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Between Concrete and Crops: A Geo-Spatial and Qualitative Analysis of Ecological and Social Costs of Peri-Urban Growth in Khulna

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ABSTRACT

Farmland decrease is a global phenomenon which is largely observed in peri-urban areas of a city. To explain the pattern and process of rapid urban transformation led impacts on farmers of Jalma Union of Khulna, this study followed a mixed method strategy. Using the state of art methodology, this study identified the pattern and process of sprawl from year 2011 to 2025 using a supervised classification algorithm, Random Forest in Google Earth engine platform. Furthermore, spatial analysis is conducted to identify the major urbanization impact zones. In qualitative part, field observations in terms of semi-structures interviews, discussion sessions with farmers, local residence, local elites, scholars provided valuable insights about the impacts (mostly negative) of peri-urbanization and policy discourses. Findings show that, peri-urbanization in Khulna is drastically changing the rural landscape over the last decade where it consumed around 1572 hectares of farmland between 2011-2025. Ecological cost of urban sprawl is staggering as it has caused a total decline of ecosystem value worth 3.83 million US $ $ha^{-1}yr^{-1}$ between 2011 and 2025, while losing of US $ 8.67 million in farmland. The interviews and discussions with the diverse respondents revealed five major themes persist in Jalma union related to rapid decline of farmland: land loss, displacement, land value inflation, water scarcity, and social segregation. Peri-urbanization in Jalma represents a "path-dependent" urban expansion characterized by institutional vacuum and speculative growth. Therefore, this study calls for robust, enforceable zoning regulations, equitable land-use planning, and targeted interventions that safeguard the rights and well-being of farming communities.

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Introduction

Farmland encroachment in developing cities, especially in South Asia, stems from decentralization and demographic shifts, fragmenting peri-urban agriculture and threatening food security. Urban sprawl has led to farmland loss, displacing smallholders and weakening traditional community systems (de Bruin et al., 2021). Under pressure from developers, farmers face income instability and are often forced into non-farming roles. In cities like Delhi, Dhaka, and Colombo, land competition has triggered shifts from food crops to cash crops or alternative livelihoods (Liang et al., 2024; Noronha Rodrigues et al., 2023; Laiprakobsup, 2023). Studies show that urban sprawl and agricultural abandonment have caused losses in provisioning services (e.g., food, fiber) and regulating services (e.g., carbon sequestration, soil retention). For instance, global analyses highlight that farmland reduction often leads to a disproportionate decline in ESV because high-value services such as nutrient cycling and climate regulation are difficult to replace. For example, one study covering years 1992-2015 found that conversion of natural ecosystems (notably tropical forests) to farmland resulted in a decrease in terrestrial ecosystem service values of USD 166.8 billion, corresponding to a decline of ~1.17 % of total terrestrial ecosystem service value globally (LI Yuanyuan et al., 2019). In China, for the region of Xinjiang from 2000-2020, although farmland expansion boosted provisioning services (+539.49 million USD), it came with large losses in regulation (−1,508.47 m USD), support (−1,084.47 m USD) and cultural services (−565.05 m USD), resulting in an overall net decline in terrestrial ecosystem service value (Cai et al., 2022).

Urban transformation in Bangladesh mirrors the global trends, with rapid farmland loss from the 1990s to 2020s affecting food security and ecological balance. Studies show large-scale peri-urban development—such as transport networks and homestead conversions—driven by market forces and economic shifts (Aziz and Podder,

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2023). In Gazipur, agricultural land dropped sharply as built-up areas expanded by 500%, especially near the Dhaka–Mymensingh Highway (Arifeen et al., 2021). Similar patterns are seen across cities, with arable land along rivers and canals being converted due to urban growth and climate-driven inundation (Alam and Ahamed, 2022). Cities like Rajshahi, Rangpur, and Barisal have seen rising urban heat due to farmland loss (Rana et al., 2022). Nationally, agricultural land declined by 11.68% from 1995 to 2021 in Bangladesh.

At sub-national scale, within Bangladesh, there is evidence that conversion of farmland (or agricultural land) within urban settings is eroding ecosystem service value. In Dhaka, one study found that from 1990 to 2020 built-up area increased ~188 %, and agricultural land, waterbodies and forest/vegetation were converted. The total ESV fell by ~59.55% ($ 85 million) from $ 142.72 million to USD 57.72 million. The annual ESV decline rate for agricultural land was ~ −2.06% per year for that period (Rahman and Szabo, 2021). The continuous erosion of crop land ultimately affecting the national economy and creating challenges for sustainable peri-urbanization particularly in secondary cities such as Khulna. While the large cities are being focused for research, in the face of rural-urban continuum, (i.e. Jalma union for Khulna city), secondary cities are overlooked predominantly.

While spatial analyses and predictive models dominate the literature (Morshed et al., 2022a), few studies address the socio-economic impacts on displaced farmers. Research often ignores how land conversion disrupts food security, livelihoods, and social identity, especially for vulnerable groups like women, elderly, and landless farmers—leaving a significant knowledge gap in understanding the lived realities of peri-urban transformation. Although megacities like Dhaka and Delhi are relatively well-studied (Tanzir et al., 2024; Naikoo et al., 2023), secondary cities like Khulna—despite experiencing rapid morphological shifts—remain under-researched. Again, empirical studies on smaller urban centers are scarce, especially concerning the fluid urban-rural interface and underdeveloped governance systems (Jalma union, Khulna). In the backdrop of the research gaps identified, this empirical study aims for examining the spatial dynamics and socio-ecological implications of peri-urbanization in Khulna, using Jalma union as a representative case. More specifically there are two objectives- to i) identify the spatial-temporal pattern of farmland reduction in peri-urban area of Khulna (Jalma union) and ii) assess the impacts of farmland reduction on the local livelihood with especial focus on farmers. Adding ecosystem service value of agricultural land to urban land, this research significantly contributes to the scholarship by providing insights on characterizing peri-urbanization (sprawl) and its economic valuation in a rapidly growing coastal city- that underwent negative population growth between 2001-2011. This paper also highlights possible policy voids to be addressed for sustainable urban transformation balancing ecological trade-offs.

Literature Review

Dynamics and Drivers of Peri-Urbanization

Peri-urbanization in developing countries poses a complex set of challenges—land conflict, service gaps, and environmental risks—requiring context-sensitive and integrated planning. It refers to the rapid, often unregulated transformation of rural outskirts into transitional zones combining rural and urban features. These areas experience changing land use, livelihoods, and infrastructure, driven by informal settlements, speculative land markets, and urban infrastructure demands.

A defining feature is urban sprawl—low-density, fragmented, car-dependent growth into rural areas—often exacerbated in the Global South due to weak governance, informal land markets, and inadequate planning (Aziz and Podder, 2023). Sprawl leads to poor land use, ecological fragmentation, and loss of agricultural and forest lands, severely affecting biodiversity, food production, and water resources (Sarif and Gupta, 2021; Roy et al., 2021). Socially, sprawl fosters inequality, segregation, poverty, and deteriorated health, particularly among peri-urban poor and farmers (Hatab et al., 2022). Economically, it reduces agricultural fertility, threatens food security, and disrupts ecosystem services (Dekolo et al., 2025). Sprawl undermines Sustainable Development Goal (SDG) 11 by impeding inclusive urban planning (Target 11.3), reducing environmental sustainability (Target 11.6), and limiting access to safe, inclusive public spaces (Target 11.7).

Livelihood and Social Implications of Farmland Loss

Peri-urbanization significantly affects farmers' sustainable livelihoods, driven by weak infrastructure, insecure land tenure, and the erosion of traditional rural practices. Urban sprawl in these zones' fuels socio-environmental vulnerability and food insecurity, as farmers face declining yields, market access barriers, and displacement, especially during crises like COVID-19 (Alemu and Kombe, 2025). Displacement often leads to income instability and restricted access to arable land, exacerbated by fluctuating land prices. Environmental degradation—urban pollution, climate change, water scarcity, and salinity—further diminishes agricultural viability (Acharya and Acharya, 2023; Qayyum et al., 2021). Socio-economic exclusion, particularly of women and peri-urban migrants, heightens marginalization and forces a shift toward home-based or non-farming livelihoods (Friend and Moench, 2015). In cities like Khulna, infrastructure-centric urban planning has displaced farming communities, weakening indigenous systems and agrarian livelihoods (Mamun et al., 2005; Ara, 2017). This ongoing "depeasantization" is compounded by social fragmentation, loss of community bonds, and reduced livability in peripheral zones (Islam et al., 2020). Altogether, peri-urbanization poses serious threats to food systems, social equity, and farmer well-being.

Ecosystem Service Value Debates

Ecosystem Service Value (ESV) measures the monetary worth of ecological land use, reflecting social, economic, and environmental benefits (Sorker et al., 2023). Used in development planning, ESV guides policy by making non-market benefits visible and highlighting risks of environmental degradation (Costanza, 2024; Van Wilgen et al., 1996). It helps in conservation and balancing ecological trade-offs (Zhao et al., 2021;). Peri-urban sprawl consumes ecologically rich land, reducing ESV in U-shaped or inverse-U trends (Wang and Sun, 2024).

Scholars use ESV in various contexts: Sannigrahi et al. (2019) highlighted mangroves' high ESV; Hettiarachchi et al. (2023) valued forests in Kenya and Vietnam; Barbier et al. (2009) categorized ESV domains; and Battisti et al. (2018) promoted peri-urban farming using ESV. Duan et al. (2024) advocated its role in policy integration. However, critics argue ESV overemphasizes monetary valuation (Hejnowicz & Rudd, 2017), ignores well-being nuances, and risks political misuse (Jadhav et al., 2017). It also excludes non-monetary values and local voices (Tinch et al., 2019), raising calls for broader frameworks post-2020.

Despite a growing post-2020 literature on peri-urbanization, the field remains fragmented. Critical gaps persist in linking spatial processes, livelihood systems, and ecosystem valuation within an integrated, justice-oriented framework. Future research must bridge the empirical (mapping and valuation) with the normative (equity and governance) to make peri-urban transitions more sustainable and inclusive. Most studies treat peri-urbanization as a land-cover or planning issue rather than a multi-scalar socio-ecological process. There is limited theorization connecting governance, informal land markets, and environmental feedback loops. While urban sprawl mapping has advanced via remote sensing, few studies trace longitudinal transitions — how peri-urban areas evolve from "rural edges" to "urban cores" over decades. Dynamic modeling that captures feedback between urban policy, migration, and ecosystem degradation is still rare. Again, despite acknowledging food insecurity, studies rarely quantify how peri-urban farmland loss affects urban food supply chains, nutrition, or prices. In terms of ESV, while ESV quantifies ecological loss, it rarely links to social equity, well-being, or poverty outcomes in peri-urban zones — a crucial omission for developing-country contexts.

Theoretical Underpinnings

Peri-urbanization refers to the process through which areas on the edge of cities (the "peri-urban" zone) undergo rapid transformation from predominantly rural in character toward more urbanized land uses, institutions, social relations, and economies. In these zones, rural–urban distinctions blur, as farming, residential, industrial and service functions intermingle (Christiawan and Nguyen, 2024). The theoretical framing emphasizes the hybrid and transitional nature of these spaces rather than viewing them as simply "suburbs" of the city. Key drivers include population growth, migration, infrastructure expansion, land-market speculation, and weak regulatory governance (Appiah et al., 2014). The emerging scholarship also emphasizes how peri-urbanization is shaped by global-local processes—land teleconnections, commodification of land, and ecological trade-offs (Huang and Chiu, 2020). Thus, from a theoretical standpoint, peri-urbanization helps us understand how the urban frontier expands into the countryside, changing land-use patterns, livelihoods, governance regimes, and ecosystem functions.

Materials and Methods

Study Area

Jalma is a rural hinterland of Khulna city corporation (Figure 1) under rural administration- Batiaghata upazila. It shares its boundary with important gateways of Khulna city. According to the Bangladesh Bureau of Statistics (BBS) 2022 census, the union has a population of 107840 (BBS, 2023). Based on 2011 census, about 3% people were engaged in agricultural profession in 2011. According to a study on Jalma union, about 55% people of this union is migrant (Alam and Rahman, 2015). Therefore, the exposure to one of the divisional cities make the union a suitable area to be studied in greater depth.

Data Sources

There are two types of datasets used in this study- spatial and non-spatial (Table 1). First, we collected satellite data using Google Earth Engine (GEE) platform to assess the urbanization pattern in the study area. We assessed urbanization using Landsat 5 (2011) and Sentinel (2022, 2025) images at 30 m resolution. Administrative boundaries were sourced from BBS and OCHA ROAP. Second, non-spatial data included demographic information from the 2011, 2022, and 2025 censuses to analyze population dynamics using an exponential growth formula (equation 7). Another non-spatial data source is the multiple field visits. Field visits provided insights into farmers' perceptions of urban expansion impacts on livelihood, health, and income. Semi-structured interviews engaged 70 local residents, including 38 farmers and 3 community elites, with efforts to ensure gender and occupational diversity. Land price data came from the Batiaghata sub-registry office.

Table 1: Data and Data sources used in this study

Data type	Data sources
Administrative boundary	https://data.humdata.org/dataset/cod-ab-bgd
Satellite images	https://developers.google.com/earth-engine/datasets/
Land use 2022, 2015	https://kda.gov.bd/
Inflation rates	https://www.bb.org.bd; Trading Economics, 2025
Distance from city	Google earth pro
Demography	Bangladesh Bureau of Statistics (BBS) 2014, 2025
Population growth rate	Self-calculation
Land price	Sub-registry office, Batiaghata; Own projection
Impact of farmland decline	Field observations, interviews, discussion sessions

Analytical Process

This study followed a mixed-method approach where several steps are included to fulfill the objectives (Table 2). To evaluate urban expansion and farmland decline in Jalma Union, we used Google Earth Engine (GEE) for image segmentation of satellite data from January–May in 2011, 2022, and 2025. Median composite images with zero cloud cover were classified using the Random Forest algorithm into five land classes: urban, water, vegetation, barren, and farmland—based on field knowledge and prior visits. Random Forest was chosen for its superior accuracy over conventional methods like KNN and SNM (Roy et al., 2021).

For supervised classification, 450 training points per class per year were used, with 70% for training and 30% for validation. After classification, we performed accuracy assessment. We conducted accuracy assessments using 500 sample points (100 per class), validated against historical Google Earth imagery and the 2022 Khulna land use database. Using spatial sampling tool in ArcGIS, we produced random 500 point within the classified image. These points are converted to KML (Keyhole Markup Language) to fit in google earth. Using the historical basemap, we corresponded each of the points and labeled them as per their real-world land class. The random points were loaded into GEE platform and accuracy metrics—producer accuracy, user accuracy, overall accuracy, and Cohen's Kappa—were calculated through GEE platform. After three rigorous validation rounds, Cohen's Kappa was 87% (2011), 88% (2022), and 92% (2025), exceeding the standard threshold of 85% (Janssen and Vanderwel, 1994), confirming high classification reliability. Feature engineering in ArcGIS Pro helped minimize classification errors due to mixed rural land pixels.

Table 2: Analytical sequence of the study

Sequence	Description/ Analytical tools used
1	Land use classification- using the GEE platform for 2011, 2022 and 2025.
2	From-to analysis to find out the conversion intensity among land uses.
3	Spatial analysis (buffer, overlay) to identify the urbanization impact zones
4	Calculation of economic service value of farmland
5	Qualitative surveys to find out the impacts of farmland destruction on farmers livelihood.

Source: Authors, 2025

Second, a 'from-to' analysis between 2011-2022 and 2022-2025 is done in ArcGIS Pro to see the transformative nature of lands to urban. The from-to analysis provided information about how much pixels of one land class transformed to another land class. Here, we focus on the crop land conversion in most cases. The pixel values are then converted to hectares (ha) by multiplying 900 with the pixel value and dividing the product by 1000000 (i.e. [742 built-up pixel*900]/1000000= 0.7 sq.km × 100 = 70 ha). To present the findings from the image classification, we calculated two indices (equation 1 and 2) (UN-Habitat 2021)-

Eq 1. Land consumption rate (LCR)/urban expansion rate (%) = $\frac{Urb_{t2}-Urb_{t1}}{Urb_{t1}} \times \frac{1}{\Delta t}$

Eq 2. % change in urban area/ Urban infill (%) = $\frac{Urb_{t2}-Urb_{t1}}{Urb_{t1}}$

Here, Urbt2 = urban extent in hectares for the final year; Urbt1= urban extent in hectares for the initial year, Δt = difference in the year between two measurement time.

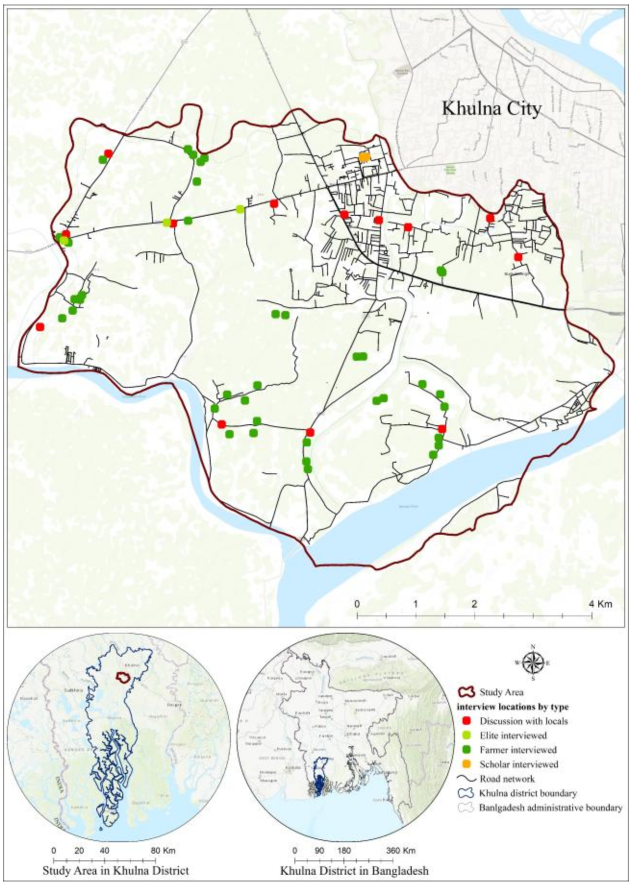

Figure 1: Study area and survey location
Source: Authors, 2025

Third, we performed spatial analysis (buffer, overlay) in ArcGIS Pro to understand and identify the urbanization impact zones- and aligned it with the existing data sources to interpret the policy discourses. These analyses provide insight about the ongoing impacts and direction of urban expansion ate current as well as future perspective. To add dimension to analysis, using Pearson correlation coefficient, we calculated the correlation between price of land (details on Annex Table C) and distance to city.

Fourth, based on the land use data, for each mauza of Jalma union, we have calculated the economic service value (ESV) (formula 3 and 4) and total land values of urban and farmland (equation 5 and equation 6- with reverse compound formula) to understand the financial stress of land. We adopted the ESV calculation process followed by Akber et al. (2018) and Sorker et al. (2023). These two papers cover Bangladeshi lands from where we considered the coefficient values of urban as 6661 US$ $ha^{-1}y^{-1}$ and 5567 US$ $ha^{-1}y^{-1}$. Furthermore, we do not have land price of 2011, therefore, we approximated the land price (equation 5 and 6) considering the annual average inflation rate of Bangladesh.

Eq 3. ESV = $\sum$ (Aj × Vck); Aj= area of particular land use type and Vck= value coefficient of that particular land use type in US $/ha/year.

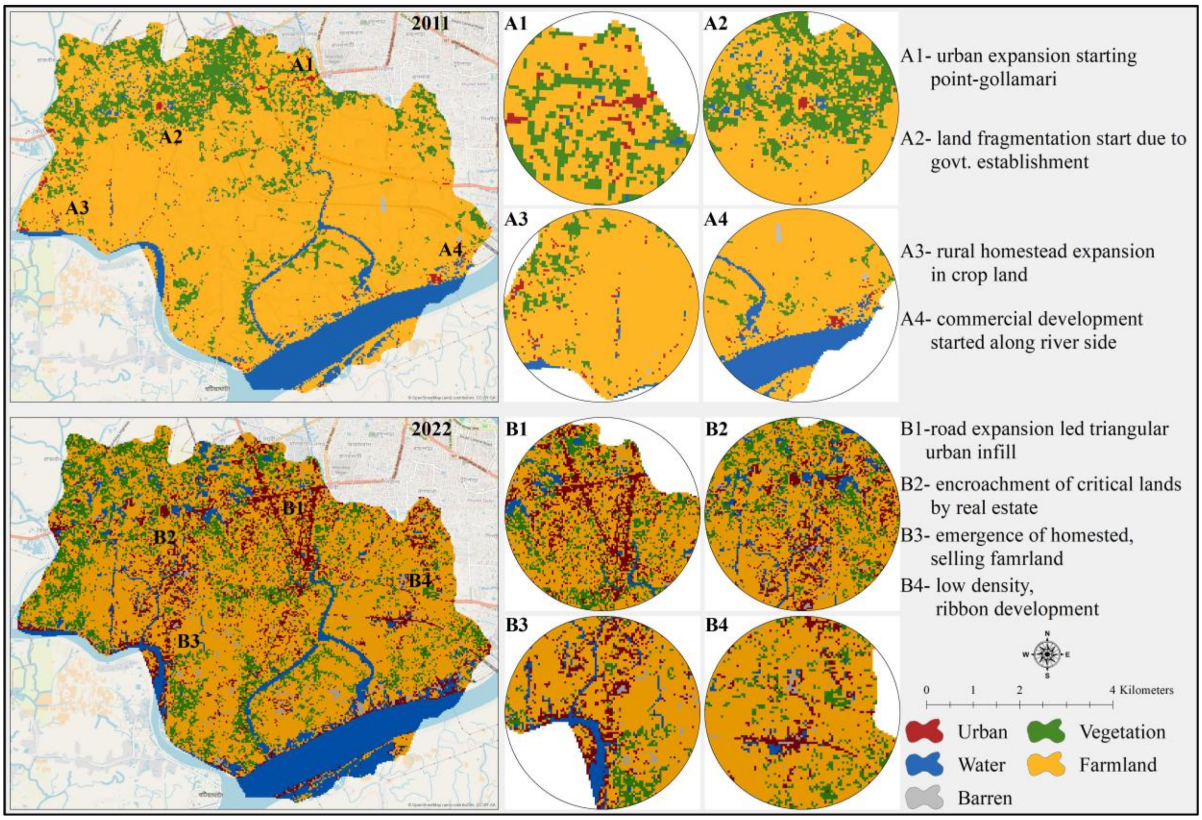

Figure 2: Land use classification of Jalma union for year 2011 and 2022
Source: Authors, 2025

Eq 4.Coefficient of sensitivity (CS) $= \frac{(ESV_j - ESV_i)/ESV_i}{(V_{ckj} - V_{cki})/V_{cki}}$;
k= land use category; 'i' and 'j'= initial and adjusted values coefficient- adjusted by ±50% (Akber et al, 2018).

Eq 5. $\text{Land price}(2011) = \frac{Land\ price_{2025}}{\frac{Cumulative\ Inflation\ factor}{(1+\ average\ inflation\ rate)^n}} =$

$$\frac{Land\ price_{2025}}{(1+\frac{10.5+10.47}{2})^{14}} = \frac{Land\ price_{2025}}{\approx 4.04}$$

Eq 6. $\text{Land price}(2022) = \frac{Land\ price_{2025}}{\frac{Cumulative\ Inflation\ factor}{(1+\ average\ inflation\ rate)^n}} =$

$$\frac{Land\ price_{2025}}{(1+\frac{10.47+7.70}{2})^{3}} = \frac{Land\ price_{2025}}{\approx 1.30}$$

Here, inflation rate in 2011: 10.50% (Ali and Islam, 2010); 2022: 7.7% and 2024= 10.47% (Trading Economics, 2025)

Eq 7. $P_n = P_0 \times e^{r\Delta t}$;

P_n= population at final year; P_0= population at initial year; e = constant (2.71828); r= exponential growth rate (5.36); Δt= time between two study intervals.

Using snowball sampling, we selected respondents based on specific criteria, including long-term residency (≥10 years) and active farming for at least 5 years. Seasonal migrants were excluded. Discussions with resident groups revealed perceived socio-economic disparities due to urbanization. No household surveys were out of the scope of this study and not conducted. Participants gave verbal consent, and identities remain anonymous to ensure confidentiality. We conducted the qualitative interviews and FGDs in Bengali and employed intelligent transcription method to identify the focus of the conversation. We were focused on only to the livelihood impacts of the farmland deduction and peri-urbanization effects, so intelligent transcription was the best choice for data analysis. The transcriptions were translated to English later and we performed thematic analysis. Based on the understandings from the field visit and interviews, we mapped the transcriptions/ comments of the locals into several themes such as impacts of urbanization on livelihood, spatial segregation, land price, income loss etc.

Finally, both quantitative and qualitative data are presented in narrative way. Some recommendations in line with the existing policy framework of Bangladesh is also proposed with some critical insights. Overall methodological flow chart is provided in Figure 3.

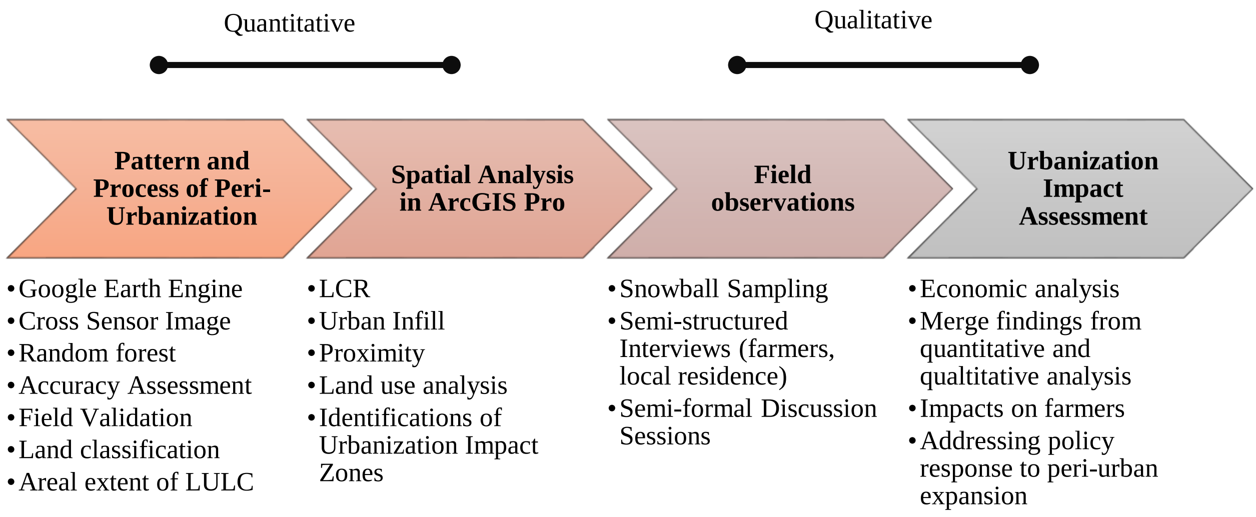

Figure 3: Methodological framework of the study
Source: Authors, 2025

Results

Between 2011 and 2022, the landscape underwent significant transformation marked by sharp increases in built-up (+664%) and barren (+886%) areas, indicating rapid urban expansion and land degradation. During this period, farmland declined by 21%, while water bodies increased moderately (+49%) and vegetation rose slightly (+11%), reflecting mixed ecological responses to development pressures. From 2022 to 2025, trends suggest continued intensification: farmland loss deepens to −25%, while built-up (+58%) and barren (+64%) lands keep expanding, though at slower rates than before. Vegetation shows a steep rise (+74%), possibly from reforestation or green space initiatives, whereas water areas decrease (−18%). Overall, the data reveal accelerating urban infill and land conversion (LCR up to 79%), driven by expanding infrastructure and settlement growth at the expense of productive cropland.

Pattern of Peri-Urbanization

Peri-urbanization in Khulna is drastically changing the rural landscape over the last decade. Between 2011-2022, urban land consumption rate is as much high as 59% per annum that has reduced to 19% per annum between 2022-2025 (Table 3). Over the last 14 years, around 738 hectares of urban built-up area increased in Jalma union with an excessive land consumption rate of 79% per annum (calculated from Table 3). The extent of urban expansion is mostly along the road network (Figure 2, Figure 4) but sporadic urban development is also observed within the pure rural settlement (Figure 2- A1-A4; B1-B4; Figure 4). Emergence of barren land is the proof of rapid urban expansion.

Urban Expansion and Ecological Threats

Valuable lands are being engulfed by impervious surfaces in the study area (Table 4). According to the analysis, urban area consumed around 1572 hectares of farmland between 2011-2025 with a negative land consumption rate of around 3% per year. Rapid urban growth shrank farmland by over 1,556 hectares, reducing from 3,874 to 2,317 hectares. Alongside farmlands, over the last 14 years, total 73.62 ha of water bodies altered to urban land. Similarly, 120.87 ha of vegetated areas converted to urban between 2011-2025. However, the transitions among the land classes still underscores the ecological threats. Spatial analysis reveals that the ongoing urbanization is engulfing areas with prime ecological lands. Based on the field observation, around 300 -500m areas from major roads are the major impact zones of urbanization (Figure 5). Within the 300m proximity of major roads, the urban expansion is heavily expanding with infill character. Jalma exuberantly experienced 664% urban infill between 2011-2022 in and around Krishnagar, Sachibunia area (calculated from Figure 2 using equation 2). It means, the urban areas are filling vacant plots within the previous urban extent first. The 500m proximity from major roads also shows urban expansion but in low density while within 1000m proximity, Jalma is undergoing sporadic urban transformation- mostly due to the emergence of plot based residential area and rural homestead. Based on the field visit, if we keep the 1000m as a buffer zone to protect the farmlands from further encroachment (Figure 5), still 46% lands can be kept as ecological important zone for future use. Areas within 1000m can be a great growth engine if planned.

Again, based on the land use database of KDA, almost 50% area of Jalma union is under land use planning of Khulna comprehensive detailed aera plan, 2022. The intense urban expansion is happening within that particular region. According the observation, we find the farmland is vastly proposed as residential land use (Figure 6) while the urban expansion is leading towards residential domination.

Ecological Cost of Urban Sprawl

It is found that rapid urban expansion in the study area has caused a net decline of ecosystem value of farmland worth 3.83 million US \$ ha^{-1}yr^{-1} between 2011 and 2025 with a decreasing trend (Annex Table A). However, between data points, the highest share of ecosystem service value decreased between 2022-2025, around 2.29 million US \$. Although the ESV of built areas rose from US \$ 0.44 million to US \$ 5.28 million, this gain pales compared to the loss of US \$ 8.67 million in farmland over the same period (Annex Table A). This evolving spatial-economic landscape signals an important shift: land once rich in ecosystem services is increasingly transformed into urban footprints, with long-term implications for ecological resilience and sustainability.

Table 3: Areal extent (in hectares) of the land classes in the study area between 2011 and 2025

Land Type	Land Area in			LCR		% change/Infill	
	2011	2022	2025	2011-2022	2022-2025	2011-2022	2022-2025
Farmland	3906	3099.69	2333.7	-1.8%	-8.2%	-20.6%	-24.7%
Vegetation	676.44	753.39	1308.24	1.0%	24.5%	11.4%	73.6%
Water	484.02	722.07	590.58	4.4%	-6.1%	49.2%	-18.2%
Urban	66.78	510.12	805.32	59.0%	19.3%	663.9%	57.9%
Barren	6.3	62.1	101.7	78.7%	21.3%	885.7%	63.8%

Source: Authors, 2025

Ecosystem Service Value Sensitivity Analysis

We calculated the coefficient of sensitivity by adjusting the coefficient value by ±50% for urban and farmland only. Analysis reveals that urban CS is 0.00015 and 0.00018 for farmland across the time line 2011-2025. The values are stable and very close to zero (0), far away from the unity- denoting the estimated ecosystem service value in the study area is robust and inelastic. Adjustment of the coefficients have little impacts on the total ESV calculation which again underscores the acceptability of the analysis.

Impacts On Farmers' Livelihood and Environment

The interviews and discussions with the diverse respondents revealed five major themes persist in Jalma union related to rapid fragmentation of farmland: land loss, displacement, land value inflation, water scarcity, and social segregation.

Socio-Environmental Impacts

Structural land-use transformation is not merely a spatial issue but a livelihood crisis that alters the social-ecological fabric of farming communities in Jalma. The encroachment of urban development (Table 2) is directly affecting local agricultural livelihoods. Farmers in areas like Chora, Hogladanga, Alutola, Bashbaria, Kholbaria and Sachibuniya express the most frustration over the transformation of fertile fields into residential plots, infrastructure (e.g., Khulna-Mongla railway), and commercial zones. Key contributing factors include subdivision of family-owned lands, government acquisition for infrastructure and private housing development. Respondents' narratives underscore a tension between traditional livelihoods and modern development pressure as one of the farmers (Harintana, Jalma, Fenruary 2024) uttered- "Most of it (cultivated lands) has been taken over by housing plots. It's disheartening to see our fertile land disappear."

Land Loss

The disappearance of the lands is sometimes against the will of the farmers and local residence. Due to the ongoing land fragmentation to urban use, for high return, many of the farmers and local residence converted their lands to plots. Those who were reluctant, could not hold their stance as surroundings of their lands became urban. This has created a fuzzy situation for the farmers who tried to stay on traditional livelihood but are giving up due to the ongoing pressure. One of the farmers at Koiya said- "When adjacent land is developed, we face challenges in water irrigation. Again, for adjacent land filling our land also become sandy which reduces its fertility. So, farming becomes hard for us on this land and we decide to sell that land"

Displacement and Social Segregation

Displacement due to urbanization creates cumulative social dislocation, eroding place-based identities and increasing vulnerability of tenant farmers and the landless in Jalma. This also fosters hidden social exclusion, reducing trust and weakening collective agency within mixed rural-urban communities. The influx of urban dwellers with different lifestyles has led to cultural fragmentation. Farmers lament the erosion of traditional social practices and weak social cohesion with new residents. "We feel disconnected and isolated in our own neighborhoods."- a farmer said, Tetuntola, January 2024.

Urban sprawl has not only forced farmers to relinquish their land but also compelled many to migrate to peripheral regions, disrupting their community networks and daily rhythms. Land-renting farmers are especially vulnerable to multiple displacements, as new urban development renders even secondary settlements unsustainable. One of the farmers in Alutala highlights- " I came here around 10 years ago from Dakshin Gollamari area. I used to rent land for farming in there but due to shortage of land I decided to shift in here with my whole family in Hogladanga. As I am experiencing same problem in this place too. I think this huge portion of land conversion will lead me towards another migration. For this reason, we have to break our social bonding which we make in a place."

Lack of Quality of Life

Peri-urban ecological collapse due to poor planning compromises both human and environmental health. Farmers highlight the loss of multi-functional landscapes (e.g., ponds for daily use), severely impacting their quality of life. Analysis finds that once the dense vegetation has become sporadic and low density in 2022- suggesting emergence of homestead and human activities. Overall, local farmers and people are worried about the continuous degradation of water bodies and loss of dense vegetation.

"Our ponds were filled… existing ponds are now full of waste." - farmer, Rajbadh, February 2024

Economic Impacts and Land Price Fluctuations

Land monetization privileges wealthier landowners, while undermining food security and farming continuity by driving speculative conversion. The increasing demand for peri-urban land has significantly inflated land prices. While some landowners benefit from lucrative sales, most smallholder farmers are priced out of land markets, limiting their ability to buy land for cultivation.

“The land prices have been increased ever since the city started expanding towards us. It's like everyone wants a piece of our land now, and we're caught in the middle. If a person wants to buy land for cultivation it will become almost impossible for him.”- local residence, Tetuntola, Jalma, January 2024

The land price has also increased due to the emergence of numerous real estate companies. Catalyst such as the extended opportunities to buy land at cheaper price at Jalma in compared to Khulna city, proximity to the city, the sense of expansion of Khulan city boundary, proposal of 215 acres of planned residential area at Thikrabadh as a future prime urban agglomeration (Aqua-Sheltech Consortium, 2002) hiked the land price. It is found that the average land price (Annex Table B) in Jalma have clear, consistent and moderate inverse relationship (-0.54) to the distance from the city. Again, with lucrative offers, real estate brokers pressurize the farmers and local residence to sell their farmland. This also has created tension among the residence. Annex table B summarize the mauza wise approximated land values.

"The developers keep knocking at our doors, offering us large sums of money for our land. But selling the land would mean the end of our way of life. It's a tough decision to make."- discussion session, Alutala, January 2024.

Table 4: Share of valuable lands (hectares) converted to urban built-up between 2011-2025

From land class	**To land class**				
Between 2011-2022	Built-up	Water	Barren	Vegetation	Farmland
Water	21.24	0	1.62	5.85	28.35
Barren	0.99	0.27	0	0.72	4.14
Vegetation	69.3	37.89	3.42	0	316.89
Farmland	396.99	244.71	55.44	491.22	0
Between 2022-2025					
Water	52.38	0	18.9	66.06	84.6
Barren	19.08	0.45	0	1.26	32.04
Vegetation	51.57	15.12	5.76	0	189.72
Farmland	433.26	53.19	48.6	694.26	0

Source: Authors, 2025

Discussion

This study focuses on tracing peri-urbanization patterns and their impacts on farmers and local residents in Jalma, a rapidly transforming fringe of Khulna. The rapid and unplanned urbanization has produced excessive ecological pressure on farmland that has substantially decreased the ESV of the farmland. The reduction of farmland has multiple effects on the farmers livelihood. As agricultural plots are fragmented or filled for residential use, irrigation systems are disrupted, soil fertility declines, and remaining lands become unviable for cultivation. The resulting pressure to sell reflects the “domino effect” of peri-urban encroachment—where individual resistance to conversion becomes unsustainable once surrounding plots urbanize. This aligns with broader evidence from South Asian peri-urban belts, where speculative real estate development and infrastructure expansion override ecological and agricultural land-use priorities. Socio-cultural and economic stress of the farmers households have heightened due to the loss of farmland, making a hostile environment for them gradually. Driven by a population growth rate of 5.36% per annum, urban expansion in Jalma resembles common sprawl patterns—low-density, ribbon, and sporadic development (Rizkiya et al., 2023).

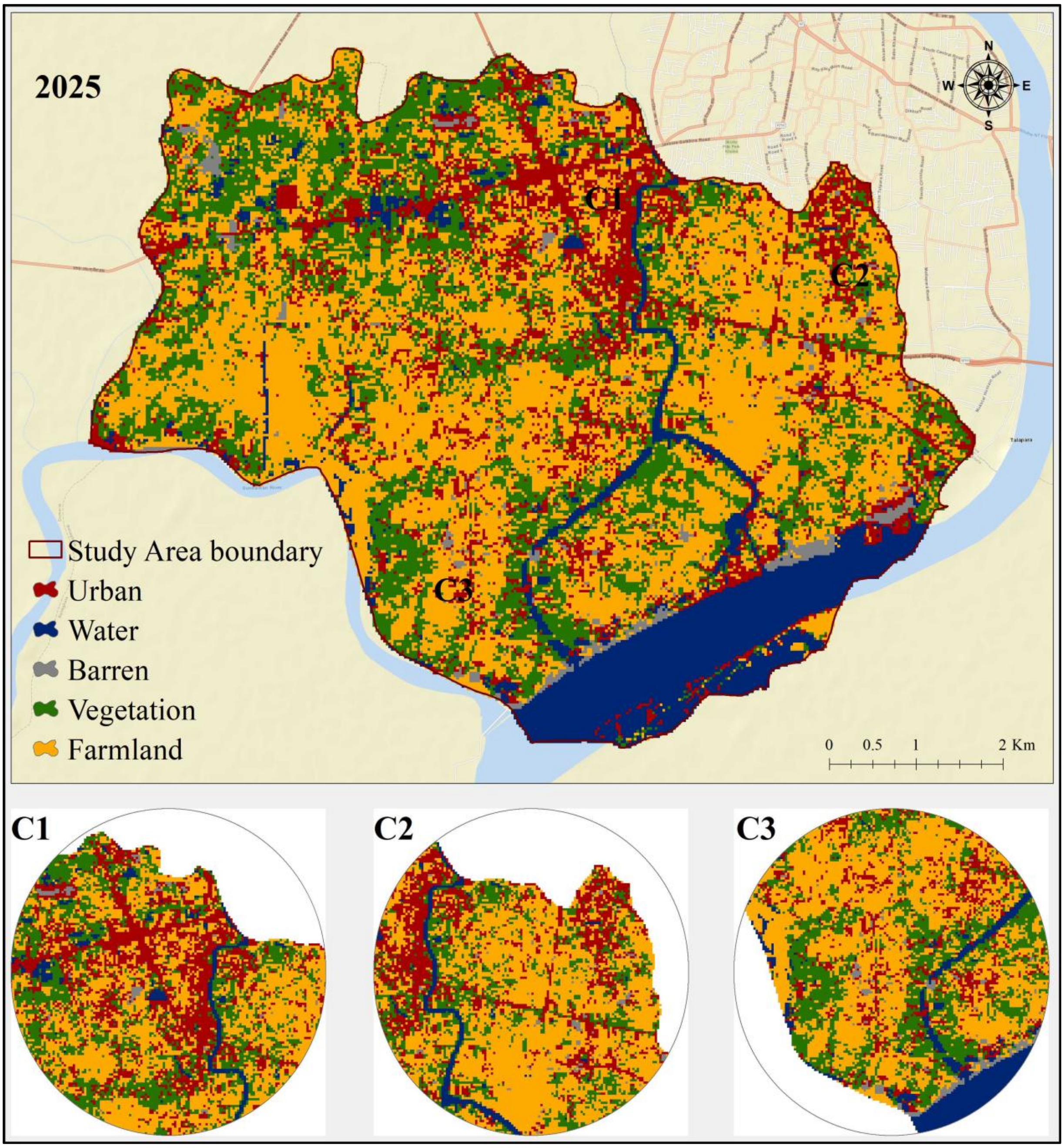

Figure 4: Major urban expansion zones in the study area in 2025
Source: Authors, 2025

Similar patterns have been reported across Bangladesh (Hassan, 2017). Urban growth is concentrated along road networks and near rural growth centers like Koiya and Sachibunia. Land conversion from homesteads and farmlands to residential and commercial uses is influenced by anticipated administrative boundary shifts and better connectivity (Pramanik and Stathakis, 2016; Wang and Sarker, 2020)**.**

Policy-driven expansion, especially the 'Khulna City Comprehensive Detailed Area Plan, 2022', promotes farmland conversion without addressing socio-ecological consequences (Aqua-Sheltech Consortium, 2002). The area's fertile geophysical features are overlooked in this process. The result is a rapid loss of ecological land driven by real estate speculation (Morshed et al., 2022) and low land prices, making Jalma a hotspot for unplanned development (Alam and Rahman, 2015). Although the share of farmland is still high in compared to other land use types in Jalma, the decreasing trend- if continued and not managed, will be a threat to the environment and livelihood. This growth has brought groundwater depletion, soil degradation, rising temperatures, and biodiversity loss (Hasan et al., 2017), stressing local agriculture and resource systems. Despite development promises, services such as sanitation and water remain substandard, leading to what Minh-Hoa (2002) terms "virtual urban planning." Socially, peri-urbanization has eroded community cohesion, increased inequality, and diminished local identity (Roy et al., 2021). Economically, urbanization has created uncertainty. Farmers struggle with rising land prices and operating costs, and many face land grabbing by companies. Those without land are excluded from profits and made vulnerable by the disappearance of irrigation systems and loss of livelihoods.

Figure 5: Farmland affected zones by mauza in the study area for different scenarios
Source: Authors, 2025

The shift to technology- and capital-intensive agriculture (Yaqoob et al., 2023) has further environmental consequences, including water table decline and soil exhaustion. Climate-resilient agriculture and adaptive planning are crucial (Podder et al., 2024). While Khulna's structure plan outlines development strategies (Aqua-Sheltech Consortium, 2002), private initiatives often disregard these guidelines. The ecological loss, measured in declining ecosystem service value (ESV), far outweighs urban economic gains (Ferdous, 2022). The ESV of farmland in the study area gradually decreased from 21.57 US \$ $ha^{-1}yr^{-1}$ to 17.12 US \$ $ha^{-1}yr^{-1}$ in 2022 to finally stands at 12.90 US \$ $ha^{-1}yr^{-1}$ in 2025. Similar trend is observed for coastal areas of Bangladesh between 1980 to 2016 (Akber et al., 2018). Again, scholars such as Sarker et al., (2023) found that the ESV of farmland has decreased significantly over time between 1990 to 2020 in Gazipur and Dhaka district. According to them, farmland ESV was 465.14 million US \$ in 2020 which decreased to 432.67 million US \$ in 2010 and finally set at 398.18 million US \$ in 2020.

Built-up areas have expanded 12-fold, but the minor ESV increase cannot compensate for the high-value farmland lost—underscoring a serious policy gap in sustainable land management. Despite numerous policies, Bangladesh faces persistent challenges in managing peri-urban land and protecting agriculture due to weak governance, overlapping mandates, and poor enforcement. Key frameworks like the National Land Use Policy (2001), Five Year Plans, and Coastal Zone Policy emphasize zoning and sustainable land use, yet implementation is undermined by vague mandates, limited local capacity, and lack of public awareness. Draft laws like the Urban and Regional Planning Act (2017) and Agricultural Land Protection Act remain unpassed, while pilot zoning efforts lack legal enforceability. Climate impacts, real estate incentives, and aquaculture expansion (e.g., shrimp farming) continue to degrade farmland. Fragmented governance among ministries and poor land monitoring hinder progress. In Jalma, the union parishad or the local government do not have any local level land use plan and therefore they do not have any grip on the land use change. Again, the study area falls within the KDA master plan, that means the land use plan is tailored by the KDA. Figure 6 shows how the KDA responses towards changing scenario of urbanization in terms of land use planning. It portrays poor realization of realities in the face of unplanned peri-urbanization. Although newer policies promote climate-sensitive planning and afforestation, urban sprawl and agricultural land loss persist in areas like Dhaka and Chattogram, driven by development priorities over ecological and food security goals (Roy et al., 2024; Jamal, 2024).

The results point to an urgent need for integrated peri-urban governance linking ecological valuation, livelihood protection, and land-use planning. Current urban expansion in Jalma exemplifies the ecological and social costs of fragmented planning, where short-term real estate gains eclipse long-term environmental and food security concerns. Incorporating Ecosystem Service Value (ESV) into municipal and regional land-use decisions could provide a quantitative basis for balancing development with ecological integrity.

The data from Jalma Union reveal that peri-urbanization is not a linear urban expansion but a hybrid transformation consistent with McGee's (1991) desakota model, where dense rural settlements evolve into mixed rural-urban environments. The coexistence of agricultural remnants with emerging residential and commercial areas exemplifies this transitional morphology. However, unlike the productive coexistence envisaged by early desakota theorists, the current trajectory in Jalma leans toward ecological simplification and social displacement.

Field interviews indicate five recurrent themes: land loss, displacement, land value inflation, water scarcity, and social segregation—all symptomatic of what Narain and Nischal (2007) call the "contested peri-urban commons". As fertile farmlands are subdivided or filled for real estate development, irrigation channels are disrupted and soil fertility declines, undermining the agrarian base. Farmers' narratives, such as "When adjacent land is developed, we face challenges in irrigation… so farming becomes hard for us," capture the lived experience of spatial marginalization. This process illustrates de-agrarianization and de-peasantization, where agricultural livelihoods erode under urban pressure. The resulting displacement and fragmentation resonate with rural–urban continuum theory, which argues that peri-urban areas operate as fluid socio-ecological zones, often governed by overlapping and conflicting institutions. In Jalma, informal land markets, speculative developers, and weak regulatory enforcement accelerate these contradictions, producing an uneven peri-urban landscape of gain and loss. Linking these findings to theory suggests that peri-urbanization in Jalma represents a "path-dependent" urban expansion characterized by institutional vacuum and speculative growth—features common in South Asian peri-urban regions (Narain et al. 2013). Finally, this study demonstrates that peri-urban change is not merely a spatial or demographic process but an ecological reconfiguration that redistributes environmental benefits and burdens

Shortfalls of the Study and Way Forward

This study is limited by the use of medium-resolution satellite imagery, affecting land use accuracy. Factors like water hyacinths, soil extraction, and human error in taking training points may distort classification. Urban patterns were visually interpreted rather than using a sprawl index. The study relies on local perceptions, which may be misinterpreted in written form. NVivo coding and policy analysis could enhance findings. Future research could include micro-scale land price data, disaggregated farmer types, SDG linkages, and yield-based farmland analysis to assess impacts on livelihoods and economic stability more comprehensively.

Conclusion

This research contributes to broader theoretical discussions on peri-urbanization and ecological political economy by empirically linking land transformation dynamics with ecosystem service valuation (ESV)—an integration often missing in existing literature. This study quantified a 1572-hectare farmland loss and a USD 3.83 million annual ESV decline, highlighting the ecological cost of unchecked urban expansion in Khulna. This study reveals the mounting challenges faced by Bangladeshi farmers as rapid urbanization transforms fertile agricultural land into urban areas, threatening rural livelihoods and deepening socio-economic vulnerability. In Khulna, many farmers report displacement, rising land commodification, and the disappearance of traditional irrigation systems. In response, they've adopted coping strategies such as agricultural diversification, alternative incomes, or exiting farming altogether. However, these changes often result in economic instability and social isolation.

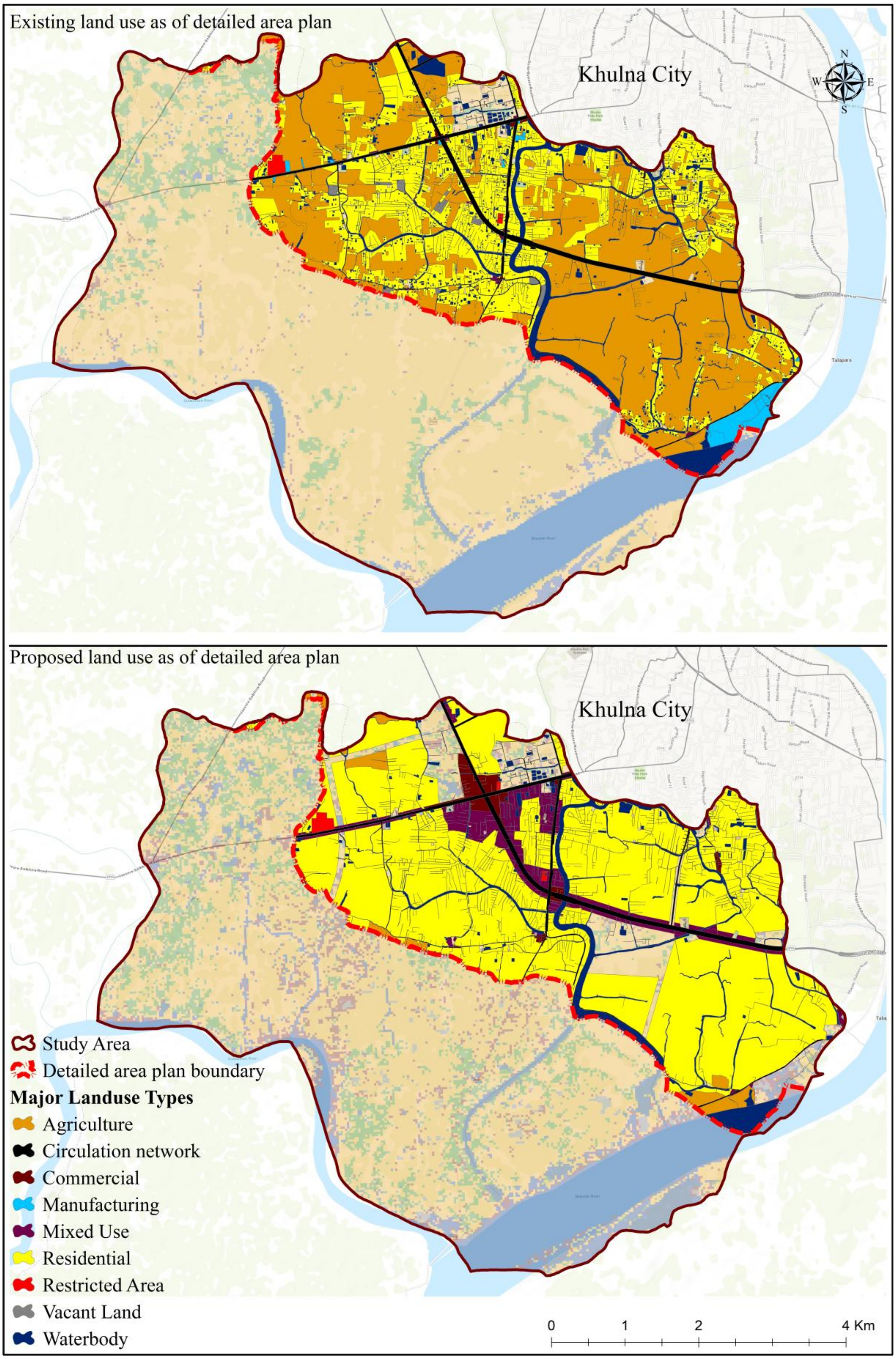

Figure 6: Comparison between existing and proposed land use of DAP of Khulna, 2022

From a policy perspective, quantifying ESV decline offers actionable insights for guiding Bangladesh's land-use zoning and peri-urban governance. By monetizing ecological loss, ESV metrics expose the hidden environmental costs of urban sprawl—costs often ignored in conventional economic valuation. Integrating ESV into urban planning instruments could help prioritize the conservation of high-value agricultural and vegetated zones. For instance, National Land Use Policy (2001) and Bangladesh Delta Plan 2100 emphasize the need for sustainable spatial balance between development and natural ecosystems. Despite policy frameworks like the Khulna Structure Plan (2001–2020), poor implementation and lack of ground-level synchronization have led to unplanned sprawl and environmental strain. The present findings suggest that peri-urban areas like Jalma should be designated as "controlled development zones", where zoning regulations incorporate ecosystem thresholds (e.g., allowable ESV loss per hectare). Moreover, ESV-based accounting can inform compensation and mitigation mechanisms and by situating ESV within Bangladesh's policy and planning context, the research bridges the gap between global urban sustainability theories and Southern urbanism debates, showing how ecological valuation can inform context-specific governance frameworks for equitable and sustainable land transitions. For example, losses in farmland ESV could be offset through eco-compensation schemes, incentivizing landholders to preserve agricultural functions or adopt agroecological practices. In rapidly urbanizing divisions such as Khulna, integrating ESV within municipal structure plans and development controls would align with SDG 11.3 (inclusive and sustainable urbanization) and SDG 15.3 (land degradation neutrality). Ultimately, this spatial-economic evidence positions ESV not merely as a valuation tool but as a policy instrument for ecological governance—bridging the gap between economic development and environmental sustainability. Institutionalizing ESV within Bangladesh's planning frameworks could enable evidence-based zoning, resilient peri-urban management, and the protection of critical ecosystem services amid accelerating urban expansion.

The findings ultimately point toward a hopeful trajectory—one where sustainable urban–rural coexistence is not only possible but essential for the future of Bangladesh's development. By embracing inclusive land governance, cities like Khulna and its peri-urban areas can become laboratories of balance—where urban growth coexists with the vitality of rural ecosystems and livelihoods. The study calls for robust zoning regulations, equitable land-use planning, and institutional reforms. Key policy recommendations include enacting a national farmland protection act with strict conversion restrictions, implementing integrated land-use planning with geospatial tools, forming an inter-ministerial land governance council, incentivizing eco-friendly farming, mandating Strategic Environmental Assessments (SEA) for urban projects, and empowering local governments through training and resources. Urbanization and agriculture need not conflict—through participatory, interdisciplinary governance, Bangladesh can pursue inclusive and sustainable development.

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Data Availability

The author confirms that all data generated or analyzed during this study are included in this published article.

Conflict of Interest

The authors have no financial or proprietary interests in any material discussed in this article.

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Ethic Approval

This research does have oral consent from the farmers and individuals participated in this study.

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Annex

Table A: Mauza wise ecosystem service value (ESV) between 2011-2022 in Jalma union (million US$ $ha^{-1}y^{-1}$) by land type (in hectares)

Mauza name	**Land in 2011**		**Land in 2022**		**Land in 2025**		**ESV 2011**		**ESV 2022**		**ESV 2025**	
	Built	Farmland	Built	Farmland	Built	Farmland	Built	Farmland	Built	Farmland	Built	Farmland
Alutola	0.45	85.77	9.99	72.72	25.56	41.58	0.003	0.477	0.067	0.405	0.170	0.231
Bashbaria	0	14.13	2.88	14.4	8.01	6.21	0.000	0.079	0.019	0.080	0.053	0.035
Chak Alipur	0	7.83	0.27	4.95	1.35	3.87	0.000	0.044	0.002	0.028	0.009	0.022
Choyghoria	5.4	416.07	37.71	313.65	55.26	258.75	0.036	2.316	0.251	1.746	0.368	1.440
Denarabadh	1.71	225.36	27.99	181.62	43.47	138.96	0.011	1.255	0.186	1.011	0.290	0.774
Dubi	0	49.41	5.67	45.81	10.17	35.01	0.000	0.275	0.038	0.255	0.068	0.195
Harintana	0.36	82.71	20.79	77.58	41.67	48.96	0.002	0.460	0.138	0.432	0.278	0.273
Jalma	3.42	171.45	17.28	118.71	26.73	61.11	0.023	0.954	0.115	0.661	0.178	0.340
Jhorvanga	0.45	68.13	10.44	47.61	16.11	31.95	0.003	0.379	0.070	0.265	0.107	0.178
Kholbaria	1.17	219.33	16.02	179.73	34.02	151.74	0.008	1.221	0.107	1.001	0.227	0.845
Krishnanagar	10.98	263.16	104.67	218.7	158.94	141.75	0.073	1.465	0.697	1.218	1.059	0.789
Mathavanga	10.8	581.31	49.77	465.39	85.95	369	0.072	3.236	0.332	2.591	0.573	2.054
Raingamari	1.62	250.2	37.35	186.66	35.37	168.03	0.011	1.393	0.249	1.039	0.236	0.935
Rajbadh	6.03	356.94	27.18	295.65	59.58	215.37	0.040	1.987	0.181	1.646	0.397	1.199
Sachibunia	5.49	256.32	47.07	232.83	59.76	151.02	0.037	1.427	0.314	1.296	0.398	0.841
Solemari	11.07	403.56	35.28	307.71	32.49	287.1	0.074	2.247	0.235	1.713	0.216	1.598
Tetuntola	5.58	299.97	24.3	201.51	48.24	147.87	0.037	1.670	0.162	1.122	0.321	0.823
Thikrabandh	1.08	122.31	27.9	110.25	50.4	59.04	0.007	0.681	0.186	0.614	0.336	0.329
Total	65.61	3873.96	502.56	3075.48	793.08	2317.32	0.44	21.57	3.35	17.12	5.28	12.90

Table B: Mauza wise approximate minimum land value (in million BDT/hectare) of farmland and urban land in 2011 and 2025

Mauza Name	land price 2011*		land price 2022*		land price 2025	
	Built	Farmland	Built	Farmland	Built	Farmland
Alutola	308	202	957	628	1244	817
Bashbaria	61	79	190	245	247	318
Chak Alipur	105	38	328	117	426	152
Choyghoria	80	53	249	164	324	213
Denarabadh	941	536	2925	1666	3803	2166
Dubi	356	218	1105	678	1437	881
Harintana	389	185	1210	576	1573	749
Jalma	45	55	140	171	182	222
Jhorvanga	121	118	375	367	488	477
Kholbaria	175	141	543	439	706	571
Krishnanagar	1110	305	3450	946	4485	1230
Mathavanga	120	66	372	205	484	267
Raingamari	82	71	254	221	330	287
Rajbadh	153	58	474	180	617	234
Sachibunia	176	118	547	367	711	477
Solemari	53	42	164	131	214	170
Tetuntola	48	36	150	111	195	144
Thikrabandh	191	140	593	434	772	564

Source: Authors 2025- calculated based on 2025 land price; *back projected considering inflation rate

Table C: Mauza wise minimum land price of different land types under personal ownership for year 2025-2026 and approximate average distance of mauzas from Khulna city

Mauza Name	Land price per decimal[1] (BDT)					Mauza distance from Khulna city (km)
	Urban land use		Non-Urban land use			
	Industry/ Commercial	Vastu	Garden/Vita	Pond	Farmland	
Alutola	*	503921	*	10180	330905	0.86
Bashbaria	*	100127	*	90909	128790	0.84
Chak Alipur	*	172493	122766	114916	61438	7.72
Choyghoria	*	131340	10000	70060	86436	6.63
Denarabadh	601010	939185	*	30000	877274	1.43
Dubi	*	581802	*	15198	356806	0.33
Harintana	242424	394630	58950	350142	303331	0.65
Jalma	12300	61381	64462	2545	89988	4.48
Jhorvanga	*	197639	*	291667	193082	2.93
Kholbaria	*	285887	*	6050	231207	0.76
Krishnanagar	1100000	716254	882578	440816	498230	1.05
Mathavanga	*	195987	254688	348837	108079	1.62
Raingamari	*	133493	252151	95671	116221	4.33
Rajbadh	70588	179229	172841	134160	94859	4.07
Sachibunia	19500	268280	423833	273635	193379	2.19
Solemari	*	86582	19234	59471	68747	6.46
Tetuntola	*	79150	58997	56566	58477	3.07
Thikrabandh	*	312462	*	187905	228537	1.82

Source: Authors, 2025 after Batiaghata upazila sub-registry office, 2024 *Not available

[1] Conversion factor: 1 decimal = 0.0045 hectares