Environmental Valuation of Land Cover Changes in Rajshahi Metropolitan Area : Integrated Approach of GIS, Remote Sensing and CVM

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INTRODUCTION

Research Background

Urbanization is transforming land use globally, especially in developing countries like Bangladesh, where rapid growth threatens agricultural land, food security, and the economy. In Rajshahi, climate change and economic factors have driven urban expansion, intensifying pressure on natural resources. This study uses GIS, remote sensing, and the Contingent Valuation Method (CVM) to evaluate the environmental impacts of land cover changes in Rajshahi over the past 15 years, providing valuable insights for sustainable urban development.

Objective of the Study

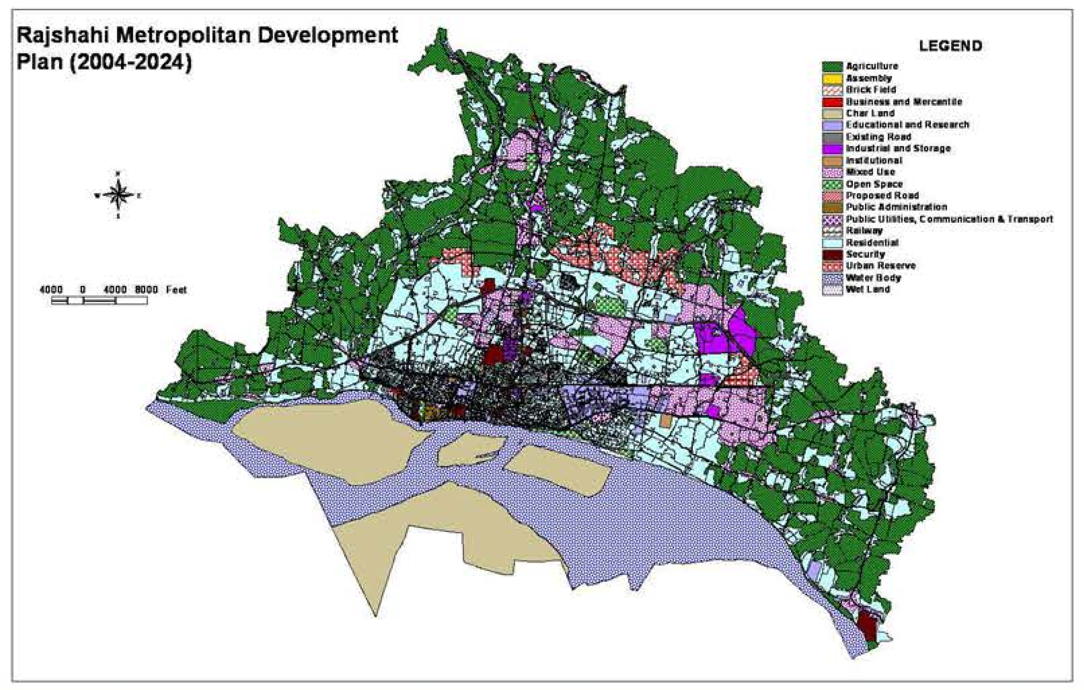
- Analyze land cover changes in Rajshahi Metropolitan area between 2000 and 2015.
- Conduct an environmental valuation of these land cover changes.
- Evaluate the factors influencing the public's willingness to pay (WTP) for environmental preservation.

Rationale of the Study

Urbanization in Bangladesh, particularly in Rajshahi, is driving the transformation of natural lands (wetlands, vegetation, agriculture) into built-up areas, causing environmental losses that have no direct market value. This study seeks to estimate the non-market economic value of these losses. With Rajshahi's potential for industrial growth and future in-migration, understanding the value of environmental degradation over the past 15 years will guide more sustainable urban planning.

Study Area

- Rajshahi, the fourth largest metropolitan city in Bangladesh, is situated in the northwest region along the banks of the Padma River.
- Covering an area of approximately 364.19 square kilometers, it serves as the administrative and educational hub of the Rajshahi Division.
- This strategic location enhances its role as a vital link for regional connectivity, facilitating trade and transportation.

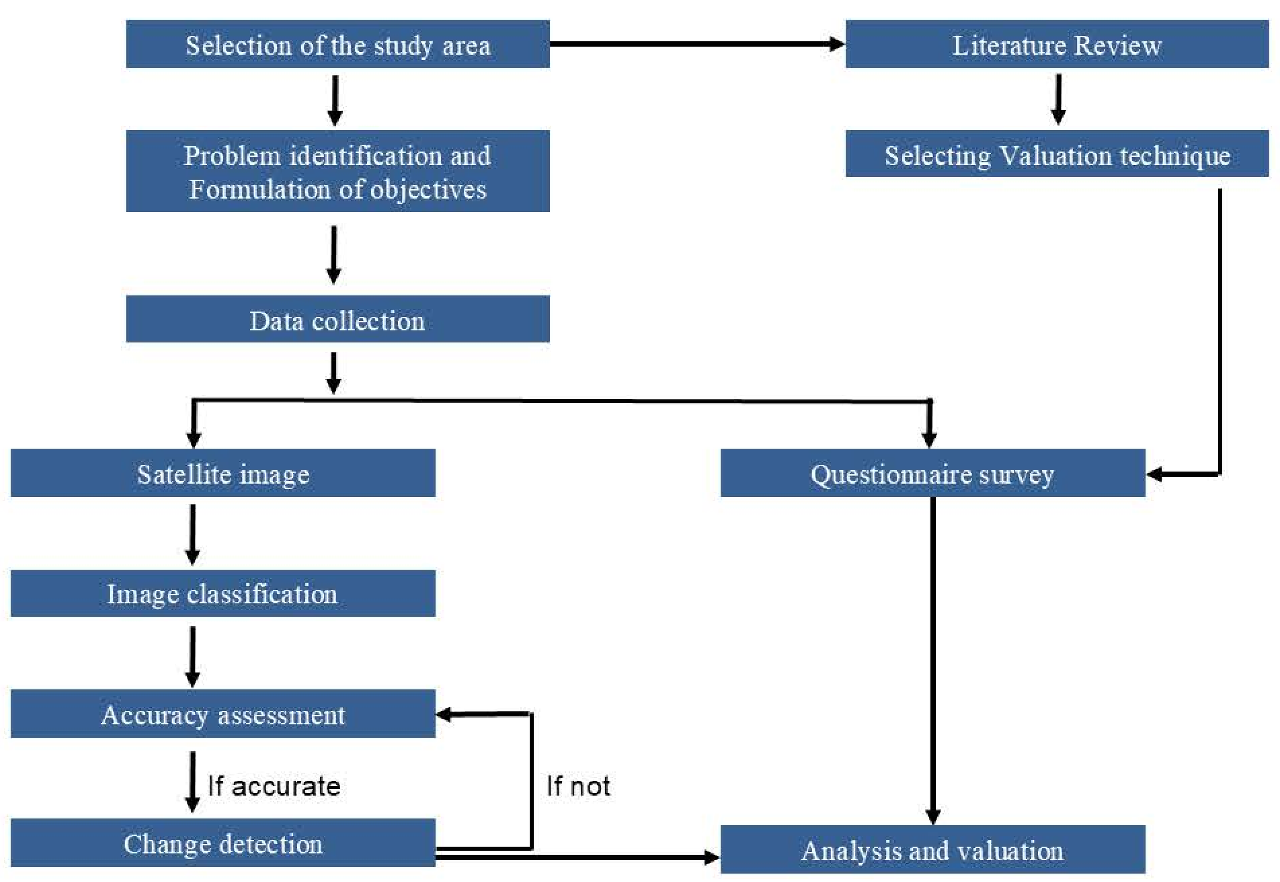


DATA AND METHODS

Data Sources

- Landsat satellite images from 2000, 2005, 2010 (Landsat 7 ETM+), and 2015 (TIRS) were collected from the USGS website.
- Census Data: Bangladesh Population and Housing Census, 2011
- Household Survey data: Conducted by authors, 2016

Research Methodology

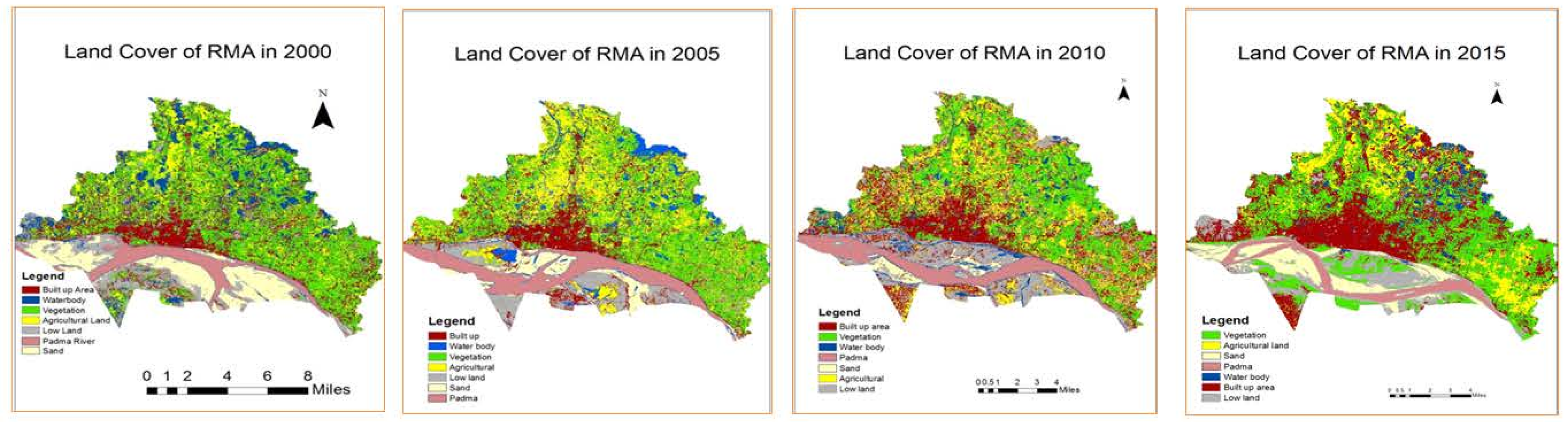


- Using Slovin's formula, a sample size of 200 was determined for a survey with a 90% confidence level and a 7% margin of errors.
- Data collected included demographics (age, sex, household composition), annual income, years living in the city, and frequency of visits to recreational sites, with households selected via random sampling.
- Turnbull and Weibull Method was utilized for calculating mean willingness to pay (WTP)
- Multivariate regression model was utilized to identify the influential factors that affect the willingness to pay.

DATA ANALYSIS & INTERPRETATION

Image Classification

Maximum likelihood supervised classification was conducted using ArcGIS software. The image was classified into seven distinct land use categories: built-up area, waterbody, vegetation, agriculture, lowland, sandy land, and the Padma River.

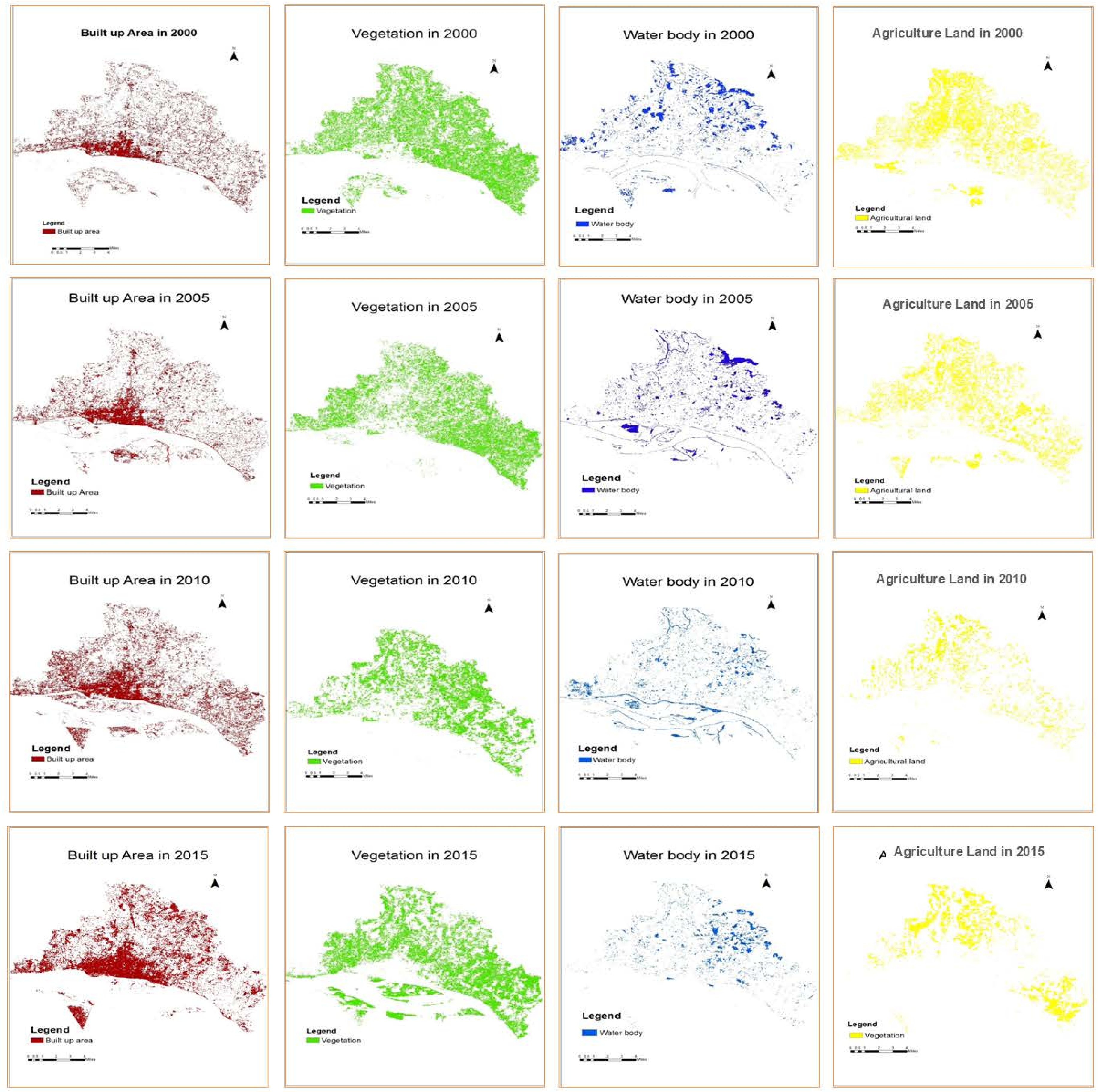


Accuracy Assessment

To assess the accuracy of image classification, we collected 70 random training samples for each of the seven land use classes from Google Earth, resulting in a total of 490 training data points. An error matrix was generated from the analysis, and the Kappa coefficient was calculated to evaluate classification performance.

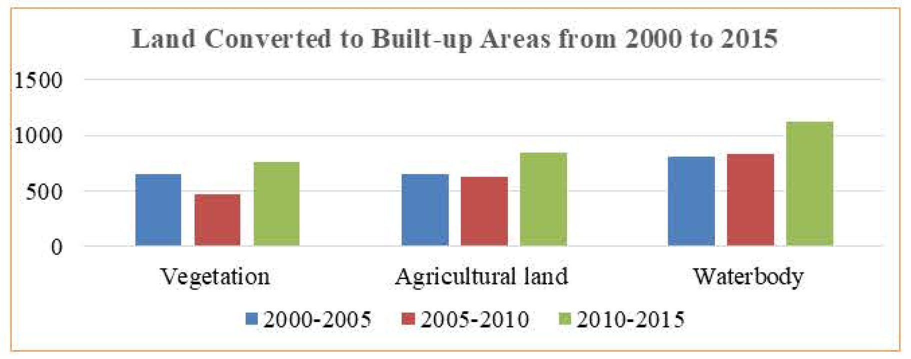
Year	2000	2005	2010	2015
Overall accuracy	90.4%	86%	84%	83%
Kappa coefficient	0.89	0.82	0.84	0.80

Change Detection



Change Detection *(in Acre)*

Land Use\Year	2000	2005	2010	2015	Change
Built up area	13425.4	15537.9	17480.3	20212.1	+ 6,786.75
Vegetation	28873.9	28216.8	27742.7	26980.9	- 1,893.01
Agricultural land	8949.16	8299.66	7669.86	6826.5	- 2,122.66
Waterbody	14003.1	13197.3	12358.7	11232	- 2,771.08



- Classified the satellite imagery into seven categories and conducted a change detection analysis focusing on built-up areas, vegetation, agriculture, and waterbodies.
- Findings revealed significant conversions, with vegetation, agricultural land, and water bodies transitioning into built-up areas.
- Specifically, built-up areas showed a positive change, reflecting nearly a 50% increase over the years.
- In contrast, waterbodies experienced a troubling decline of approximately 20%. Furthermore, both agricultural land and vegetation also faced noticeable reductions in the study area.

RESULTS & MAJOR FINDINGS

Environmental Valuation

Environmental Valuation of change in Waterbody has been performed in two ways:

- According to the global value of wetlands (Costanza, 1997)

  Yearly Loss = Losses Waterbody (in acre) * Monetary value (per acre in Taka)
  = 184.739 acre * 1.21 million Taka
  = 223.16 million Taka ≈ 2.86 million USD

- According to the Contingent Valuation Method (Willingness to Pay by the Households)
  - Conducted a questionnaire survey in which earning members from each HH were asked about their maximum WTP for waterbody conservation.
  - Applied bidding game Method, bidding base price Tk. 500 per year.

Calculation of Mean WTP [Turnbull and Weibull Method]

$$LL = \sum_{yy} LnS(T_{hr}) + \sum_{nn} Ln[1 - S(T_{li})] + \sum_{yn\ or\ ny} Ln[S(T_{li}) - S(T_{hr})$$

Here,
LL = the maximum likelihood estimate (mean WTP)
$S(T)$ = the probability to accept bid value T
T_{hr} = highest bid value
T_{li} = the lowest bid value to the *ith* individual
yy = the set of respondents who answered *yes* for both the bid values
nn = the set of respondents who responded both time *no*
yn = the set of respondents first time *yes* and then *no*
ny = the set of respondents first time *no* and then *yes*

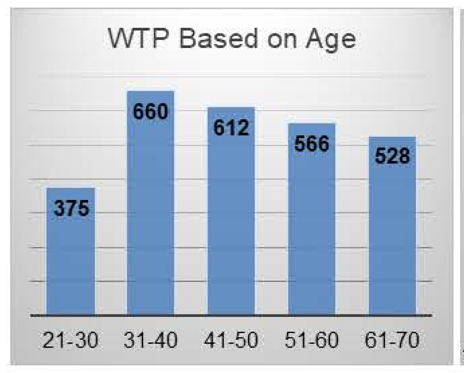
Yearly WTP for the Conservation of Waterbody = Mean WTP Value * Total Household
= 601 Taka *165275 HH
= 99.33 Million Taka ≈ 1.27 million USD

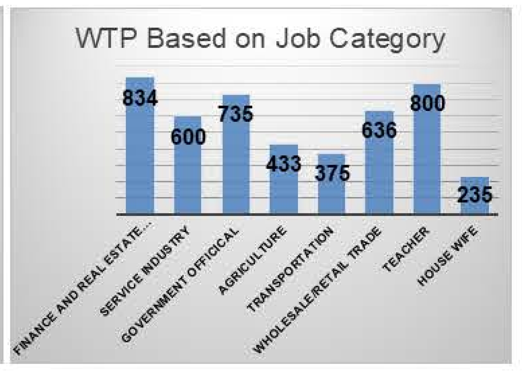
Assessing the Factors Influencing WTP

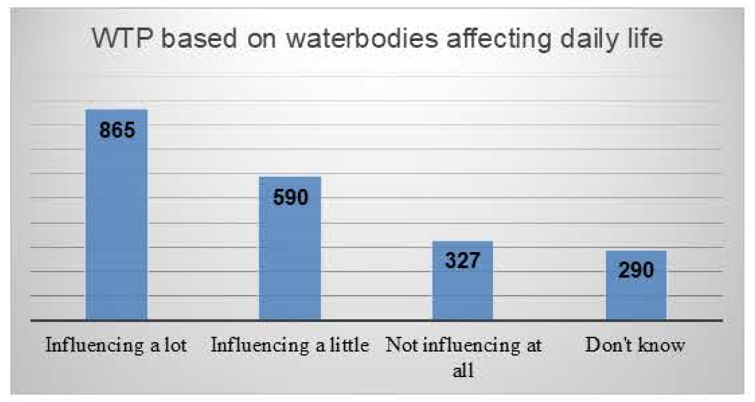
- **Multivariate regression model** was constructed to determine the factors that influence willingness to pay for preserving water bodies.
- It comprised the variables that are assumed to influence willingness to pay, such as bid value, visit, job category, annual income, demographics (age and sex), etc.
- Five variables were found statistically significant as P-value less than 0.05
- Number of child members, annual Income, and living year are positively influenced while visiting natural recreational sites and affected by natural resources are negatively influenced to WTP

$$Y = b_0 + b_1\,(\text{Child\_M}) + b_2\,(\text{Income}) + b_3\,(\text{Living\_Y}) + b_4\,(\text{Visit}) + b_5\,(\text{Affect\_Natural\_R})$$

$$Y = 594.58 + 75.66\,(\text{Child\_M}) + 67.96\,(\text{Income}) + 9.89\,(\text{Living\_Y}) - 97.64\,(\text{Visit}) - 123.25\,(\text{Affect\_NR})$$







- **Reasons for Willingness to Pay**: The most common reasons are to protect the natural environment (41.8%) and to protect it for future generations (26.9%).
- **Reasons for Unwillingness to Pay**: Half of the respondents believe the waterbody is not valuable (50%), while others are unwilling to pay as a fund (42.9%).

DISCUSSION & CONCLUSION

- Integration of GIS and remote sensing quantified land cover changes in Rajshahi from 2000 to 2015, showing that urban expansion has significantly reduced vital agricultural and waterbody areas, impacting ecological balance.
- Study quantified the annual loss from reduced waterbody areas at **184.739 acres**, equating to approximately **2.86 million USD**. Furthermore, the CVM estimated that the public's willingness to pay for preservation efforts is only around **1.27 million USD** annually.
- Multivariate regression showed that factors like income, education, and environmental awareness influence willingness to pay.
- Using high-resolution satellite imagery combined with a comprehensive survey of socioeconomic, behavioral, environmental, and land use data can enhance understanding of land cover dynamics and support sustainable urban planning

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REFERENCES