

Research Article

Land use change, driving mechanisms, and future rural land use planning: An empirical analysis of a rural area in Bangladesh

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ABSTRACT

With the rise of regional case studies, land use/land cover change (LULCC) has always been one of the important concerns in geography and environmental studies as a local environmental issue with worldwide significance. In recent years, Bangladesh has experienced major changes in land use and land cover. The majority of LULCC research in Bangladesh has focused on urban land use change, and while urban land use has changed rapidly in coastal areas, modest but significant rural land use changes have also occurred. This study focuses on Manda Upazila (sub-district) in Naogaon District, Bangladesh. In the study area, agricultural land is gradually decreasing as a result of land use change. Brick kilns and housing settlements are occupying agricultural land, thereby reducing land productivity and fertility. Low profitability and low market prices of agricultural products are the main driving mechanisms behind land use change. Young villagers are also seeking employment opportunities in other sectors. Therefore, the study proposes policy measures to address these problems through appropriate land use planning and policy implementation.

Keywords: Land use, Land cover, Driving mechanism, Bangladesh

Introduction

Land use and land cover are fundamental components of the global environmental which have a significant impact on the Earth's temperature, ecology, and human society (Rai *et al.*, 2017), as well as the environment and socioeconomic conditions. The interaction between human activities and the local biophysical circumstances determines the paths and rate of change, which vary over time and space (Zhou *et al.*, 2020). Although Bangladesh has experienced significant land use and land cover changes (LULCC) in recent years, there has not yet been a national-scale quantitative investigation of LULCC determinants (Verburg *et al.*, 2004). Bangladesh's land use pattern is evolving quickly as a result of changes in physiographic and socioeconomic conditions, climate change, adaptation, and population growth (Islam & Hassan, 2011). Agricultural land, urban and built-up areas, forests and vegetation, water bodies, and wetlands make up the majority of Bangladesh's LULCC classes. Agriculture makes up the majority of the country's surface, followed by urban regions, which have been growing quickly (Rai *et al.*, 2017). Bangladesh is a small country with a sizable population, leading to a very high population density and a very high intensity of resource and land utilization. Only roughly 0.0526 hectares of land is thought to be available per person. The country's general situation of economic development and environmental imbalance is driven by the high pace of population expansion and the lack of land. As a result, there is a rapid change in the nation's land use pattern. Due to population growth and the expansion of its infrastructure, the nation loses 1% of its arable land, or 82900 ha of crop land, per year, and everyday 221 ha of arable land is losing in Bangladesh (Islam & Hassan, 2011). To the disadvantage of both forests and agricultural land, metropolitan areas and water bodies have been expanding

over the past few decades (Rai *et al.*, 2017). The usage of the land is changing, particularly the agricultural land, which is disappearing at a startling rate in Rajshahi District. The study area's agricultural land is disappearing by 0.46% annually, while the area used for infrastructure is growing by 5.86% annually. Within the next 217 years, all of the agricultural land will have been destroyed if the current rate persists (Islam & Hassan, 2011). The objectives of this study are to evaluate the current state of land use in the rural area and assess the potential impacts of ongoing land use changes on rural development, to identify the driving mechanisms behind land use changes in the rural area, and to determine future land use plans in the rural area.

Literature review

Conceptual definitions

Land cover: The physical covering of the Earth's surface is known as land cover (Duhamel, 2009).

Land use: The functional use of land is land use (Duhamel, 2009). Land use refers to any intentional development and use of land resources.

Study related to land use change

This study used a geo-detector model, bivariate spatial autocorrelation analysis, land-use dynamic degree (LUDD), and socioeconomic, topographic, and climate data from 1995 to 2015 to examine the spatio-temporal pattern and underlying causes of land use/cover change (LUCC) in rural China's 31,275 townships. Results indicate that the amount of cultivated land increased in northeast and northwest China, and the amount of built-up area increased in the provinces of Henan and Anhui, as well as the Yangtze River

Delta, Pearl River Delta, and Beijing-Tianjin-Hebei region. The occupation of cultivated land accounted for more than 80% of the expansion of built-up land. The areas with the greatest loss of agricultural land are the Loess Plateau, Sichuan Basin, Hebei, Henan, western Xinjiang, and southern Jiangsu. With respect to time, space, and kind of land use, LUCC's motivating factors varied widely. While terrain-driven conversion of cultivated land into forest land gradually increases from west to east, the intensity of population and economic growth driving built-up land expansion declines from east to west (Zhou *et al.*, 2020).

Tools for supporting the analysis of the causes and effects of land use dynamics include land use change models. Planning and policy for land use can be supported by scenario analysis using land use models. There are many land use models available that were created from various disciplinary backgrounds. This study examines the most pressing concerns for upcoming land use change modelling research. Six ideas crucial to land use models serve as the foundation for this discussion: Analysis level is followed by cross-scale dynamics, driving forces, spatial interaction and neighborhood effects, temporal dynamics, and integration level. An overview of the many techniques used to incorporate these principles into operational models is provided for each of these ideas (Verburg *et al.*, 2004).

The Rajshahi District was the subject of this study, and the main goals were to examine the district's land use patterns, trends in changing land uses, and, in particular, difficulties facing agricultural land. Remote sensing data (Landsat MSS-1977, TM-1990, and TM-2010) and GIS techniques were employed in the analysis, while secondary data were gathered from SPARRSO, including published

and unpublished data on crops, population, and other ambient information from primarily government sources. Results indicate that Rajshahi District's land use pattern is changing, particularly since agricultural land is disappearing at an alarming rate and becoming increasingly susceptible. The study area's agricultural land is disappearing by 0.46% annually, while the area used for infrastructure is growing by 5.86% annually. Within the next 217 years, all of the agricultural land will have been destroyed if the current rate persists (Islam & Hassan, 2011).

Methodology

Study area

The study was conducted in Manda Upazila (sub-district) of Naogaon district, a predominantly rural area undergoing noticeable land use change (Figure 1). The Upazila (sub-district) is characterized by intensive agricultural activities, scattered rural settlements, and the presence of major rivers such as the Atrai and Shiva. Administrative and spatial information on the study area was obtained from relevant government sources and existing documents.

Data sources

The research was based on both primary and secondary data. Primary data were collected through a structured questionnaire survey administered to residents of the rural area. The questionnaire was designed to obtain information on existing land use, changes in the use of agricultural land, perceived impacts of land use change, driving mechanisms behind these changes, expectations about future land use,

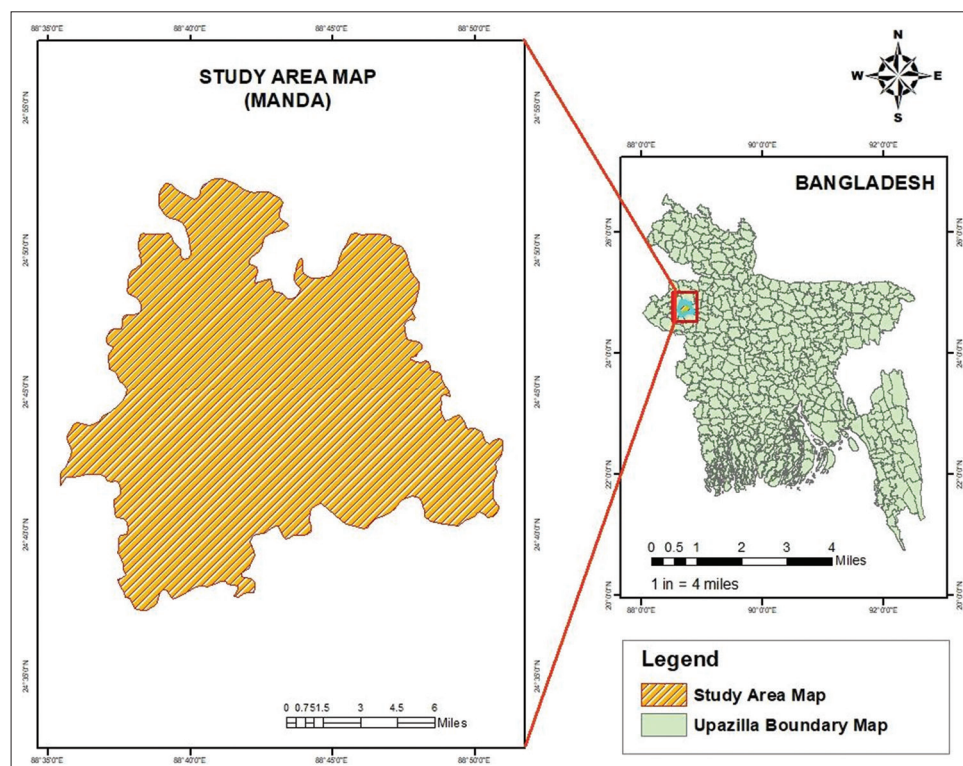


Figure 1: Location and administrative map of Manda Upazila (sub-district), Naogaon District, Bangladesh

preferred types of industry, and key factors and challenges related to land use planning.

Secondary data, including maps, satellite images, previous studies, and statistical reports, were collected from government organizations and other relevant institutions. These data provided background information on the physical, socioeconomic, and environmental context of the study area and supported the interpretation of the primary survey findings. The full survey questionnaire used for data collection is provided in Supplementary Figure S1.

Sampling and survey procedure

A sample of rural households was selected from the study area to represent different land use situations and socioeconomic conditions. Respondents were chosen in such a way that farmers, non-farm residents, and other local stakeholders were included. The survey was conducted through faceto-face interviews using a pre-tested questionnaire. Questions covered current land use patterns, conversion of agricultural land to other uses, perceptions of consequences, motivations for changing land use, views on desirable future land use, and opinions on suitable industries and planning priorities.

Data processing and analysis

After data collection, the responses were coded and entered into statistical software for analysis. Descriptive statistics were used to summarize the characteristics of respondents and the distribution of different land use categories and opinions. Various graphical techniques, such as area charts, bar charts, and pie charts, were applied to visualize current land use, reported changes in agricultural land, perceived consequences of land use change, dominant driving mechanisms, expected future land use, preferred industry types, and important factors for determining future land use.

To examine relationships between key variables, inferential statistical methods were employed. Correlation analysis was used to explore associations among existing land use patterns, agricultural productivity, driving mechanisms of land use change, and factors considered important for future land use decisions. Analysis of variance (ANOVA) and simple regression models were applied to assess whether selected explanatory variables had a statistically detectable influence on indicators related to land use and its perceived impacts. All analyses were carried out to understand how land use is evolving in the study area and which mechanisms and perceptions are most relevant for future rural land use planning, without drawing policy conclusions at this stage. The operationalization of research objectives into measurable variables and their data sources is detailed in Supplementary Figure S2.

Results and discussion

The respondents cooperated with us by providing information during the survey. With their help, the

questionnaire survey was successfully completed, and the opinions of local people and business groups were analyzed. The analysis shows that the current land use pattern is mainly agricultural, covering 60.57% of the total land, while 26.09% is used for industrial purposes, and the rest is used commercially. This indicates that a large portion of the rural area is still used for agricultural purposes.

However, the statistical analysis shows that the relationship between the current land pattern and existing land use is not significant. The ANOVA results indicate that the regression model has a very low sum of squares and a small F-statistic (0.001), with a p-value of 0.972 (Table 1), which means the regression model is not statistically significant. The coefficient of the constant term is 1.928 (Table 2), while the coefficient of the current land pattern variable is -0.002 , with a standardized beta value of -0.006 . The t-value (-0.036) and p-value (0.972) also indicate that the current land pattern is not significant for explaining existing land use.

The analysis indicates that a significant portion of land previously used for agriculture has been converted to other uses, with residential and pond uses being the most common (20% each), followed by industrial (18%), commercial (8%), and bare land (8%), while only 18% of the land remains in agricultural use.

The correlation coefficient between the current land pattern and productivity in terms of agricultural purposes is 0.135 (Table 3), which indicates a weak positive correlation. The p-value is 0.405, which means the relationship is not statistically significant. The total number of observations used in the analysis is 60.

Table 1: ANOVA for the relationship between current land pattern and existing land use

ANOVA ^a					
Model	Sum of Squares	df	Mean Square	F	Sig.
1					
Regression	0.000	1	0.000	0.001	0.972 ^b
Residual	2.775	59	0.073		
Total	2.775	60			

^aDependent Variable: Impact of rural areas for existing land use,

^bPredictors: (Constant), Current land pattern

Table 2: Coefficients for the relationship between current land pattern and existing land use

Coefficients ^a					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1					
(Constant)	1.928	0.096		20.143	0.000
Current land pattern	-0.002	0.052	-0.006	-0.036	0.972

^aDependent Variable: Impact of rural areas for existing land use

Table 3: Correlation between current land pattern and productivity in terms of agricultural purposes

Variable	Correlations	
	Current land pattern	Productivity in terms of agricultural purposes
Current land pattern		
Pearson Correlation	1	0.135
Sig. (2-tailed)		0.405
N	60	60
Productivity in terms of agricultural purposes		
Pearson Correlation	0.135	1
Sig. (2-tailed)	0.405	
N	60	60

The analysis of the consequences of changing land use shows that reduced agricultural productivity (67%) is the primary impact, followed by loss of biodiversity (23%) and disruption of rural communities (10%).

The analysis of the driving mechanisms behind land use change indicates that low agricultural profitability is the primary factor, accounting for 36.23% of responses. This suggests that many landowners are shifting away from agriculture due to insufficient economic returns. Other contributing factors include market forces such as land prices and crop demand (18.84%), population growth (14.49%), land fragmentation (10.14%), foreign migration and urbanization (7.25% each), and limited government subsidies (5.8%), all of which further influence the transition of land to non-agricultural uses.

The correlation coefficient between the driving mechanisms of changing land use and agricultural productivity in terms of agricultural purposes is -0.073 (Table 4), which indicates a very weak negative correlation. The p-value is 0.655, which means the relationship is not statistically significant. The total number of observations used in the analysis is 60.

Regarding expected future land use patterns, respondents expressed diverse opinions. Nearly half of the respondents (49.28%) preferred a mixed land use pattern that integrates agriculture, commercial, and industrial activities. In contrast, 24.64% supported increasing agricultural land, while equal proportions of respondents (13.04% each) favored expanding industrial land and commercial land use.

The correlation between driving mechanisms of changing land use and factors for future land use shows a Pearson correlation coefficient of 0.127 with a p-value of 0.436 based on 60 observations (Table 5), which indicates a weak positive correlation.

The analysis of preferred industry type shows that 84.06% of respondents prefer agriculture-based industries in the area. When determining future land use, respondents mentioned that environmental, economic, and social factors should be considered, with market demand as the priority.

Table 4: Correlation between driving mechanisms of changing land use and productivity in terms of agricultural purposes

Variable	Correlations	
	Driving mechanisms of changing land use	Productivity in terms of agricultural purposes
Driving mechanisms of changing land use		
Pearson Correlation	1	-0.073
Sig. (2-tailed)		0.655
N	60	60
Productivity in terms of agricultural purposes		
Pearson Correlation	-0.073	1
Sig. (2-tailed)	0.655	
N	60	60

Table 5: Correlation between driving mechanisms of changing land use and factors for future land use

Variable	Correlations	
	Driving mechanisms of changing land use	Opinion for future land use
Driving mechanisms of changing land use		
Pearson Correlation	1	0.127
Sig. (2-tailed)		0.436
N	60	60
Opinion for future land use		
Pearson Correlation	0.127	1
Sig. (2-tailed)	0.436	
N	60	60

When determining future land use patterns, respondents emphasized the importance of considering economic, social, environmental, and policy-related factors. Market demand was identified as the most important factor by 37% of respondents, followed by community preferences and needs (26%) and climate change considerations (24%). In comparison, government policies and regulations (9%) and soil and water quality (4%) were considered less influential in determining future land use.

In terms of factors, importance and challenges, 50% of respondents identified economic viability as a challenge, 35% mentioned environmental impacts, and 15% identified social acceptance. The survey also shows that 79.71% of respondents consider land use planning very important, 18.84% moderately important, and 1.45% slightly important. In addition, 75.64% of respondents agreed that policies and regulations are important, while 24.64% remained neutral.

The discussion indicates that the study area has vast agricultural land (about 61%), but the current land pattern and existing land use are not proportionate. The current land pattern has a negative relationship with agricultural productivity. Brick kilns negatively affect agricultural productivity and the environment, although they create employment opportunities. Young villagers are not interested in agriculture because of low profit, and due to limited employment opportunities, they prefer cottage industries and agriculture-based industries. Residential use is occupying agricultural land, and current land use is reducing agricultural productivity by almost 67%. Low

profit and low market price are the main driving mechanisms for changing land use, and these driving mechanisms are hampering agricultural productivity.

From the land use classification map of Manda Upazila (sub-district) in 2017 (Figure 2) found that 6% of the land was water bodies, 10% vegetation cover, 12% built-up area, and 71% agricultural land, while flooded vegetation, bare land, and rangeland accounted for 0.2%, 0.3%, and 0.5%, respectively. After five years, the land use classification map of Manda Upazilla (sub-district) (Figure 2) shows changes where water bodies decreased to 3% and vegetation cover decreased to 4%, while built-up areas increased to 24%. Agricultural land decreased to 69%, and rangeland, bare land, and flooded vegetation were no longer present. These results show that agricultural land is gradually decreasing while built-up areas are increasing.

Policy recommendation

Proper use of agricultural and non-agricultural land

According to the quality and fertility of agricultural lands, crops to be produced should be selected for maximum production. Agricultural lands are not just used for agricultural purposes but also for non-agricultural purposes like housing, infrastructure development, industries, etc. Agricultural land shall be protected by this Act and its use-based classification shall not be changed in any way. Whether the agricultural land is mono-cropped or multi-cropped, it shall be used as agricultural land. No dwelling house, industrial factory, brick kiln or any other non-agricultural structure shall be constructed by destroying any agricultural land. Housing, houses, industrial factories, etc. can be established on barren, non-agricultural land (Government of the People's Republic of Bangladesh,

Ministry of Land, 2001). All the agricultural lands shall have the right of any farmer or agriculturist of the country, and the right to usufruct the same by purchase or by inheritance or by settlement received from the Government shall remain intact. Anyone can buy or sell agricultural land, but the agricultural land must be used only for agricultural purposes and if it is not observed, the ownership of the said land will be vested in the government. Only the landless shall be entitled to acquire and occupy all the special lands. For households owning a small amount of agricultural land (approximately 1,310–2,182 sq ft), limited use of a portion of the land for essential homestead needs may be considered, provided that such use is consistent with local land-use zoning and does not substantially reduce agricultural productivity.

In the case of land acquisition for construction, several institutions are emphasized on compact placement in this area. A lot of land can be used for agriculture if poultry farms are arranged in multi-storied buildings in phases (Government of the People's Republic of Bangladesh, Ministry of Land, 2001).

Land and water bodies

It must be ensured that the traditional areas for fish production, namely rivers, canals, banks, wetlands, and oxbow lakes, etc., are not adversely affected in any way. As many of these areas dry up during the summer, there is a tendency to convert them into agricultural land on a large scale. Increasing the area of agricultural land alone will not solve the problem but will cause various problems like destruction of natural balance and deficiency in intake of fish protein by people. The natural change of existing wetlands should be avoided for the sake of protecting the water environment. Wetlands should be utilized in the light of

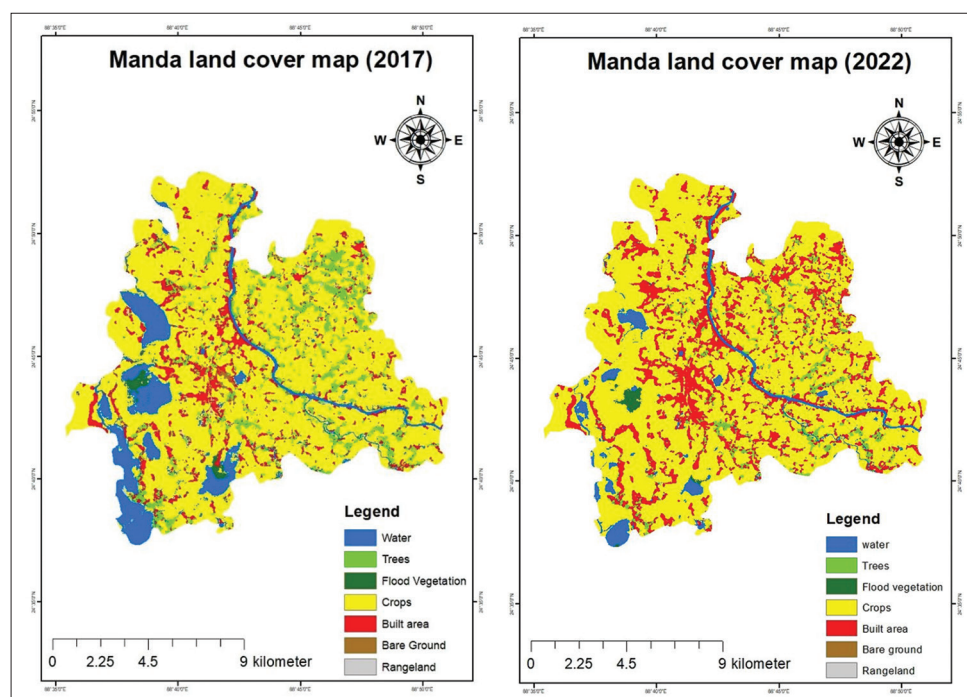


Figure 2: Land use classification maps of Manda Upazila (sub-district) in 2017 and 2022

the National Fisheries Policy (Government of the People's Republic of Bangladesh, Ministry of Land, 2001). Proper fisheries shall be carried out scientifically in the currently used open and closed reservoirs.

Land and industry

Homesteads and fertile agricultural land should be avoided as far as possible in the construction of roads and thoroughfares. New industrial plants may be set up near industrial areas, but it should be noted that homesteads and fertile agricultural land is not damaged. Only industries of that nature shall be set up in the area identified for establishment of industrial plants of a particular nature (Government of the People's Republic of Bangladesh, Ministry of Land, 2001). Agriculture-based industries, food processing, and cottage industries shall be established. Proper measures and procedures for waste disposal or discharge of industrial plants should be strictly followed so that there is no harm to the land or the environment. Approximately 500 yards of land on both sides of the main roads of the area should be set aside for future industrialization (Government of the People's Republic of Bangladesh, Ministry of Land, 2001).

Certificate of land ownership

In the current system of land administration, ownership of land is not dependent on any single document. Enrollment in registered deeds, land deeds, and survey records are various parts of this process. On the one hand, land acquisition disputes and lawsuits are increasing; on the other hand, innocent people are subjected to various scams, including mutation/land-title registration through fake documents. In order to resolve this situation, efforts are being made to confirm the ownership of the landowner by issuing a universally acceptable single document. It is expected that the present trend of large-scale private ownership of state-owned land will be largely curtailed if the IB scheme is successfully implemented. The ETH scheme can play a helpful role in the preparation and regular updating of land data (Government of the People's Republic of Bangladesh, Ministry of Land, 2001).

Others

Fragmentation of land shall be limited (Government of the People's Republic of Bangladesh, Ministry of Land, 2001). The forest area declared by the Ministry of Forests and Environment shall be designated as forest land. Conservation, maintenance, and removal of currently used forest land should be undertaken. Change in category of land earmarked for forest land shall be prevented. Subsidies, technological training, and other incentives shall be provided to encourage youth in the agricultural sector. Village market for agricultural products and other products should be established (at least one village market for a 1 km radius area). Tourism and historical sites shall be preserved. Recreation space for rural people shall be created (1% of each hectare).

Conclusion

Land use/land cover change is a crucial environmental issue with implications at the local level that extend to global significance. The study focused on Manda Upazila (sub-district), located in the Naogaon district, to examine the current land use patterns and the factors driving these changes. The study also analyzed land cover data from 2017 to 2022, revealing concerning trends such as a gradual decline in forested areas, water bodies, and grasslands, while witnessing a significant increase in built-up areas.

Several driving mechanisms behind the observed land use change were identified through survey data analysis. Firstly, population growth played a pivotal role, putting additional pressure on land resources as more land was needed for settlement and agriculture to meet the increasing demands of the growing population. Secondly, low profitability and a limited market value of agricultural products discouraged farmers from pursuing traditional farming practices, leading to land use conversion for alternative purposes. Thirdly, land fragmentation, which is the division of large agricultural plots into smaller ones over generations, reduced overall agricultural productivity and encouraged land conversion for non-agricultural purposes.

The findings of this study hold significant implications for policymaking and land management strategies in the study area. The researchers have proposed specific policies to address the identified problems. These policies may include sustainable land management practices, reforestation and afforestation efforts to counter the decrease in forested land, and promoting the preservation of water bodies and grasslands to maintain ecological balance and biodiversity.

Moreover, the study highlights the importance of conducting further research in different rural areas to gain a comprehensive understanding of the factors driving land use change and to develop tailored policy recommendations. By expanding the scope of research to various regions, policymakers can gain insights into region-specific challenges and opportunities, leading to more effective and targeted strategies for mitigating adverse land use changes.

The overall significance of this study lies in recognizing that local land use changes can have far-reaching consequences beyond the immediate area. As these changes can impact ecosystems, biodiversity, and even contribute to climate change, addressing land use issues becomes vital at both local and global scales. By implementing the recommended policies and conducting additional studies, it is possible to develop sustainable land use practices that strike a balance between meeting local needs and preserving the environment for the benefit of future generations.

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Supplementary Figures

Objectives	Complex Variables	Simple Variables	Source of Data	Variable type	Technique
To evaluate the current state of land use in a rural area and assess the potential impacts of ongoing land use changes on rural development.	Land use	Land use patterns	Remote sensing data, GIS data	Quantitative	Data analysis, statistical modelling, regression modelling
	Agricultural production	Crop yield, land productivity, land use intensity	Field survey, secondary data	Quantitative	Data analysis, statistical modelling, regression modelling
To identify the driving mechanism behind land use changes in the rural area, including economic, social, and environmental factors that have influenced land use decisions	Economic factors	Market demand, land value, subsidies	Secondary data	Quantitative	Data analysis, statistical modelling, regression modelling
	Social factors	Population growth, land inheritance, cultural factors	Secondary data	Qualitative	Content analysis, policy analysis, case study analysis
	Environmental factors	Soil quality, topography, climate	Remote sensing data, field surveys	Quantitative	Data analysis, statistical modelling, regression modelling
To explore different future land use plans in the rural plan.	Future land use plans	Zoning, Land use regulations, land use options, Alternative futures	Spatial planning documents, Government policies, Stakeholder consultation, Expert opinions	Qualitative	Policy analysis, Content analysis, Scenario analysis, Expert elicitation

Figure S1: Research objectives and variables matrix

Serial :
Name :
Phone :

Questionnaires Survey

I. Demographic Data:

Age	Gender	Education	Occupation
☐ >18	☐ Male	☐ Primary School	☐ Farmer
☐ 18-30	☐ Female	☐ High School	☐ Landowner
☐ 30-50		☐ College	☐ Shopkeeper
☐ <50		☐ Bachelor's Degree	☐ Business
		☐ Master's Degree	☐ Day labour
			☐ Education
			☐ Govt. Job
			☐ Non-govt Job

II.

1. How long have you been living in rural area?	
2. How much land do you own in a rural area?	
3. Do you have own land in rural area?	☐ Yes ☐ No
4. Have you been involved in the rural development of the study?	☐ Yes ☐ No

III. General Information:

1. Have you noticed any changes in land use in your area?	☐ Yes ☐ No
2. How would you describe the level of efficient land use in rural area?	☐ Low ☐ Moderate ☐ High
3. What factors do you think are driving land use pattern in rural areas?	☐ Population growth ☐ Expansion of urban areas ☐ Agricultural practices ☐ Fragmentation
4. Do you think use has a positive or negative impact on rural area?	☐ Positive ☐ Negative ☐ No impact
5. What are the potential consequences of land use in rural use in rural areas?	☐ Loss of biodiversity ☐ Reduced agricultural productivity ☐ Disrupted rural communities ☐ Others(specify):

A. Land Use and Agricultural Production:

1. In your opinion, how land use affected agricultural production in rural area?	☐ Positively ☐ Negatively ☐ No effect
2. How has land change over time due to land use in rural areas	☐ More intensive land use ☐ More extensive land use ☐ No change ☐ Not sure
3. In your opinion how has the increase in land use impacted the environment in rural areas?	☐ Positively ☐ Negatively ☐ No effect
4. How would you describe the current land use patterns in the rural area?	☐ Mainly agricultural ☐ Mainly residential ☐ Mainly commercial ☐ Mixed (agricultural, residential, and commercial)
5. What are the potential impacts of land use on rural development in the study area? (Please select all that apply.)	☐ Decreased agricultural productivity ☐ Increased land degradation ☐ Higher production costs Reduced profitability ☐ Limited access to credit and financing ☐ Barriers to adoption of new technologies and practices
6. How are the industries of this area polluting environment and agricultural production?	☐ Low ☐ Moderate ☐ High
7. How productive is the land in the rural area for agricultural purposes?	☐ Very productive ☐ Moderately productive ☐ Not very productive ☐ Not at all productive

B. Driving Mechanisms of Land Use Change

1. What economic factors have contributed to land use change in rural areas? (Check all that apply)	☐ Low market demand ☐ Increase in land use ☐ Lack of government subsidies ☐ Low profit ☐ Low labour cost ☐ Others(specify):
2. What social factors have contributed to land use change in rural areas? (Check all that apply)	☐ Population growth ☐ Land inheritance practices ☐ Shortage of information ☐ Communication lacking ☐ Others (Please specify):
3. What are the driving mechanisms behind the evolution of land use change in the study area? (Please select all that apply.)	☐ Population growth ☐ Urbanization ☐ Inheritance laws and customs ☐ Intensification of agriculture ☐ Market forces (e.g. land prices, demand for specific crops) ☐ Government policies ☐ Others (please specify):

C. Future Land use in Rural Areas:

1. How important is it to have a clear plan for land use in the rural area?	☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not important at all
2. In your opinion, what are the most important land use options for the rural area in the next 5-10 years?	☐ More agricultural land ☐ More residential land ☐ More commercial land ☐ Mixed use (agricultural, residential, commercial and industrial)
3. What is the main challenge in implementing the chosen future land use for the rural area in the case study?	☐ Economic viability ☐ Social acceptance ☐ Political will ☐ Environmental impact
4. What factors should be considered in determining the future land use for the study area?	☐ Soil and water quality ☐ Climate conditions ☐ Market demand ☐ Government policies and regulations ☐ Community preferences and needs ☐ Others (please specify):
5. 'There should be policies and regulations to control changing of land use in the rural area' Do you agree?	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree

Figure S2: Survey Questionnaire