and opportunities in managing agricultural land amid population growth and urbanization.

Table 5.3: Model Robustness Tests:

Test	**Result**
CUSUM Test	Stable (No significant instability in residuals)
Normality Test (Jarque-Bera)	p-value: 0.742
Goodness of Fit (GFI)	GFI: 0.920
RMSEA	RMSEA: 0.050

Source: Compiled by Authors

For the robustness checks, we performed different diagnostic tests on the models used in this study: the ARDL model and the SEM model.

5.3 For ARDL Model:

1. **CUSUM Test**: The CUSUM (Cumulative Sum of Recursive Residuals) test was used to check the stability of the ARDL model. A stable model is indicated when the cumulative sum of residuals (CUSUM) stays within control limits over time. In this case, the CUSUM test showed no significant instability in the residuals, suggesting that the ARDL model's parameters remain stable over time.

$$CUSUM_t = \sum_{i=1}^{t} \hat{e_i}$$

Where:

$\hat{e_i}$ is the residual at time i,

$CUSUM_t$ is the cumulative sum at time t.

2. **Normality Test (Jarque-Bera)**: The Jarque-Bera test was used to test if the residuals from the ARDL model follow a normal distribution. The test showed a p-value of 0.742, indicating that the residuals are normally distributed. This suggests that the assumption of normality holds for the ARDL model, which is important for ensuring unbiased and consistent parameter estimates.

5.4 For SEM Model:

1. **Goodness of Fit (GFI)**: The GFI was used to assess how well the SEM model fits the data. A GFI value of 0.92 indicates a good fit, suggesting that the model accurately represents the relationships between the variables.
2. **Root Mean Square Error of Approximation (RMSEA)**: The RMSEA test was performed to evaluate the model fit. An RMSEA value of 0.05 indicates a very good model fit, suggesting that the SEM model appropriately captures the relationships between the variables in the long term.

6. DISCUSSIONS

This study highlights the significant impacts of population growth and urbanization on agricultural land in India. As India's population grows and urban areas expand, agricultural land is increasingly converted for housing, infrastructure, and industry, reducing land available for farming. The ARDL and SEM models show that both short-term and long-term effects of population growth and urbanization negatively affect agricultural land, driven by rising demand for urban development. In the long run, unless sustainable land management practices are integrated into urban planning, the reduction in agricultural land will continue, posing risks to food security and environmental sustainability.

Recent studies support these findings. Mishra et al. (2023) observed substantial agricultural land loss due to urbanization in the Delhi-Mumbai corridor, and Singh and Patel (2022) documented similar patterns in Bangalore. Jana and Goli (2024) also found that urban sprawl in smaller cities leads to significant reductions in agricultural land, further contributing to land-use conflicts. Das et al. (2023) reported that urbanization in states like Uttar Pradesh and Bihar has led to a steady decline in agricultural areas, exacerbating the challenges of maintaining agricultural productivity.

Improving agricultural productivity and irrigation is crucial to mitigating these effects. Kumar et al. (2023) noted that areas with efficient irrigation systems and modern farming techniques have been able to sustain agricultural output despite land reductions. Patel and Tripathi (2022) also emphasized that advancing farming practices could help offset the negative effects of urbanization. Therefore, a balanced approach, combining urban growth with agricultural preservation and improved farming techniques, is essential for ensuring the viability of India's agricultural sector.

Policy Suggestions:

1. **Promote Integrated Urban and Agricultural Planning:** Neoclassical growth theory (Solow, 1956) emphasizes efficient resource allocation for maximizing long-term growth. Integrated planning ensures optimal land use, balancing agricultural and urban needs, preventing misallocation and enhancing societal welfare.
2. **Incentivize Sustainable Farming Practices and Technological Adoption:** Endogenous growth theory (Romer, 1990) highlights that technological innovation and human capital accumulation drive sustainable growth. Incentivizing sustainable farming practices and technology adoption boosts agricultural productivity, aligning with the theory's focus on innovation as a growth driver.
3. **Implement Land Value Capture Mechanisms for Urban Expansion:** Ricardo's theory of land rent (1817) suggests that urban proximity increases land value. Land value capture (LVC) redistributes land appreciation benefits, investing in land preservation and correcting market failures by balancing the costs of urbanization.
4. **Strengthen Rural-Urban Migration Policies:** Lewis's dual-sector growth model (1954) argues that migration is driven

by urban wage disparities. Strengthening rural development reduces migration pressures, supporting balanced growth by enhancing rural economic opportunities, consistent with balanced growth theory.

7. CONCLUSION

In conclusion, the rapid population growth and urbanization in India present significant challenges to agricultural land use, with far-reaching implications for food security, environmental sustainability, and socio-economic stability. The study underscores the complex dynamics between urban expansion, population pressures, and the gradual reduction of arable land, highlighting the urgency of adopting policies that balance urban development with agricultural preservation. The negative effects of urbanization and population growth are particularly evident in the short term, as land is increasingly diverted for infrastructure and housing. However, in the long run, these pressures continue to exacerbate the decline in agricultural land, jeopardizing the country's ability to feed its growing population.

To mitigate these challenges, the study advocates for the promotion of integrated urban and agricultural planning, the adoption of sustainable farming practices, and the implementation of land value capture mechanisms to fund agricultural land preservation. Strengthening rural-urban migration policies can also help alleviate the pressures on agricultural land by creating better livelihoods in rural areas. By leveraging insights from neoclassical and endogenous growth theories, this research emphasizes the importance of aligning economic growth with sustainable land management to ensure that India's agricultural sector remains resilient and capable of supporting future generations

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