



Research article

Environmental benefits of blue ecosystem services and residents' willingness to pay in Khulna city, Bangladesh

Md. Nazmul Haque^{*}, Mustafa Saroar, Md. Abdul Fattah, Syed Riad Morshed

Department of Urban and Regional Planning, Khulna University of Engineering and Technology, Khulna, Bangladesh

ARTICLE INFO

Keywords:

Blue ecosystem services
Contingent valuation method (CVM)
Urban ecosystem
Willingness to pay (WTP)

ABSTRACT

Nature-based solutions for urban problems gaining popularity globally. The well-functioning ecosystem could offer a nature-based solution to many urban problems including water, drainage and flooding problems. Therefore, conservation and restoration of urban blue ecosystem components such as pond scape are crucial. This research taking Khulna city of Bangladesh as a case has examined the low-income fringe community's willingness to pay (WTP) for conservation and restoration of pond scape/blue ecosystem service (BES) in their locality from where they benefit. The various types of ecosystem services enjoyed by the local community were identified. To assess the community's WTP for conservation and restoration of pond scape, the payment card approach of the Contingent Valuation Method (CVM) was used. Three environmental attributes were considered to assess the existing condition of the blue ecosystem services in the study area. Findings show that 54% of respondents are not satisfied with the existing conditions of the ecosystem services resulting from the pond scape. Respondent's WTP for eleven types of service facilities was calculated. Results show that only 65.20% are eager to pay an amount of 38 Tk to 138 Tk per month for different service facilities. It means about one-third of the community people want to be free riders. The influences of different attributes of the respondents on their WTP were also analyzed. Education, income, and house-ownership appear to have a positive significant influence on WTP for conservation and restoration of pond scape in the study area. In line with the findings if policy measures are taken without further delay it would help conserve the remaining pond scape.

1. Introduction

Globally the pace of urbanization is unprecedented and more than two-thirds of the population would be living in the urban areas before the middle of this century (Adams et al., 2016; Panday 2017; Allam 2020; Kirikkaleli and Sowah 2020). The counties in the developing global south have been experiencing an even faster rate of urbanization (Panday 2017; Allam 2020). Unmanaged urbanization in some parts of the globe causes deteriorated environmental quality that ranges from air pollution, water pollution, soil degradation, loss of biodiversity etc (Adams et al., 2016; Caro-Borrero and Carmona-Jiménez 2019). Some of these have severe consequences for public health and wellbeing and ecosystem functioning (Breuste et al., 2017; Kabisch 2019; Kirikkaleli and Sowah 2020). A well-functioning ecosystem provides various services (Chien, 2022; Jaung et al., 2022). In urban areas, ecosystem services components are broadly divided into two parts; the green ecosystem components and the blue ecosystem components (Caro-Borrero and Carmona-Jiménez 2019; Hagemann et al., 2020; Mukherjee and Shaw 2021; Sang et al.,

2021). The green components include all sorts of green infrastructures and the blue components include all sorts of natural water structures/systems (Caro-Borrero and Carmona-Jiménez 2019; Kazmierczak and Carter 2010). The use of provisioning ecosystem services in the form of water, food, fibre, medicine, building materials, biomass fuel is centuries-old practice (Haase 2017; Kabisch 2019). The use of regulatory services of the ecosystem as part of the nature-based solution is gaining popularity [over engineered solution] to address many of the problems urban community encounters (Mukherjee and Shaw 2021). Particularly the use of water-related ecosystems which is often termed as the blue ecosystem to control/regulate climatic problems (e.g. temperature, humidity, precipitation) (Amini et al., 2019), water pollution, soil degradation (erosion and pollution) Uy and Tapnio (2021); flooding and drainage problem (Tong and Nguyen 2021) have recently been popularized as part of the nature-based solution (NBS) (Oertli and Parris, 2019; Haase 2017; Costanza et al., 1997).

The International Union for Conservation of Nature (IUCN) defines nature-based solutions as actions to protect, sustainably manage, and

^{*} Corresponding author.

E-mail addresses: nhaque13@urp.kuet.ac.bd, nhaque.kuet13@gmail.com (Md.N. Haque).

restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. More generally, the nature-based solution is a term that can be used to describe an alternative and non-traditional approaches to environmental issues, like flooding, water scarcity, or soil erosion, by harnessing natural capital (Haase 2017; Chen et al., 2022). They also provide a wide range of other important benefits, such as cleaner air and water, economic benefits, and increased biodiversity (Amini et al., 2019; Hagemann et al., 2020; Sang et al., 2021). Nature-based solutions span a wide range of practices, and people sometimes disagree about exactly what counts as a nature-based solution. Broadly, nature-based solutions fall into four categories: forestry practices, wetland-related practices, restorative agriculture, and ocean-based practices (Haase 2017; Ferrari et al., 2019; Bhatt et al., 2020; Kumar and Singh 2020). Wetland-related practices focus on conserving and restoring multifunctional wetlands that provide blue ecosystem services. Therefore, in an urban area, the availability and quality of wetland-related nature-based solutions largely depend on the well-functioning blue ecosystem and its components (Haase et al., 2014). In an urban area, blue ecosystem components are primarily rivers, lakes, canals, swamps, bogs, ponds, ditch, and natural drainage. These are important components of a healthy living environment.

Due to population pressure and shortage of buildable land, most cities in developing countries that experience massive land use transformation fail to conserve blue ecosystem components, especially ponds. The resulting effects are filling of low-lying water retention bodies, and ponds (Panday 2017; Adams et al., 2016; Allam 2020). This ultimately causes networks of problems including high surface runoff, heavy flooding, water pollution, soil degradation, temperature rise, loss of aquatic habitat and biodiversity. Bangladesh a densely populated and fast urbanizing country is no exception to these problems most of which have been resulting from poor management of blue ecosystem services particularly urban ponds Haase (2015) (Niemczynowicz, 2009). Historically hundreds of thousands of ponds were an integral part of the urban ecosystem in many parts of the world including Bangladesh (Panday 2017; Almenar et al., 2018). Unlike other blue ecosystem components, the ponds had been present throughout the city as ponds were artificially constructed (Saroar et al., 2019). In cities, ponds were used for multiple purposes, including the source of drinking and bathing water, recreation, washing, water retention for irrigation, and other purposes (fishing) (Flowra et al., 2012). Ponds are also used for the beautification of urban landscapes and microclimate control. Therefore ponds have been a very crucial blue ecosystem component in the urban landscape (Saroar et al., 2019). However, over the decades, the urban ponds and water ecosystems' condition in the cities of Bangladesh has increasingly deteriorated (Flowra et al., 2012; Akhtar et al., 2017). In the last 50 years, more than 4000 ponds have been filled only in the major cities of Bangladesh because of uncontrolled landfilling for rapid urban expansion (Akhtar et al., 2017). In Khulna metropolitan city alone more than 1000 ponds of varying sizes have been filled to expand urban build-up area. In Khulna city broadly two types of pressures are observed to degrade the pond landscape. First, the discharge of wastes from factories, industries, households, and other sources such as slaughterhouses, and urban agriculture cause massive degradation and consequent loss of impotence of pond ecosystem. Second, the rapid increase in urban built-up areas causes massive filling of water bodies including private ponds (Mahmud et al., 2020; Fattah et al., 2021a).

Degradation and disappearance of pond ecosystems in Bangladesh in general and Khulna city, in particular, are attributed to two factors. The first one is related to policy failure and the second one is related to lack of community participation in pond conservation and restoration. Regulatory instruments in Bangladesh keep provision for controlling of discharge of waste to water bodies including ponds. However, due to poor enforcement of regulatory regimes and monitoring the degradation of the pond environment is rampant (Marufuzzaman et al., 2019; Morshed et al., 2021). Moreover, as most of these policies emphasize

regulation and laws for environmental protection and pay less attention to the importance of public participation, therefore degradation of pond scape became unavoidable. Another impotent issue is the lack of policy incentives for the conservation and restoration of private ponds. Due to the lack of such market-based policy instruments (such as payment for ecosystem services- PES), the pond owners find it profitable to fill the pond for real-estate business. Therefore, it is urgent to develop a framework to conserve the remaining ponds and restore the degraded ones wherever possible to maintain a healthy urban environment in Khulna city (Haquet et al., 2020).

In this connection, scholarships at the global level are emerging, particularly addressing the private sector's willingness to participate in ecosystem-based adaptation and nature-based solutions to climate change (Costanza et al., 2017; Daniel et al., 2012; TEEB, 2010; Haase, 2015; Oertli and Parris, 2019; Swartz et al., 2019; Chaichana et al., 2011; Khan et al., 2020b). Ali et al. (2020), for example, ranked different ecosystem services in the Heihe River Basin, China based on the stakeholder's WTP; Khan et al. (2020a) evaluated the WTP for improved ecosystem services on a regional scale. Similarly, Almenar et al. (2018), Baskent (2020), and Maes et al. (2013) used almost similar conceptual frameworks for non-spatial analysis of ES in varied contexts. Kohyama et al. (2005) and Nedkov et al. (2015) although used spatial analysis to map out the ecosystem services they did it for wetlands' ecosystem services for the welfare of wildlife. Previous studies, in general, used the Contingent Valuation Method (CVM) for the valuation of ecosystem services. CVM is a review-based monetary appraisal method for the assessment of non-market goods/services (Jeong et al., 2017). The contingent valuation strategy follows the most extreme measure of cash that individuals are eager to spend on improving the nature of any ecosystem services/component (Chung and Chiou, 2017). The approach asks individuals to reveal their WTP to get any ES, or willingness to acknowledge (WTA) to surrender a service from the ecosystem. Obeng et al. (2018); Bamwesigye et al. (2020); Githiru and Njambuya (2019) showed that most of the free riders don't show any willingness to pay for the conservation of ecosystem services. The WTP has been employed in several studies in Bangladesh as well. For example, Gunatilake and Tachiri (2014) identified WTP for an improved water supply system; (Fattah et al., 2022) calculated WTP for sustainable solid-waste collection and management system; Ahmed et al. (2016) assessed WTP for health insurance; Afroz et al. (2009) works with community WTP for an improved waste management system; Ahsan et al. (2021) and Islam et al. (2019) work with WTP for safe drinking water; and more recently Kabir et al. (2021) used WTP framework for COVID vaccination. However, there is no prior study in Bangladesh that has holistically used the WTP framework for the assessment of blue ecosystem services (BES) in the Khulna context in a participatory way. A participatory approach must look at the willingness of the local community to conserve and restore the pond scape in their locality. Earlier experience shows that externally driven donor-funded conservation projects lack sustainability after the project fund is over (Oertli and Parris, 2019; Swartz et al., 2019; Chaichana et al., 2011). Therefore, there is a need for research that would explore how the community values the conservation and restoration of ponds and under what circumstance/policy context the community could be a vehicle of a locally driven initiative to conserve and restore local ponds for healthy living.

This study fills these gaps in knowledge and practices and expects to contribute to the policy process in three ways. First, it has employed a spatial analysis tool for quick visualization of the current status of available blue ecosystem services (BES); second, it has identified how community value the blue ecosystem services and their willingness to pay for sustained provision of those services by conservation and restoration of pond scape; third, it has modelled the drivers of community's WTP for conservation and restoration of BES. Finally, this study findings would improve our understanding of the factors that potentially determine local urban community's engagement in blue ecosystem service provision. Such findings would inform the policy process aimed at designing a

framework for community-based conservation and restoration of urban pond scape within the broader land use planning framework of a city.

2. Materials and methods

2.1. Study area

Khulna is one of the four major cities in Bangladesh that has more than one million population. Locating on the Bank of Bhairab-Rupsha River, Khulna City (officially known as Khulna City Corporation- KCC) has been developed as the main center of trade, commerce, industry, administration, health and education in the southwest region for half a century (Haque et al., 2020). This city offers all kinds of urban amenities and services and has a well-developed transportation network, therefore, the city experiences a huge influx of people from nearby cities and regions (Haque et al., 2020). A significant proportion of new migrants find their destiny in the fringe areas of the city. Therefore, in the urban fringe areas of Khulna city huge land use transformations have been taking place for the last couple of decades. A common pattern of such land use transformation is landfilling of low lying pockets and ponds to accommodate the new migrants (Haque et al., 2020). About 1.5 million people live in Khulna city within an estimated area of 45.65 sq km (Morshed et al., 2021). About 0.2 million (200 thousand) poor people live in low-income settlements mostly located in the urban fringe developed on low lands.

Although landfilling is rampant throughout the city fringes, there are still some ponds scape remaining in the southeast part of the city covering KCC wards- (administrative unit) 29, 30 and 31. The total area covers roughly less than 10 sq km. This part of the city fringe possesses peri-urban characters. The community residents do not have access to the piped water supply system and sewerage system. They use pond water and tubewell water for drinking, bathing and other household use. Urban agriculture and artisanal fishing in community water bodies and ponds are still observed. As land use transformation is rapid, if conservation and restoration initiatives are not taken the remaining pond scape will disappear soon. For this study, this part of the city is selected as the study unit (Figure 1). The study area is a linear-shaped area developed on the west bank of the Rupsha River. This low-income, relatively low-density

urban fringe is well-known for housing the climate migrants that originate from the southwest coastal tract of Bangladesh. This fringe settlement is only 2–4 km away from the main city centre where all kinds of trading and commercial activities take place. Moreover, the fish processing factories and the water vessel landing station for the offloading of fish, timber, salt, building materials are located just 2–3 km away from this area. The residents of this fringe area are engaged in diverse portfolios of income; most notable occupations are peri-urban agriculture, rickshaw pulling (diver of three-wheeler), wage labor in the water vessel landing station, local kitchen market, fish processing factories

2.2. Socio-economic survey and data collection

This study heavily draws on a mixed method of research; it has used both quantitative and qualitative research protocols. Apart from these, literature concerning the ecosystem services in varied contexts is reviewed to have a solid basis for positing findings of this research from a comparative perspective. Initially, during February–March 2020 reconnaissance survey was done in the study area to familiarize with the site and for environmental scanning of pond scapes. To examine how the local community appraises the ecosystem services received from blue ecosystem components especially pond scape a questionnaire survey was conducted using a semi-structured questionnaire. The questionnaire was divided into three sections. In the first section, the sociodemographic data including age, sex, household size, occupation, income, resource ownership, and education of the respondents were collected. The second section was designed to collect information about the community residents' knowledge/perceptions, use of BES and their level of satisfaction about the use of BES. The third section contains information on community residents' willingness to pay for the ecosystem services they receive from the pond scape. The contingent valuation method (CVM) was employed to obtain this information. A hypothetical scenario of conserved and restored pond scape was narrated/presented to the respondents. Eleven service facilities identified from the literature review earlier were included in the questionnaire and the respondents were asked to rank the services that they thought would be more important for the community if the conservation scenario is implemented. After that, the respondents were asked if they are willing to pay for any services. If

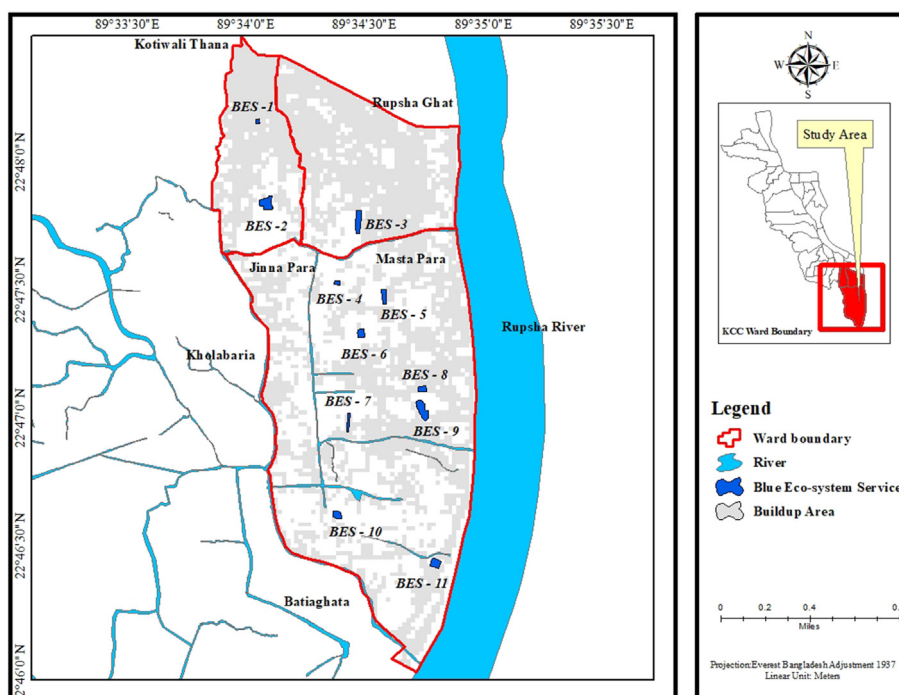


Figure 1. Study area map showing the locations of BES.

the respondents replied “Yes” for any service, a payment card was given to them and asked them to mark the preferred amount that they would like to pay.

This research was conducted as part of a Master Thesis having a modest budget of 1000 US\$. While a large sample could benefit the research but due to homogeneity in respondents’ occupational, income and educational profile, a 10% error margin was used in a 95% confidence level to have an optimum sample size that could be administered with a modest budget. To determine the sample, formula was used; which offers 96 samples. A stratified random sampling technique was followed for survey-based data collection. To substantiate the finding of the household survey, three focus group discussion sessions were conducted. This helps to triangulate our findings.

2.3. Methods of spatial analysis of available ecosystem services from blue ecosystem

For spatial analysis alongside GIS maps, the Landsat 8 OLI image was used which was obtained from the USGS. Spatial analysis related procedures are presented below.

In the study area different blue ecosystem service benefits are enjoyed by local residents and community which includes reduction of emitted carbon, moisture rich soil for agriculture and similar uses, thermal comfort due to low surface temperature resulted from colling of microclimate by available water bodies etc. The spatial coverage (i.e. service coverage area) of all these services need to be determined to accurately assess the role and value of BES. The Service coverage area or catchment area of a service is often recognized as the area having significant influence of that particular services (Flisek and Lewandowicz 2019). To compute the service coverage area of blue ecosystem services (BES), the data of each of the BEE was collected from various sources. Using the GPS, the location of each BES of the study area was collected and fed into ArcGIS. Using the Thiessen Polygons Method (Widaningrum, 2015) in ArcGIS the service area of each of the BE was calculated which is shown in the result section.

2.3.1. Determination of benefits of absorption of emitted carbon

The contribution of different land covers to anthropogenic carbon emissions in the last 150 years was nearly 33% of overall emissions (Houghton et al., 2012). Land cover type such as built-up area, agricultural land emits carbon to the environment, while vegetation and waterbody absorb carbon from the environment (Cui et al., 2018; Hong-xin et al., 2012; Fattah et al., 2021b). The yearly carbon absorptions capacity of the BEs was estimated using Eq. (1).

$$CA_i = \sum A_i \times \delta w \times \left(\frac{MCO_2}{MC}\right) \quad (1)$$

where CA_i is the Carbon absorption by i BEs (ton/year); A_i is the area of i BEs (acres), δw is the carbon absorption coefficient of waterbodies (0.0459 kg C m⁻²a⁻¹) and MCO₂/MC = 44/12 = 3.6667 (Cui et al., 2018). The area of each BE was measured from the spatial shapefile of Khulna City Corporation, provided by Khulna Development Authority.

2.3.2. Determination of benefits of moisture rich soils

Moisture rich soil provides valuable condition for productivity and production of plants, crops and other aquatic resources by ensuring supply of soil nutrient. Soil moisture is high in areas close to water bodies. To assess the soil moisture and the presence of water bodies, the Normalized Difference Water Index (NDWI) is used. The NDWI is a remote-sensing based index used to estimate the moisture and water level. This study used the NDWI index to illustrate the spatial soil moisture profile of the study area. It is calculated using the near-infrared and the short-wave infrared reflectance in the GIS environment through Eq. (2).

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR} \quad (2)$$

NDWI values vary from -1 to +1, with values close to -1 suggests lack of water bodies to provide soil moisture and values close to +1 indicates the presence of dense water bodies (Gao, 1996). The NDWI was calculated for the entire Khulna City for more accurate results and later the result for the study area was extracted through the extraction tool in GIS. As the data are derived from the satellite image then the cross-check was done with the existing land cover and field survey to mark the exact location of the waterbodies.

2.3.3. Determination of benefits of thermal colling

The BES has tremendous potential to provide thermal cooling benefit (comfort) in urban build up areas by regulating the local/micro-climate. To assess the impacts of BES on its neighboring area’s surface temperature, this study calculated the land surface temperature (LST) of the study area. In this regard, Landsat 8 OLI image of the study year (Path/Row: 137/44) was collected from USGS. The derivation of LST from Landsat 8 OLI images was derived by using Eqs. (2), (3), (4), (5), (6), and (7), which is a widely accepted method and employed in earlier studies (Kafy et al., 2021); (Gazi et al., 2020; Georgiana & Urişescu, 2019; Fattah et al., 2021a). The LST was calculated for the entire Khulna City from where the result for the study site was extracted through the extraction tool in GIS. Eqs. (3), (4), (5), (6), (7), and (8) have been used to determine the LST values.

$$L_\lambda = AL + ML \times QCAL \quad (3)$$

where L_λ is the TOA Spectral Radiance (W/(cm²×sr×µm)).

ML is the Radiance multiplicative scaling factor for the band,
AL = Radiance additive scaling factor for the band
QCAL is the quantized calibrated pixel value in DN.

TOA spectral radiance (L_λ) values are converted into another variable called At-Satellite Brightness Temperature (TB)

$$TB = \frac{K_2}{\ln(K_1/L_\lambda + 1)} \quad (4)$$

where, TB = At-Satellite Brightness Temperature, in Kelvin (K)

K₁, K₂ = Thermal conversion constants for the band. Finally, the TOA Brightness Temperature was converted to LST values.
ε = Surface emissivity, calculated according to Eq. (5).

where, P_v is the vegetation proportion calculated following equation, and Land-surface emissivity was calculated through Eq. (7)

$$P_v = [(NDVI - NDVI_{min}) / (NDVI - NDVI_{max})]^2 \quad (5)$$

$$\varepsilon = 0.986 + P_v \times 0.004 \quad (6)$$

Using Eq. (6) the LST was calculated in Kelvin unit and later converted in °C unit using Eq. (7).

$$LST = [TB / (1 + (\lambda \times TB / \alpha)) \times \ln \varepsilon] \quad (7)$$

$$LST_{0C} = LST_k - 273.15 \quad (8)$$

where, λ = the wavelength of emitted radiance, α = hc/k = 1.438 × 10⁻² mK.

2.4. Method of determination of residents’ willingness to pay (WTP) for BES

For sustainable provision of benefits of ecosystem services, there is need for community/residents’ ownership of BES in their locality.

Literature shows that there is a direct link between ownership and contribution to own (Haab and McConnell 2002). As the ecosystem services benefits received by the community/residents are no-market goods/services and most of the benefits are intangible in nature, the Contingent Valuation Method (CVM) was employed to assess the WTP of the residents/community for sustained provision of the benefits by conserving BES.

The CVM was first used to assess the benefit of outdoor recreation in the United States' backwoods of Maine (Haab and McConnell 2002). It is a simple, and flexible non-market approach which is widely used for assessing the environmental impact of non-market resources and cost benefit analysis (Lopez-Feldman, 2010). Despite the fact that the approach has been criticized for the reliability and validity of the outcome, the CVM has been applied in many research fields such as renewable energy (Botelho et al., 2016), wetlands conservation (Siew et al., 2015), recreation (Henry et al., 2018), watersheds (Zhou and Li 2015), waste management (Afroz et al., 2009), water quality improvement (Sehreen et al., 2019) and other nonmarket resources (Wang et al., 2018; Fogarassy and Neubauer 2016). The use of CVM in the field of environmental protection study has been increasing day by day.

The CVM is a survey-based strategy that contains a hypothetical scenario in the survey's heart, creating a hypothetical market for a service or good. Respondents are asked how much they would be ready to pay for a change in the quantity or quality of the services or goods (Kristrom, 1990;). A CVM is characterized by different parameters based on the type and needs of the researches, such as period of payment (e.g., month, year), payment vehicle (e.g., donation, tax) and format of the response (e.g., dichotomous choice, open question) (Orlowski and Wicker, 2019). We have employed the CVM method to calculate the residents' willingness to pay (WTP) for ensuring sustained supply of different benefits obtained from the blue ecosystems (BES) in their area/locality.

There are several layouts of CVM study such as "Dichotomous choice, Open-ended, Iterative bidding, Multiple bounded dichotomous choices and Payment cards" (Sehreen et al., 2019; Banna et al., 2016). In this study we have employed the Payment Cards Method (PCM) of CVM due to some difficulties and prejudices of other approaches. During field survey, the respondents were explained the details of the PCM, service facilities, BES and decision rules by a payment card which was adopted from Rowe et al. (1996). A list of payment amounts (per month) is displayed on the payment card, from which respondents selected the amount that best represents their maximum WTP for the services. The WTP for each of the services was calculated using Eq. (9).

$$WTP = G_{WTP} \times \text{Highest bid amount for each service} \quad (9)$$

Here, G_{WTP} is the cumulative distribution for the random response.

WTP of the respondents relies upon different variables like pay, family size, instruction level, separation, age, occupation, and so on. In this way, here the needy variable is WTP and the autonomous factors are the remainder of the components (equation 10). In any case, the issue ought not be the equivalent to the entirety of the components that WTP isn't similarly subject to all credits, some are emphatically where the vast majority of them are contrarily related (Loomis et al., 1999).

The equation of

$$WTP = B1(X) + B2(Y) + B3(Z) + B4(M) + B5(N) + B6(G) + C \quad (10)$$

where B is constant and X, Y.....G are the parameters.

Since people essentially react with a "yes" or "no" to a solitary dollar sum, the probability of paying a given dollar sum is determined measurably utilizing a subjective alternative model, for example, a logit model (Hanemann, 1984).

The basic relationship (equation 11) is:

$$\text{Probability(Yes)} = 1 - \{1 + \exp[B0 - B1(\$X)]\}^{-1} \quad (11)$$

Here, B's are coefficients to be determined utilizing logit measurable methods; $\$X$ is the amount respondents agreed to pay.

The coefficients at any rate indicates the offer that the individual is being agreed to pay. Extra coefficients are the factors which have influences on WTP such as respondent's age, education level, income, knowledge, family size etc. Based on literature review, for this study, we have hypothesized that respondent's age, household income, education level, distance of residence from BES, household ownership, family size etc., are the possible determinants of residents' WTP. These determinants variables are used in the regression model proposed by Hanemann (1984).

Hanemann (1984) proposed the logistic regression Eq. (12) to calculate the WTP.

$$\text{Mean WTP} = (1 / B1) \times \ln(1 + eBo) \quad (12)$$

Here, B_1 = the coefficient gauges on the offer sum; B_0 = The assessed consistent. The flow diagram showed the overall methodological framework (see Figure 2)

3. Results and discussion

3.1. Respondents socio-demographic profile

The study was carried out in the Rupsha area of Khulna City and considered the residence of the Rupsha area. Out of 96 respondents, 80.65% were male. About 62.5% of families belonged to 2–5 members,

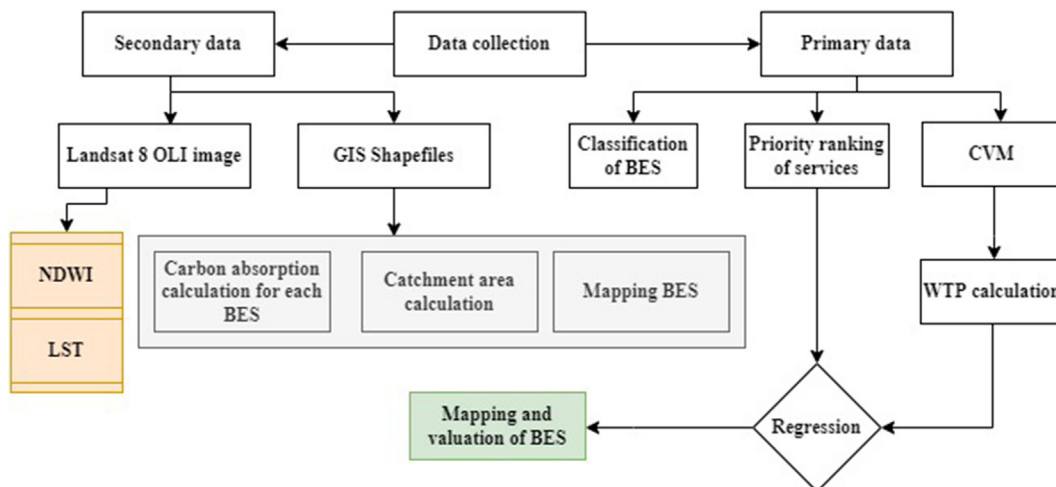


Figure 2. Represents the methodological flow diagram of this research.

with 20.8% of families having more than 5 members. Most of the respondents were in the age group of 45–59. The educational profile was also very interesting in that most people had only completed secondary education. There was also a large number of illiterate people. The main income source for most of the respondents was business, where 1% of the respondents were found unemployed. People were so close to the river that 1 km was calculated at 36.5%. 37.5% of respondents reported an income level of less than BDT 5000 (US \$1 = 80 BDT), whereas 14.6% of respondents earned more than BDT 20,000. Moreover, 75% had ownership of a house and 25% were renting out their houses.

3.2. Existing conditions of ecosystem services

3.2.1. Spatial coverage of ecosystem services

Figure 3 and Table 1 represent the service area of each BE in the study area that was calculated using the Thiessen Polygon Method in the GIS environment. The catchment area analysis provides information on the prevalence areas of each BES that provides knowledge about the quality of the BEs and the dependency of the people of the community. The analysis shows that some of the BES cover moderately large areas and most of them cover only small areas. Analysis shows that BE 3, 7, and 10 cover relatively large areas. Whereas BE-8 covers only 3% of the total areas. This indicates that some of the BES poorly serve the ecosystem services to the community people. It can be added that the service area is calculated based on the nearby location of the water bodies and the study is designed as the same with considering other issues. So that, the served area is not covered the whole study area and some portions are marked as the unserved zone.

3.2.2. Characterization of the ecosystem services

Ponds or blue ecosystems are important for the sustainable ecological integrity of urban areas. The urban blue ecosystems have considerable ecological value. Figure 4 represents the existing blue ecosystems of the study area. Out of 11 BES, 8 are located in Ward 31 and most of them provide supporting services like indirect help for biodiversity. Four BES provides supporting services i.e., helps to conserve biodiversity, four were found providing regulating services by regulating the behavior of human as well as urban environment, two provisioning services i.e.,

Table 1. Synopsis of the Existing scenario of BEs.

BES No ¹	Catchment Area Percentage	Carbon Absorption from waterbody area (ton/year)	Ecosystem Service Type
BES-1	8%	9.26	Provisioning ²
BES-2	7%	13.69	Regulating ³
BES-3	16%	14.46	Provisioning ²
BES-4	9%	9.74	Cultural ¹
BES-5	8%	11.14	Supporting ⁴
BES-6	9%	13.16	Regulating ³
BES-7	12%	12.30	Supporting ⁴
BES-8	4%	12.33	Supporting ⁴
BES-9	6%	7.87	Regulating ³
BES-10	15%	12.67	Regulating ³
BES-11	6%	13.05	Supporting ⁴

¹ Tourism, Recreation, Spirituality.

² Food, Fresh Water.

³ Water Retention, Heat absorption, Climate regulation.

⁴ Maintenance of community, Shelter for species.

supports the community by fish and serve as the purifier of water, air and other toxic environmental elements and only one provides cultural services by supporting the community bonding and enhancing the ability to prevent the natural calamity. In ward no 28, two BES are available to serve as provisioning and regulating services. However, the rapid urban development, excessive pressure, discharge of drain water and storm water, waste dumping, etc. are polluting and destroying the urban blue ecosystems and reducing their services.

3.3. Benefits from moisture rich soil of BES in the study area

The NDWI was used to illustrate the soil moisture profile of the study area and presented in Figure 5B. The value of NDWI lies between -1.0 and +1.0. The positive values of NDWI values indicate the presence of water bodies or the presence of moisture in the soil of any area. The NDWI value range was found between -0.431 and +0.521. The result of NDWI

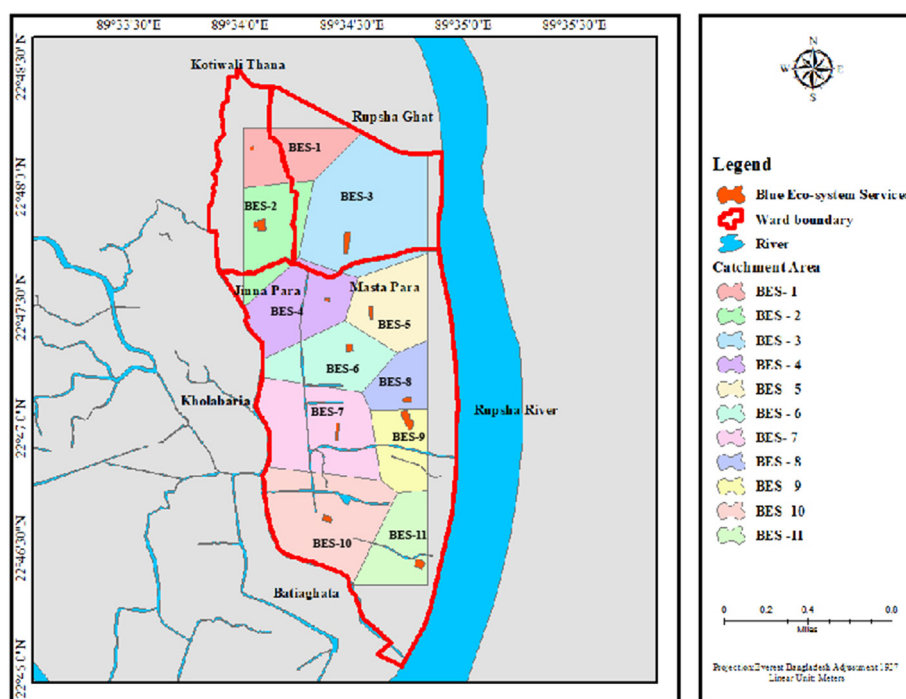


Figure 3. Spatial coverages (catchment areas) of different BES- water bodies in the study area.

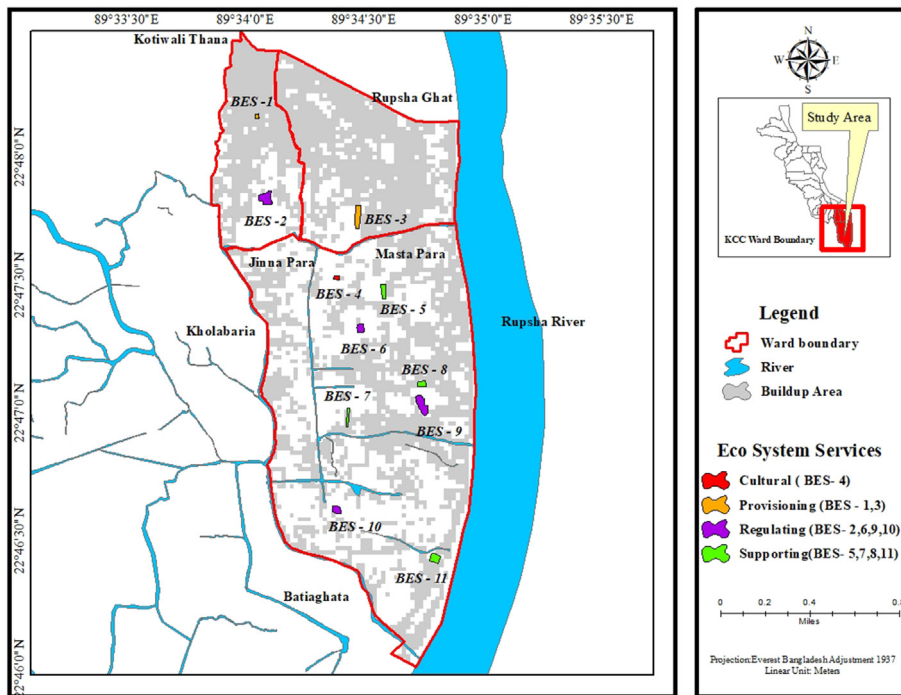


Figure 4. Different ecosystem services are provided by different blue ecosystems of the study area.

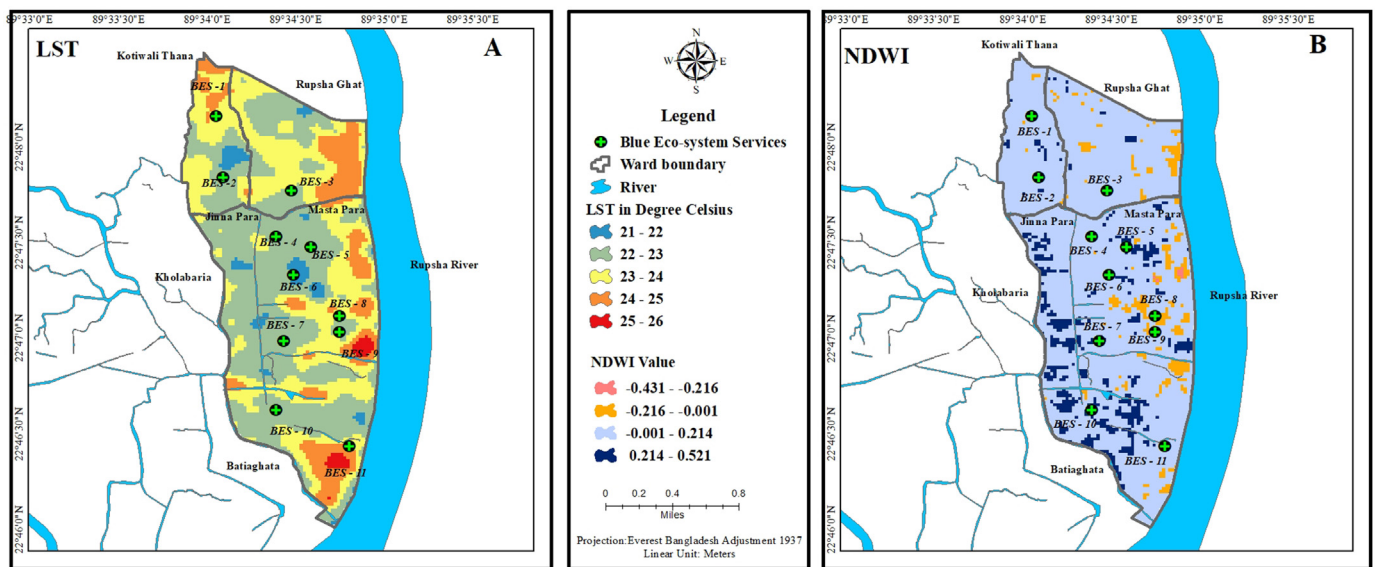


Figure 5. (A) Land surface temperature and (B) NDWI map of the study area.

indicates the poor soil moisture profile of the study area. Only 9% of the total area's soils have relatively higher moisture, and most of these are adjacent to the BES. The excessive built-up area has resulted in the poor soil moisture conditions of the study area, but the ponds of the study area help to retain the moisture in the soil.

3.4. Benefits from land surface temperature regulations of BES

Waterbodies such as lakes, ponds, and wetlands have profound impacts on cooling the surrounding climatic temperature as well as surface temperature. Figure 5A represents the LST of the study area where LST value range was found between 21 °C and 26 °C. Figure 5A shows that the BES are influencing the reduction of LST in the study area. This study found the lowermost LST in the area with the highest NDWI values. The

lowest LST was measured 21.94 °C in the location of BE no 3 whereas the other BES showed LST less than 23.68 °C. High LST was observed in the built-up areas, whereas BES in the study areas was found to reduce the LST in their catchment areas and also helping to lower the ambient temperature. This spatial analysis of BES helped to pinpoint the positive impacts of BES on the study area. Since the riverbank side has so many industries, the high-temperature zone was found.

3.5. Benefits from absorption of emitted carbon by BES

The blue ecosystem is an important indicator of ecosystem dynamics and is sensitive to climate change. Urban areas account for excessive carbon emissions due to excessive built-up areas, industrialization, vehicular activities, etc. Built-up areas emit carbon into the atmosphere,

but ponds or water bodies absorb carbon and reduce net greenhouse gases from the environment. There are a total of 10.2 acres of ponds in the study area, which absorb 129.67 tons of carbon every year, while 464.11 acres of river area absorb 3505.36 tons/year of carbon. The amount of carbon absorbed by each BE is presented in Table 1. The BE 2, 3, 6, and 11 absorb relatively higher amounts of carbon. Thus, the blue ecosystems of the study area are helping to stabilize the micro-climate by reducing carbon emissions from the environment and providing regulating ecosystem services. Though other landscapes of the study area, such as vegetation, absorb carbon from the environment, analysis shows that the BEs absorb a greater amount of carbon than other landscapes of the study area. This signifies the need for the restoration and conservation of the urban blue ecosystems and an increase in the use of BEs.

The last column of the Table 1 showed that diversity prevails in ecosystem service profiling in the candidate area. The selected BEs are often used for prescribed purposes.

3.6. Respondents appraisal of the benefits of the BES

3.6.1. Satisfaction level

The role of rivers and ponds should be to supply many services to the community. Urban ponds, especially those in the slum areas, are mostly used for bathing, washing dishes, and cleaning. In this regard, clean water is important. Water pollution and discharges of drain water into the pond area decrease water quality. Out of the 96 respondents, 54% were not satisfied with the water quality of the BEs in the study area (Figure 6). The most interesting result was found when it was found that 40% of the respondents were indecisive about choosing an answer because of a lack of consciousness. Only a few respondents expressed little satisfaction with the river condition.

3.6.2. Priority rankings of services

From the prior literature, eleven types of services provided by urban ponds have been identified and documented, using respondents' opinions to document the responses to different services they are willing to pay for. The respondents were asked to rank the significance of different BE services in their area. Table 2 shows that recreation facilities were the first choice of the local people (16.7%) because of the scenic beauty of the riverside. The community people decided to pay for the improvement of existing recreation facilities. Businessmen may find an extra benefit if a huge number of people regularly visited the riverside. The second choice was agricultural use (15.3%), as most of the respondents were illiterate. Fishing (12.8%) was ranked in the third position as it may earn a livelihood. Private fish cultivation was motivated by the government and organizations. Air quality (11.1%) another top-ranked choice, meaning that purifying the adjacent air may increase the movement of visitors and therefore increase the income of those living there. For the

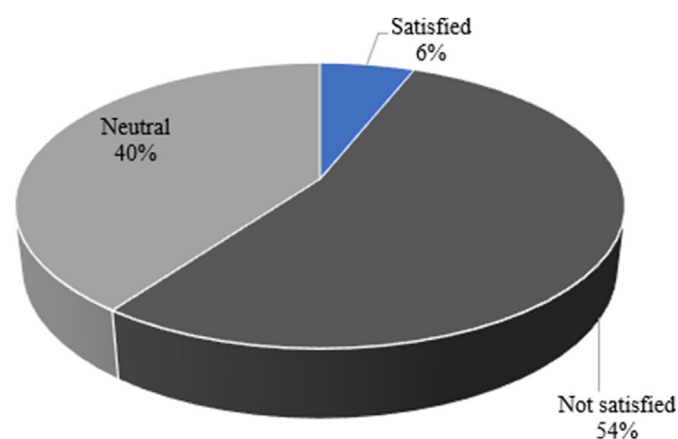


Figure 6. People's satisfaction level on the existing situation.

Table 2. Priority ranking of services.

Services	Percentage (%)	Priority Ranking
Recreation	16.70%	1
Agriculture use	15.30%	2
Fishing	12.80%	3
Air quality	11.10%	4
Erosion control	10.00%	5
Domestic use	8.60%	6
Industrial use	6.40%	7
Disease control	6.40%	8
Boating	5.60%	9
Tourism	4.70%	10
Aquatic organisms	2.20%	11

lack of consciousness, people are not willingly paying for a large number of aquatic organisms (2.2%). Parallely, some respondents, basically the educated, are willingly paying (if urgent) for the up-gradation of blue ecosystem facilities on behalf of enjoying the expected facilities.

3.6.3. Respondents attitudes for the conservation

The impacts of urban ponds in all aspects signify the need for the conservation of urban water systems. In this regard, this study documented respondents' attitudes towards paying for conservation and providing services in the blue ecosystems of the study area. A huge variation has been found in the responses of the respondents. Table 3 shows that out of 96 respondents, 65.62% agreed to pay different amounts for the services of the BEs, where 44 of them showed a willingness to pay less than BDT 100 (1 USD = BDT 85). Only 2.1% of people willingly pay between BDT 400 and 500, and the income of these two respondents was more than BDT 20,000. This variation has been observed because of the differences in income level. As most of the residents of the Rupsha area are poor income class (slum people) they showed less willingness to pay, as they earn less.

Table 3 shows that about 34.4% of the respondents refused to pay any money for the improvement of services in the blue ecosystems. Figure 7 shows the opinions of these respondents regarding not being willing to pay. Most of the people are low-income wage groups, so they didn't want to pay for the services. Poverty is the main cause here. About 21% of people denied paying money because they lived far from the BEs. Moreover, they think that this is the responsibility of Khulna City Corporation. Then the education level is the main reason because of the lack of consciousness about the factor. As the concept of family planning is related to any kind of decision-making, family members who have large families are not willingly paying for any services. Illiterate people are not interested in investment as they are already deprived of basic needs; extra benefits should not be needed by them. With the increase in education level, people's perceptions may change, and the respondents who completed higher secondary levels willingly invest the money. The highest bid is chosen by the technically educated people, which is between BDT 400 and 500, because of their knowledge of the adverse effects of ecosystem disservices. Some informally educated people were also surveyed and most of them were interested in BDT 200–300 as the

Table 3. Composition of people's view.

Amount (BDT)	Respondents	%
0	33	34.38
≤100	44	45.83
101–200	12	12.50
201–300	3	3.13
301–400	2	2.08
401–500	2	2.08

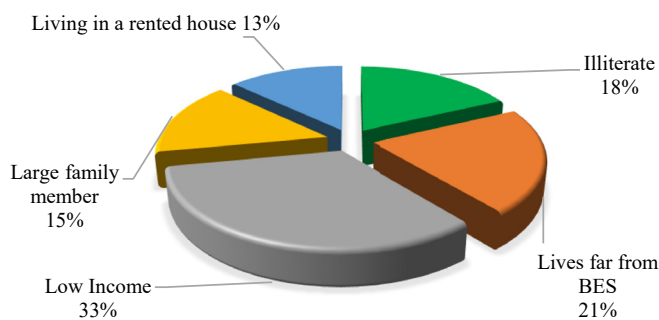


Figure 7. Reasons for no willingness to pay for any services.

monetary value of the services. According to Yoo and Kwak (2009), Acquah (2011), and Shao et al. (2018), higher income and educated people are more willing to pay for environmental protection.

Figure 8 shows the impacts of the distance of respondent's residence from the BEs on their WTP. Findings show that all the respondents who reside on the river bank agreed to pay for the services. Figure 8 shows that respondent lives more than 3 km shows no willingness to pay, and respondents lives within the 1 km from the BE showed more willingness to expend for the services of BEs.

Afroz et al. (2009) employed the CVM method to calculate WTP for the improvement of the waste management system of Dhaka City. A study by Sehreen et al. (2019) reveals that 67.20% of the people of Dhaka City are willing to pay BDT 0 to 1500 for water quality management whereas most of them were agreed to pay less than BDT 200 which is inconsistent with the findings of this study.

3.7. Respondents WTP for sustained provision of various ecosystem services in the study area

We employed the CVM to calculate the WTP for all the selected eleven service facilities. The offering approach of the CVM was utilized to gather data about the ability to pay for all the service facilities. As recreational services ranked first in the priority ranking of the services (Table 2), the authors illustrated the calculation process of WTP for recreational facilities only. The following WTP in Table 4 has been documented for recreational services, where 60 respondents out of 96 showed a willingness to pay for recreational services.

In this method, the cumulative distribution for the random responses i.e. - $G_{WTP}(A)$ have been calculated, where A denotes individual responses. The responses have been found between BDT 25 to 200. Hence, the probability yes answer for each of these responses is represented in Table 5.

Willingness to pay for Recreational use was calculated here by plotting the yes answer and their corresponding $G_{WTP}(A)$. Here, the 50th

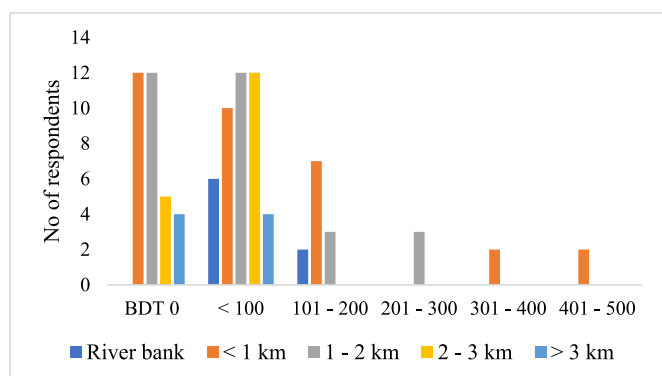


Figure 8. Influences of distance on WTP.

Table 4. Response of Willingness to pay for recreational use.

Amount BDT	Frequency
25	6
50	5
75	11
100	20
125	9
150	4
175	2
200	3
Total	60

Table 5. Bid amount for recreational use.

Bid amount, (A) BDT	$G_{WTP}(A) = A/\text{Highest bid}$	Prob. ("Yes") = $1 - G_{WTP}(A)$
25	0.125	0.875
50	0.25	0.75
75	0.375	0.625
100	0.5	0.5
125	0.625	0.375
150	0.75	0.25
175	0.875	0.125
200	1	0

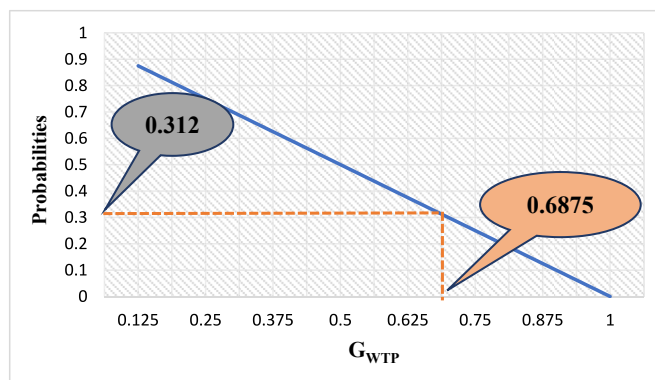


Figure 9. Probability of "Yes" answer and cumulative Distribution of WTP.

Table 6. Calculation of WTP for all the services.

Services	Percentile	Monthly WTP (BDT/ household)	Monthly total WTP of Rupsha (BDT)
Domestic use	50%	113	1972415
Agriculture use	31%	138	2408790
Industrial use	70%	38	663290
Aquatic organisms	50%	63	1099665
Erosion control	64%	63	1099665
Air quality	58%	63	1099665
Disease control	50%	88	1536040
Fishing	25%	113	1972415
Boating	50%	75	1309125
Recreational	31%	136	2373880
Tourism	60%	50	872750

Table 7. Effects of each variable on WTP.

Variables	Coefficient	Std. Error	Significance
(Constant)	1.262	1.441	0.383
Age	0.116	0.172	0.004
Education	0.425	0.120	0.001
Distance	-0.296	0.151	0.002
Income	0.728	0.190	0.000
Family member	-0.220	0.292	0.003
Ownership	0.879	0.378	0.002

percentile indicates the responses of 20 people with BDT 100. Similarly, the 12.5th percentile indicates the responses of 2 people with BDT 175. However, 31.25th percentile has been considered here reasonable as it has created equilibrium between both amounts of taka and responses. Therefore, the following result (Figure 9) has been found, where $G_{WTP}(A)$ is 0.6875.

G_{WTP} has been plotted along the x-axis and Probabilities have been plotted along the y-axis.

$$\begin{aligned} \text{Thus, the } WTP &= G_{WTP} \times \text{Highest bid.} \\ &= 0.6875 \times 200. \\ &= 135.5 \approx 136. \end{aligned}$$

Hence, the WTP for Recreation use calculated BDT 136. Table 6 represents the calculated WTP of the residence of Rupsha for other service facilities. Table 6 shows that people are willing to spend a maximum of BDT 138 (about \$1.73) for agricultural use and a minimum of BDT 38 for industrial use. Most of the people of Rupsha are lower-income groups, and a large percentage of the residence depend on ponds water for daily purposes such as domestic use, cleaning, bathing, etc. The WTP of domestic use was calculated BDT 113. Table 6 also represents the monthly total WTP for all the 17455 households of the study area for each service facility. The total WTP for different services is huge in comparison to the need for the development of the services, which will be a good

contribution to the budget for the management and development of urban blue ecosystems as well as the urban environment.

3.8. Determinants of respondent's WTP for BES

A linear regression model was used to identify the effects of the respondents' different sociodemographic status on their WTP. The respondents' WTP was considered as the dependent variable, and the independent variables were age, education level, distance from household, income, family size, and household ownership. The findings are shown through the Eq. (13) below:

$$\text{The equation of } WTP = B_1(\text{AGE}) + B_2(\text{EDU}) + B_3(\text{DIS}) + B_4(\text{INC}) + B_5(\text{NUM}) + B_6(\text{HOU}) + C \tag{13}$$

where, NUM = Number of family members; EDU = Education level; INC = Monthly Income; HOU = House ownership; DIS = Distance of the house from BEs, AGE = Individual age of respondents and B= Coefficient and C= Constant. WTP is the dependent variable.

Hence the obtained regression model (Eq. (14)) of this study:

$$WTP = 0.116(\text{AGE}) + 0.425(\text{EDU}) - 0.296(\text{DIS}) + 0.728(\text{INC}) - 0.220(\text{NUM}) + 0.879(\text{HOU}) + 1.262 \tag{14}$$

Table 7 represents the factors and their significances in the respondents' WTP for BEs. The negative correlation between the distance of houses from the BEs and WTP means that with the increase in distance from the ponds, the payout level of the people decreases. As the ponds are located far, they think that the improvement of the BEs will not help them much, for why the showed unwillingness. The inverse correlation with family members indicates that small families have a higher payout level. The higher level of expenditure in large families is the main reason for this. On the other hand, a strong positive correlation was found between household ownership and WTP which suggests that temporary living people are less willing to pay since they will not stay there forever.

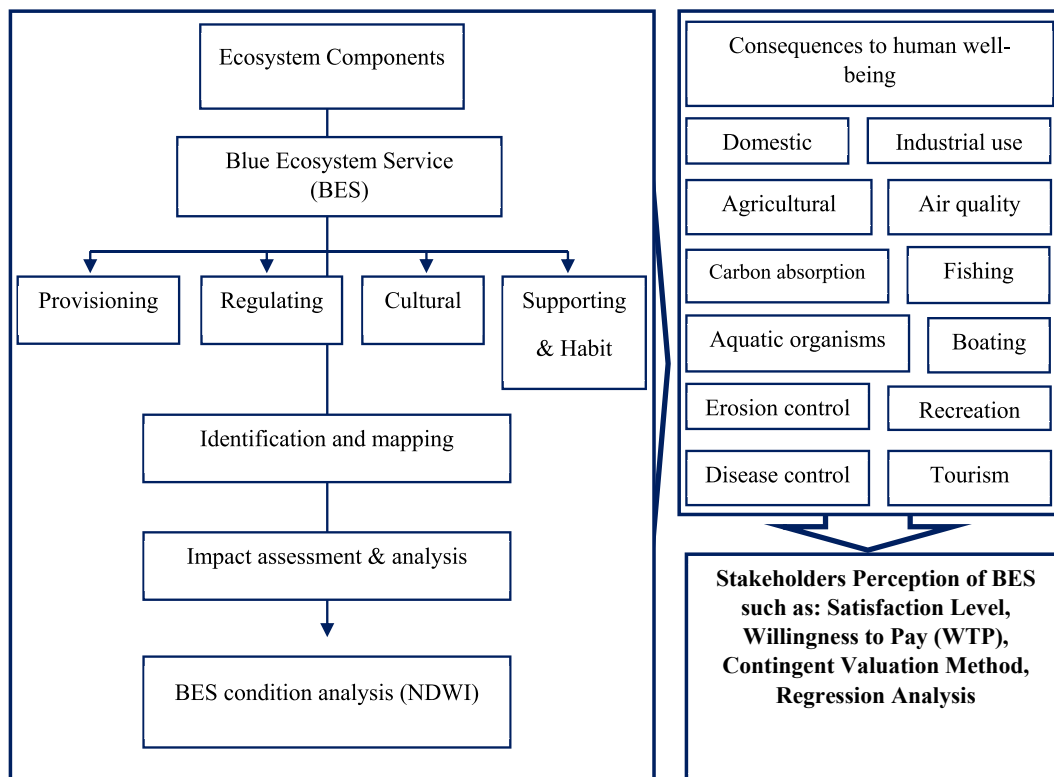


Figure 10. Concept of monitoring the BES for society's well-being.

Table 7 shows that WTP values for different services were influenced significantly by income level and education, which is consistent with the findings of the prior studies of Dhaka City on water pollution management by Sehreen et al. (2019), waste management system by Barmon et al. (2015) and Afroz et al. (2009). Similar findings are common for other studies conducted on the attitudes of people towards the WTP for environmental protection including Akhtar et al. (2017), Banna et al. (2016), Bilgic (2010), Masud et al. (2015), Moffat et al. (2011), Shao et al. (2018). People in the study area are mainly from lower income groups, and they have to focus on their survival. Those who have a higher income do not have to worry about survival, and they show more concern about environmental protection and luxurious services. This is inconsistent with the prior studies of Bangladesh (Afroz et al., 2009); (Fattah et al., 2022)) and also for other countries (Acquah, 2011; Khoshbeen et al., 2019; Afroz and Masud, 2011; Shao et al., 2018).

4. Conceptual framework derived from current study to address the inter-linked issues of BES

The theoretical structure for the valuation of non-market ecosystem services includes a cycle that starts with a stock of the scale, synthesis, and design of environments to decide their impact on human prosperity (Almenar et al., 2018). Figure 10 presents the proposed framework by the author for the valuation of the blue ecosystem services of an area. The system is explained around four stages (distinguishing proof and planning, sway evaluation, condition investigation, valuation) and three ideas (character, administration, and worth). This structure advances the mix of spatial investigation, non-spatial examination, and public support for the valuation of blue environment administrations in any area. The framework looks to enhance the preservation and regulation of BES by providing (i) knowledge of the importance of BES in climate control (ii) recognition of ecosystem cost; (iii) incorporation of different services with ecosystem services and (iv) help in understanding the method of valuation of BES and the importance of the BES to the professionals, decision-makers and responsible authorities for the preservation of BES.

5. Conclusion

Cities around the world stepped up their efforts to ensure a sustainable urban environment. The government of Bangladesh paid more attention to conserving the environmentally sensitive zones and components including the ponds, especially urban ponds or blue ecosystems. In this study, we have documented the existing conditions of the blue ecosystems and their ecosystem and environmental services. We have employed the CVM to calculate WTP for implementing eleven types of service facilities in the blue ecosystems of south-east urban periphery in Khulna city of Bangladesh.

The results show that the eleven BEs of the study area provides four types of ecosystem services to the community residences along with absorbing 129.67 tons of carbon from the atmosphere each year and lowering the surface temperature of the study area. But more than 50% of the residents are not satisfied with the existing conditions of the BEs. Hence, 65.62% of the residents have a positive WTP for the protection of the BEs by providing different service facilities. Respondents are willing to pay a maximum of BDT 138/month for agricultural services, while BDT 136/month for recreational services and a minimum of BDT 38/month for industrial use. The education level, family size, income, the distance of residence from BEs, household ownership, and age are significantly related to the respondents' WTP, where the distance of residence from BEs and family size inversely correlated with WTP. There are slums, buildings, industries such as cottage, fish, wood, cement etc., in this small urban unit which is responsible for the substantial differences in the BEs and their accessibilities.

The participation of community people in activities related to environmental protection with the government is essential for sustainable urban management. There will have the possibility of the shortage of

finances if we rely just on the government's budget for conservation/restoration of BES in community scale. So we need to properly motivate the majority of inhabitants to encourage to participate in conservation and restoration of community scale BES in Khulna City through their voluntary contribution. Thus, the following suggestions will be helpful.

The government should give more focus on the conservation, development of urban blue ecosystems and the initiatives to increase the number of ponds in urban areas needs to be taken and implemented. Therefore, to enhance the people's awareness of the importance of blue ecosystems, the government should propagate the significance of urban blue ecosystems through radio, tv, social media, internet. In this way can we improve the people's WTP and payout level of urban people for the protection of urban ponds.

Second, it is more important to promote education and investment in the education sector. The findings of this study showed that the higher the respondents' education levels, the higher is their WTP for conservation/restoration. Consequently, we must expand educational spending, particularly among primary and secondary school students. The government should organize environmental protection courses and raise environmental awareness. To establish a strong foundation for the future, we should approach youngsters during their adolescence. We can invest in higher education and ongoing re-education in the sustainability of sensitive landscapes so that an increasing number of individuals will give compensation for BEs and environmental protection.

Third, promotion of family planning. This study found the significant negative impacts of family size on the WTP of the respondents. This is because large families have higher monthly expenses, which makes them reluctant to spend extra in other sectors. In this regard, mass education will be more effective.

Fourth, the initiatives of increasing city economic levels and per capita income are important. The empirical findings of this study reveal that as household income level increases, the WTP rises as well. The government must create enabling environment to increase residents' income as much as possible; continually motivate to increase income channels, and continuously improve residents' satisfaction levels so that more people join the conservation of urban ponds and increase the usability of urban blue ecosystems.

Considering only one or two types of analysis (spatial, non-spatial, and stakeholder perception) is not a good approach for the valuation of BES. The traditional framework cannot reflect properly, how different ES are to be incorporated during the valuation of BES. However, the blue ecosystem comprises various types of goods and services for humankind. There are a couple of provisos to consider during the valuation of blue biological systems for numerous environmental merchandise and ventures. It is vital to consider all the ES types and services for the valuation of BES. Setting up the useful connections between the blue biological system and the human advantages is fundamental. That's because logistic regression and multiple regression have been conducted. This study highlighted the interest of most free riders, or poor class people in the conservation of ecosystem services while many previous studies showed free riders have less or no interest in paying. This study proposes a framework considering the systematic methodology of the distinguishing proof, planning, valuation, and appraisal of all services to assess the BEs of any zone. Further studies should focus on large scale WTP evaluation with a large sample size for BES. The proposed conceptual framework for the valuation of BES will help the professionals, decision-makers, and responsible authorities to consider spatial, non-spatial, and survey-based analysis for the valuation of BES. This study demonstrated the significance of BES and their valuation.

Declarations

Author contribution statement

Md. Nazmul Haque: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Mustafa Saroar: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Md. Abdul Fattah, Syed Riad Morshed: Performed the experiments; Analyzed and interpreted the data.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

References

- Acquah, H.D., 2011. Farmer's perception and adaptation to climate change: a willingness to pay analysis. *J. Sustain. Dev. Afr.* 13 (5), 150–161.
- Adams, S., Adom, P.K., Klobodu, E.K.M., 2016. Urbanization, regime type and durability, and environmental degradation in Ghana. *Environ. Sci. Pollut. Res.* 23, 23825–23839.
- Afroz, R., Hanaki, K., Kurisu, K.H., 2009. Willingness to pay for waste management improvement in Dhaka city, Bangladesh. *J. Environ. Manag.* 90, 492–503.
- Afroz, R., Masud, M.M., 2011. Using a contingent valuation approach for improved solid waste management facility: evidence from Kuala Lumpur, Malaysia. *Waste Manag.* 31 (4), 800–808.
- Ahmed, S., Hoque, M.E., Sarker, A.R., et al., 2016. Willingness-to-Pay for community-based health insurance among informal workers in urban Bangladesh. *PLoS One* 11 (2), e0148211.
- Ahsan, M.N., Hadiujjaman, S., Islam, M.S., et al., 2021. Willingness to pay for improved safe drinking water in a coastal urban area in Bangladesh. *Water Pol.* 23 (3), 633–653.
- Akhtar, S., Saleem, W., Nadeem, V.M., Shahid, I., Ikram, A., 2017. Assessment of willingness to pay for improved air quality using contingent valuation method. *Glob. J. Environ. Sci. Manag.* 3 (3), 279–286.
- Allam, Z., 2020. Data as the new driving gears of urbanization. In: *Cities and the Digital Revolution*. Palgrave Pivot, Cham.
- Ali, M.A.S., Khan, S.U., Khan, A., Khan, A.A., Zhao, M., 2020. Ranking of ecosystem services on the basis of willingness to pay: monetary assessment of a subset of ecosystem services in the Heihe River basin. *Sci. Total Environ.* 734.
- Almenar, J.B., Rugani, B., Geneletti, D., Brewer, T., 2018. Integration of ecosystem services into a conceptual spatial planning framework based on a landscape ecology perspective. *Landscape Ecol.* 33, 2047–2059.
- Amini Parsa, V., Salehi, E., Yavari, A.R., et al., 2019. Evaluating the potential contribution of urban ecosystem service to climate change mitigation. *Urban Ecosyst.* 22, 989–1006.
- Bamwesigye, D., Hlavackova, P., Sujova, A., Fialova, J., Kupec, P., 2020. Willingness to pay for forest existence value and sustainability. *Sustainability* 12, 891.
- Banna, H., Afroz, R., Masud, M.M., Rana, M.S., Koh, E.H., Ahmad, R., 2016. Financing an efficient adaptation programme to climate change: a contingent valuation method tested in Malaysia. *Cah. Agric.* 25 (2), 25003.
- Barmon, B.K., Mohiuddin, K., Islam, G.E., Laila, N., 2015. Willingness to pay for solid waste management system in Dhaka City, Bangladesh: a socio-economic analysis. *East-West Univ. J.* 4 (2), 29–52.
- Baskent, E.Z., 2020. A framework for characterizing and regulating ecosystem services in a management planning context. *Forests* 11, 102–112.
- Bilgic, A., 2010. Measuring willingness to pay to improve municipal water in southeast Anatolia, Turkey. *Water Resour. Res.* 46 (12).
- Bhatt, I.D., Negi, V.S., Rawal, R.S., 2020. Promoting nature-based solution (NbS) through restoration of degraded landscapes in the Indian Himalayan region. In: Dhyani, S., Gupta, A., Karki, M. (Eds.), *Nature-based Solutions for Resilient Ecosystems and Societies. Disaster Resilience and Green Growth*. Springer, Singapore.
- Botelho, A., Pinto, L.M., Lourenço-Gomes, L., Valente, M., Sousa, S., 2016. Social sustainability of renewable energy sources in electricity production: an application of the contingent valuation method. *Sustain. Cities Soc.* 26, 429–437.
- Breuste, J.H., Anwar, M.M., Nawaz, R., Rani, M., 2017. Urban ecosystems: functions, value and management. In: Sandhu, H. (Ed.), *Ecosystem Functions and Management*. Springer, Cham.
- Chaichana, R., Leah, R., Moss, B., 2011. Conservation of pond systems: a case study of intractability, Brown Moss, UK. *Hydrobiologia* 664, 17–33.
- Caro-Borrero, A., Carmona-Jiménez, J., 2019. The use of macroinvertebrates and algae as indicators of riparian ecosystem services in the Mexican Basin: a morpho-functional approach. *Urban Ecosyst.* 22, 1187–1200.
- Chien, H., 2022. Evaluating impacts of researchers to enable sustainability transition: using urban ecosystem service literature as an exemplary field. *Environ. Dev. Sustain.* 24, 2345–2361.
- Chen, V., Bonilla Brenes, J.R., Chapa, F., et al., 2022. Correction to: development and modelling of realistic retrofitted Nature-based Solution scenarios to reduce flood occurrence at the catchment scale. *Ambio* 51, 291.
- Chung, Y.-S., Chiou, Y.-C., 2017. Willingness-to-pay for a bus fare reform: a contingent valuation approach with multiple bound dichotomous choices. *Transport. Res. Pol. Pract.* 95, 289–304.
- Costanza, R., Groot, R.D., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Grasso, M., 2017. Twenty years of ecosystem services: how far have we come and how far do we still need to go? *Ecosyst. Serv.* 28, 1–16.
- Costanza, R., d'Arge, R., Groot, R.D., Farber, S., Grasso, M., Hannon, B., Belt, M.V., 1997. The value of the world's ecosystem services and natural capital. *Nature* 387, 253–260.
- Cui, Y., Li, L., Chen, L., Zhang, Y., Cheng, L., Zhou, X., Yang, X., 2018. Land-use carbon emissions estimation for the Yangtze river Delta urban agglomeration using 1994–2016 Landsat image data. *Rem. Sens.* 10, 1334.
- Daniel, T.C., Muhar, A., Aramberger, A., Aznar, O., Boyd, J.W., Chan, K.M., Dunk, A.V., 2012. Contributions of cultural services to the ecosystem services agenda. *Perspective* 109, 8812–8819.
- Fattah, Md. Abdul Afroz, Reshma, Morshed, Syed Riad, 2022. Knowledge, behavior, and drivers of residents' willingness to pay for a sustainable solid waste collection and management system in Mymensingh City, Bangladesh. *J. Mater. Cycles Waste Manag.* 24 (3).
- Fattah, M.A., Morshed, S.R., Morshed, S.Y., 2021a. Impacts of land use-based carbon emission pattern on surface temperature dynamics: experience from the urban and suburban areas of Khulna, Bangladesh. *Remote Sens. Appl.: Soc. Environ.* 22, 100508.
- Fattah, M., Morshed, S.R., Morshed, S.Y., 2021b. Multi-layer perceptron-Markov chain-based artificial neural network for modelling future land-specific carbon emission pattern and its influences on surface temperature. *SN Appl. Sci.* 3, 359.
- Ferrari, B., Quatrini, V., Barbati, A., et al., 2019. Conservation and enhancement of the green infrastructure as a nature-based solution for Rome's sustainable development. *Urban Ecosyst.* 22, 865–878.
- Flisek, P., Lewandowicz, E., 2019. A methodology for generating service areas that accounts for linear barriers. *ISPRS Int. J. Geo-Inf.* 8, 423.
- Flowra, F., Ghosh, J., Tumpa, A., Jahan, S., 2012. Assessment of three different parameters of urban ponds at Rajshahi, Bangladesh. *J. Bio. Sci.* 19, 59–63.
- Fogarassy, C., Neubauer, E., 2016. Evaluation of the regional water usage in Hungary with water allowance coefficient (WAC). *Appl. Ecol. Environ. Res.* 14 (1), 161–173.
- Gao, B., 1996. NDWI—a normalized difference water index for remote sensing of vegetation liquid water from space. *Rem. Sens. Environ.* 58 (3), 257–266. ISSN 0034-4257.
- Gazi, M., Rahman, M., Uddin, M., Rahman, F., 2020. Spatio-temporal Dynamic Land Cover Changes and Their Impacts on the Urban Thermal Environment in the Chittagong Metropolitan Area, Bangladesh. *GeoJournal*, pp. 1–16.
- Georgiana, G., Urişescu, B., 2019. Land use/land cover changes dynamics and their effects on surface urban Heat Island in Bucharest, Romania. *Int. J. Appl. Earth Obs. Geoinf.* 80, 115–126.
- Githiru, M., Njambuya, J.W., 2019. Globalization and biodiversity conservation problems: polycentric REDD+ solutions. *Land* 8.
- Gunatilake, H., Tachiri, M., 2014. Willingness to pay and inclusive tariff designs for improved water supply services in urban Bangladesh. *J. Sustain. Dev.* 7 (5), 212–230.
- Haque, M.N., Saroar, M., Fattah, M.A., Morshed, S.R., 2020. Public-Private Partnership for achieving sustainable development goals: a case study of Khulna, Bangladesh. *Publ. Administr. Pol.: An Asia-Pacific J.* 23 (3), 283–298.
- Haab, T.C., McConnell, K.E., 2002. *Valuing Environmental and Natural Resources: the Econometrics of Non-market Valuation*. Edward Elgar Publishing.
- Haase, D., 2015. Reflections about blue ecosystem services in cities. *Sustain. Water Qual. Ecol.* 5, 77–83.
- Haase, D., Larondelle, N., Andersson, E., et al., 2014. A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. *Ambio* 43, 413–433.
- Haase, D., 2017. Urban wetlands and riparian forests as a nature-based solution for climate change adaptation in cities and their surroundings. In: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (Eds.), *Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transitions*. Springer, Cham.
- Hagemann, F.A., Randrup, T.B., Sang, Å.O., 2020. Challenges to implementing the urban ecosystem service concept in green infrastructure planning: a view from practitioners in Swedish municipalities. *Socio Ecol. Pract. Res.* 2, 283–296.
- Hanemann, W.M., 1984. Welfare evaluations in contingent valuation experiments with discrete responses. *Am. J. Agric. Econ.* 66, 332–341.
- Henry, M., Mittelhammer, R.C., Loomis, J.B., 2018. An information theoretic approach to estimating willingness to pay for river recreation site attributes. *Water Res. Econ.* 21, 17–28.
- Hong-xin, S., Xing-min, M., Ying-long, Z., Ming-quan, L., 2012. Effects of different land use patterns on carbon emission in Guangyuan city of Sichuan Province. *Bull. Soil Water Conserv.* 32, 101–106.
- Houghton, R., House, J., Werf, G.v., DeFries, R., Hansen, M., Ramankutty, N., 2012. Carbon emissions from land use and land-cover change. *Biogeosciences* 9, 5125–5142.

- Islam, M.S., Afrin, S., Ahsan, M.N., et al., 2019. Households' willingness to pay for disaster resilient safe drinking water sources in southwestern coastal Bangladesh. *Int. J. Disast. Risk Sci.* 10, 544–556.
- Jeong, J.S., García-Moruno, L., Hernández-Blanco, J., Sánchez-Ríos, A., Ramírez-Gómez, Á., 2017. Identifying priority areas for rural housing development using the participatory multi-criteria and contingent valuation methods in Alange reservoir area, Central Extremadura (Spain). *J. Rural Stud.* 50, 117–128.
- Jaung, W., Carrasco, L.R., Richards, D.R., et al., 2022. The role of urban nature experiences in sustainable consumption: a transboundary urban ecosystem service. *Environ. Dev. Sustain.* 1–21.
- Kabir, R., Mahmud, I., Chowdhury, M.T.H., Vinnakota, D., et al., 2021. COVID-19 vaccination intent and willingness to pay in Bangladesh: a cross-sectional study. *Vaccines* 9 (5), 416.
- Kabisch, N., 2019. Urban ecosystem service provision and social-environmental justice in the city of Leipzig, Germany. In: Schröter, M., Bonn, A., Klotz, S., Seppelt, R., Baessler, C. (Eds.), *Atlas of Ecosystem Services*. Springer, Cham.
- Kafy, Abdulla - Al, Faisal, Abdullah-Al, Rakib, Abdullah Al, Fattah, Md. Abdul, Rahaman, Zullyadini, Sattar, Golam, 2021. Impact of vegetation cover loss on surface temperature and carbon emission in a fastest-growing city, Cumilla, Bangladesh. *Build. Environ.* 207 (14), 108573.
- Kazmierczak, A., Carter, J., 2010. *Adaptation to Climate Change Using green and Blue Infrastructure*. A Database of Case Studies. University of Manchester.
- Khan, S.U., Hayat, S., Xia, X., Liu, G., Zhao, M., 2020a. Improvisation of indigenous environmental benefit transfer and valuation for cleaner environment: choice experiment across northwest China. *J. Clean. Prod.* 274 (123176).
- Khan, S.U., Liu, G., Zhao, M., et al., 2020b. Spatial prioritization of willingness to pay for ecosystem services. A novel notion of distance from origin's impression. *Environ. Sci. Pollut. Res.* 27, 3100–3112.
- Khoshteen, A.R., Logan, M., Visvanathan, C., 2019. Integrated solid-waste management for Kabul city, Afghanistan. *J. Mater. Cycles Waste Manag.* 22, 240–253.
- Kohyama, T., Canadell, J., Ojima, D.S., Pitelka, L.F., 2005. Forest ecosystems and environments: scaling up from shoot module to watershed. *Ecol. Res.* 20, 241–251.
- Kriström, B., 1990. A non-parametric approach to the estimation of welfare measures in discrete response valuation studies. *Land Econ.* 66 (2), 135–139.
- Kirikaleli, D., Sowah, J.K., 2020. A wavelet coherence analysis: nexus between urbanization and environmental sustainability. *Environ. Sci. Pollut. Res.* 27, 30295–30305.
- Kumar, M., Singh, H., 2020. Agroforestry as a nature-based solution for reducing community dependence on forests to safeguard forests in rainfed areas of India. In: Dhyani, S., Gupta, A., Karki, M. (Eds.), *Nature-based Solutions for Resilient Ecosystems and Societies*. Disaster Resilience and Green Growth. Springer, Singapore.
- Lopez-Feldman, A., 2010. *Doubleb: Stata Module to Estimate Contingent Valuation Using Double-Bounded Dichotomous Choice Model*. Available at: <http://ideas.repec.org/c/boc/bocode/s457168.html>.
- Loomis, J.M., Blascovich, J.J., Beall, A.C., 1999. Immersive virtual environment technology as a basic research tool in psychology. *Behav. Res. Methods Instrum. Comput.* 31, 557–564.
- Maes, J., Teller, A., Erhard, M., Bidoglio, G., et al., 2013. Mapping and assessment of ecosystems and their services: an analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. *Europ. Comm.* 5.
- Mahmud, A., Sikder, S., Joardar, J.C., 2020. Assessment of groundwater quality in Khulna city of Bangladesh in terms of water quality index for drinking purpose. *Appl. Water Sci.* 10, 226.
- Marufuzzaman, N., Khanam, M.M., Hasan, M.K., 2019. Exploring the impact of urban development on changing surface waterbody area in Khulna city corporation Bangladesh using GIS and RS techniques. In: *Proceedings of International Conference on Planning, Architecture and Civil Engineering 2019*. Rajshahi University of Engineering and Technology (RUET), Rajshahi, Bangladesh.
- Masud, M.M., Junsheng, H., Akhtar, R., Al-Amin, A.Q., Kari, F.B., 2015. Estimating farmers' willingness to pay for climate change adaptation: the case of the Malaysian agricultural sector. *Environ. Monit. Assess.* 187 (2), 38.
- Moffat, B., Motlaleng, G.R., Thukuza, A., 2011. Households' willingness to pay for improved water quality and reliability of supply in Chobe ward, Maun. Botswana. *J. Econ.* 8 (12), 45–61.
- Morshed, S.R., Fattah, M.A., Haque, M.N., Morshed, S.Y., 2021. Future ecosystem service value modeling with land cover dynamics by using machine learning based Artificial Neural Network model for Jashore city, Bangladesh. *Phys. Chem. Earth* 103021. Parts A/B/C.
- Mukherjee, M., Shaw, R., 2021. Forward-looking lens to mainstream blue-green infrastructure. In: Mukherjee, M., Shaw, R. (Eds.), *Ecosystem-Based Disaster and Climate Resilience*. Disaster and Risk Research: GADRI Book Series. Springer, Singapore.
- Mustafa Saroar, M., Mahbubur Rahman, M., Bahauddin, K.M., Abdur Rahaman, M., 2019. Ecosystem-based adaptation: opportunities and challenges in coastal Bangladesh. In: Huq, S., Chow, J., Fenton, A., Stott, C., Taub, J., Wright, H. (Eds.), *Confronting Climate Change in Bangladesh*. The Anthropocene: Politik—Economics—Society—Science, vol 28. Springer, Cham.
- Nedkov, S., Boyanova, K., Burkhard, B., 2015. Quantifying, modelling and mapping ecosystem services in watersheds. In: Chicharo, L., Müller, F., Fohrer, N. (Eds.), *Ecosystem Services and River Basin Ecohydrology*. Springer, Dordrecht.
- Niemczynowicz, J., 2009. Megacities from a water perspective. *Water Int.* 21, 198–205.
- Obeng, E.A., Aguilar, F., McCann, L., 2018. Payments for forest ecosystem services: a look at neglected existence values, the free-rider problem and beneficiaries' willingness to pay. *Int. For. Rev.* 20, 206–219.
- Oertli, B., Parris, K.M., 2019. Review: toward management of urban ponds for freshwater biodiversity. *Synth. Integr.* 10, 1–10.
- Orlowski, J., Wicker, P., 2019. Monetary valuation of non-market goods and services: a review of conceptual approaches and empirical applications in sports. *Eur. Sport Manag. Q.* 19, 456–480.
- Panday, P.K., 2017. Scale and magnitude of urbanization in Bangladesh. In: *Reforming Urban Governance in Bangladesh*. Palgrave Macmillan, Cham.
- Rowe, R.D., Schulze, W.D., Breffle, W.S., 1996. A test for payment card biases. *J. Environ. Econ. Manag.* 31 (2), 178–185.
- Sang, Å.O., Hagemann, F.A., Ekelund, N., et al., 2021. Urban ecosystem services in strategic planning in Swedish municipalities. *Urban Ecosyst.* 24, 1343–1357.
- Shao, S., Tian, Z., Fan, M., 2018. Do the Rich Have Stronger Willingness to Pay for Environmental protection? New Evidence from a Survey in China, 105. *World Development*, pp. 83–94.
- Siew, M.K., Yacob, M.R., Radam, A., Adamu, A., Alias, E.F., 2015. Estimating willingness to pay for wetland conservation: a contingent valuation study of Paya IndahWetland, Selangor Malaysia. *Procedia Environ. Sci.* 30, 268–272.
- Swartz, T.M., Coon, J.J., Mattes, J.R., Miller, J.R., 2019. Identifying opportunities to conserve farm ponds on private lands: integration of social, ecological, and historical data. *Land* 8, 127–138.
- TEEB, 2010. *Biodiversity, ecosystems and ecosystem services*. In: Kumar, P. (Ed.), *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Earthscan, London, UK; Washington, DC, USA.
- Tong, T.M.T., Nguyen, N.H., 2021. Ecosystem-based approaches and policy perspectives: towards an integrated blue-green solutions in vietnam. In: Mukherjee, M., Shaw, R. (Eds.), *Ecosystem-Based Disaster and Climate Resilience*. Disaster and Risk Research: GADRI Book Series. Springer, Singapore.
- Uy, N., Tapnio, C., 2021. Turning blue, green and gray: opportunities for blue-green infrastructure in the Philippines. In: Mukherjee, M., Shaw, R. (Eds.), *Ecosystem-Based Disaster and Climate Resilience*. Disaster and Risk Research: GADRI Book Series. Springer, Singapore.
- Wang, J., Ge, J., Gao, Z., 2018. Consumers' preferences and derived willingness-to-pay for water supply safety improvement: the analysis of pricing and incentive strategies. *Sustainability* 10, 1704.
- Widaningrum, D.L., 2015. A GIS - based approach for catchment area analysis of convenience store. In: *The Third Information Systems International Conference*. Elsevier, Bali, Indonesia.
- Yoo, S.H., Kwak, S.Y., 2009. Willingness to pay for green electricity in Korea: a contingent valuation study. *Energy Pol.* 37 (12), 5408–5416.
- Zhou, C., Li, G.P., 2015. The influencing factors for willingness to pay of payment for watershed services: a case of the water receiving area of Zhengzhou city of the middle route project of the south-North water transfer project. *Econ. Geogr.* 6, 38–46.