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REVIEW ARTICLE

Economic and socioecological perspectives of urban wetland loss and processes: a study from literatures

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Abstract

Existing literatures across the world highlighted the causes and rate of wetland loss; however, so far, no researches tried to analyze how these are guided by the socioeconomic and ecological conditions. The current review work wished to explore how economic and socioecological perspectives could control the rate and drivers of urban wetland loss. Through meta-analysis, this study also intended to explore the changing polarity in research publication and collaborative research. Total 287 original research articles indicating the rates and drivers of wetland loss from 1990 to June 2022 for the first objective and 1500 articles focusing wetland researches from Dimensions AI database for the last objective were taken.
Results clearly revealed that the rate of urban wetland loss varies from 0.03 to 3.13% annually, and three main drivers like built-up, agricultural expansions, pollution were identified all across the world. Loss rate was found maximum in the developing and least developed countries. Pollution, built-up expansion, and agriculture expansion, respectively, in developed, developing, and least developed nations were identified as the most dominant drivers of urban wetland loss. Linking loss rate and drivers with socioecological and economic perspectives revealed that human development index (HDI), ecological performance index (EPI), sustainable development goal index (SDGI), and social progress index (SPI) is negatively associated with the rate of urban wetland loss. Contrarily, a poverty rate encouraged higher rate of loss. This study articulated that improving these socioecological and economic conditions could help wetland conservation and restoration to achieve SDGs.

Keywords Urban wetland loss · Drivers · Meta analysis · Socioecological issues · Linkages and Kernel density analysis

Introduction

Wetlands encompass a wide array of "wetlands" also called marshes, bogs, swamps, fens, peatlad, and pocosins (Ramsar convention Article 1.1, 1971; Tiner, 1999). It covers all types of waterlogged area that is wet for some period of time of a year or permanently. Wetlands are among the most productive ecosystem (Sun et al., 2017; Wu et al., 2018; Li et al., 2020), and it represents an ecotonian ecosystem in between aquatic and terrestrial ecosystems (Cowardin and Golet, 1979; Das and Pal, 2016; Pal et al., 2020). It provides diverse flows of provisional, regulating, cultural, and supporting services (Alam et al., 2017; Malekmohammadi and Jahanishakib, 2017; Mandal et al., 2021) to nature in general and human society in particular. Healthy functioning wetlands provide a multi-dimensional ecosystem functions like flood control (Bassi et al., 2014; Pattison-Williams et al., 2018), ground water level, maintenance to the biodiversity (Kumar et al., 2005; SAC, 2011; Yang et al., 2016; Thapa et al., 2020), water purification (Hammer and Bastian, 2020; Salimi et al., 2021), carbon sequestration (Villa and Bernal, 2018; Were et al., 2019), climate regulation, coastal protection, fish, fiber, water supply (Jisha and Puthur, 2021), tourism (Khoshkam et al., 2016; Marasinghe et al., 2021) and contribute cultural, social, economic, spiritual inspiration (Carter, 2015; Chaudhary et al., 2019), and many more services for human well being.

In spite of its vast ecological importance, the wetland has been facing a more serious threat than any other ecosystem in the world (MEA 2005, Pal and Talukdar, 2018; Saha and Pal, 2019a, 2019b). Since 1970, the number of wetland

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areas worldwide has decreased by 35% (Ramsar convention, 2018). About 5000 km^2 of wetland area has been disappearing each year in Asia alone (Bassi et al., 2014). Wetland losses in India are substantially higher than those worldwide, at 2–3% every year (Prasher, 2018). The forms and rates of wetland transformation vary across rural and urban areas. Faster population growth, greater needs of land resources for housing, dumping, building infrastructures, and rate of wetland loss in urban area are often faster than rural counterpart.

According to world urbanization prospect 2014, around 30% of people lived in urban regions in the 1950s, and by 2050, it is predicted that this number will have increased to 66%. In spite of having the immense contribution of urban and peri-urban wetlands to urban people for their well-being and quality of life, growing urban pressure on wetland and flood plain areas often caused wetland loss or qualitative deterioration hampering the service abilities. Urban and peri-urban wetlands are those which are situated in or proximate to the city (Das and Basu, 2020) and essentially meet up the sustainable development goals (UNDP, 2015). Due to having a keen affinity with urban areas, such wetlands tender various ecosystem benefits to urban dwellers and absorb many of the burdens posed by anthropogenic activities (McInnes, 2013; Yan et al., 2018). Local climate modification, water purification, carbon sinking, urban flood regulation, storm regulation, etc., are some worthy goods and services which help the urban dwellers a lot (Boyer and polasky, 2004; Cai et al., 2016; Schäfer et al., 2019). Nascimento et al. (2016) and Bellizoni et al. (2021) worked on the role of green and blue infrastructures (GBIs) in urban areas, and they presented a wide array of urban and peri-urban goods and services that support to the urban dwellers. Considering the benefits, currently planned urban centers often are associated with either natural (if already exists) or constructed wetland in order to support urban area and enhance the resilience of the city (Frantzeskaki, 2019; Kumar et al., 2021; Omayer, 2022). GBIs in this perspective are treated as significant factors in making resilient urban areas (O'Donnell et al., 2021; Shah et al., 2021; Simon et al., 2021). Despite of having many of such evidences across the world, it has not been stopped completely. Some examples are also there where new wetland was constructed after losing the natural wetlands in UK, USA, and Spain (Zhao et al., 2020; Ricart and Rico-Amorós, 2021; Stefanakis, 2022).

Degradation of urban wetlands with varying intensities is a more or less conspicuous all across the world (Jia et al., 2011; Kingsford et al., 2016). Biophysical and anthropogenic factors are particularly responsible for the loss of urban wetlands. Its core lies in the history of economic progress. In this case, the beginning of the economic progress of developed and developing countries is not the same. The history of economic progress and urbanization of developed countries is far archaic. The rate of urban wetlands loss in the nineteenth and twentieth centuries was the highest in developed countries (Herrera et al., 2017; Peteet et al., 2018; Schieder et al., 2018). Rapid urban and industrial growths were majorly responsible for that (Petrişor et al., 2020; Pejic Bach et al., 2019; Corbau et al., 2019). On the other hand, economic progress and urbanization events (in developing and underdeveloped countries) are very recent, even in the late twentieth century to twenty-first century (Keho, 2016; Maparu and Mazumdar, 2017; Wang et al., 2018). A good many literatures (Sica et al., 2016; Lin and Yu, 2018) recently reported high rate of urban wetland loss in those countries.

A good many causes were identified by many a scholar for urban wetland loss in different parts of the world. Li et al. (2010) and Mondal et al. (2017) identified built-up area expansion as the dominant cause of urban and peri-urban wetland loss. Mao et al. (2018) and Kabiri et al. (2020) reported urban agricultural encroachment as a prevalent cause; Harikumar and Jisha (2010) and Dar et al. (2021) documented that metal and non-metal pollutants are more dominant across the world. In the flood plain area, urban wetland conversion is also associated with hydrological modification triggered by climate change (Lee et al., 2006; Junk, 2013). The mechanism of changes spatially varies across the world; however, built-up expansion is a very common incident irrespective of wetland types and geo-environmental situations (Li et al., 2014; Mao et al., 2021). In developing countries where urban growth is very fast, building infrastructure is also going at a faster pace and built-up expansion is more commonly found.

Now the question is the rate of wetland loss and processes behind is solely driven by the local or regional direct causes as mentioned? Different socioecological conditions of a nation are also responsible for its holistic development, including environmental and societal. In this consonance, how the socioecological conditions can determine the urban wetland loss, a natural capital, and the causes behind is a question that is attempted to be answered in the present review article.

According to United Nations Development Programme (UNDP), human development index (HDI) is the brief indicator of a country's level of achievement in reference to the key dimensions (long and healthy life, knowledge, decent standard of living). Countries with high HDI have good quality of health facilities, standard educational status, and high income. Such conditions could have influence on determining the rate of urban wetland loss. Environmental health and vitality depict environmental stresses to human health, ecosystem health, and natural resource management. Environment performance index (EPI) is the international ranking system that measures the environmental health and vitality of a country by World Economic Forum (2002). Good or poor EPI can determine the status of environmental resources and human interaction, leading to the nature of environmental sustainability and human well-being. The countries with high EPI score probably conscious of the urban growth, not reclaiming the wetland, which is considered as the kidney of the urban system (Mandishona et al., 2019). The social progress index (SPI) gauges a society's health by tracking social and environmental developments, capturing three major dimensions (opportunity, foundation of well-being, and basic human need). Often, economically advanced countries achieved these major three dimensions quite easily and therefore having high SPI score. A progressed society not only thinks about its economic growth but also thinks about protecting natural resources. In this perspective, there is a probability that countries with high SPI scores are likely to have lower resource depletion, including urban wetland loss (Stiglitz et al., 2009; Siddiqui et al., 2017). SDGs are the layout to achieve a better and more sustainable future of the world. Poverty, inequality, climate, environmental degradation, and justice are the key global challenges that demand urgent actions. Out of 17 goals, uprooting poverty (SDG 1), zero hunger (SDG 2), pure water and sanitation (SDG 6), sustainable cities and communities (SDG 11), climate action (SDG 13), and life below water (SDG 14) are directly and indirectly related to wetland. So the countries are diligently working more towards achieving the SDG score, possibly sustaining the wetland resources. A good many researches (Ehrenfeld, 2000; Asomani-Boateng, 2019; Jisha and Puthur, 2021) since clearly established the role of wetlands to build a resilient urban, and this hypothesis will not be very absurd.

Existing review articles focused on causes of wetland loss on different continents across the world (Ballut-Dajud et al., 2022), ecosystem services of the urban wetlands (Alikhani et al., 2021), ecosystem services of wetland (Xu et al., 2020), and nonmarket valuation studies of urban wetland (Boyer and polasky, 2004). Let and Pal (2023) investigated spatial differences in wetland loss rate and the causes concerned indiscriminating the rural and urban space. But so far the knowledge is concerned; no such works were done focusing spatial differences in rate of urban wetland loss and dominant cause behind in the context of economic and socioecological conditions like human development, environmental performance, social progress, and sustainable development goals of the urban dwellers. Considering this gap, the present review work intended to account for the spatial differences in the rate of urban wetland loss across the world and the dominant causes behind it. Also, the paper aimed to explain how the economic and socioecological perspectives of a country are responsible for controlling urban wetland loss rate and process.

Materials

For this review work, total 287 research articles in between 1990 and June 2022 were taken into consideration in order to explore the urban wetland loss rate and major driver(s) concerned. Total 105 articles were considered covering 23 countries to show the urban wetland loss rate. Total 182 articles covering 30 countries were studied to analyze the drivers of urban wetland loss.

In order to exhibit the spatial nature of publication frequency on urban wetland transformation and causes over time, articles from the Dimensions AI database were taken, subdividing the entire time spectrum into three phases (1) phase 1: 1990–2008 (500 articles), (2) phase 2: 2009–2017 (500 articles), and (3) phase 3: 2018–2022 (500 articles). Overall year-specific publication frequency was shown using the same number of publication. We did not consider the detail content of those articles, and all were not taken for computing the rate of wetland loss and drivers. These were only taken for analyzing the changing polarity of wetland research. The abovementioned 287 articles were mainly studied for exploring the rate of loss and causes behind fall within 1500 articles taken from the Dimensions AI database.

The present study acquired economic and socioecological parameter-related information from different worldwide-accepted agency endorsed data as mentioned in Table 1.

Methods

The method regarding meta-data analysis

In the meta-analysis section, two works were done (1) quantifying spatio-temporal publication frequency on urban wetland loss and processes behind in order to explore the changing polarity in research publication and (2) changing pivot of international research collaboration in reference to major concerned countries. Total of 1500 publication samples obtained from the Dimensions AI database were taken and grouped into three phases as mentioned earlier. Three choropleth maps on publication frequency were prepared to present the spatial view and time series changes in its polarity. A simple bar diagram was prepared in order to present the time series change in publication frequency all across the world. A network view map of scientific publication was constructed in VOS viewer software in order to show the nature of international collaboration. The same was made in two phases, (1) 1990–2008 and (2) 2009–June 2022, for explaining the time series change in international collaboration.

Table 1 Socioecological parameters used for making correlation with the rate of wetland loss and causes behind

Parameters used	Indices used for quantitative expression	Number of indicators adopted	Method used	Sources
Human development	HDI	Three dimensions, viz., standard of living, health, and education	Equally weighted geometric mean	Human development report published by UNDP (2022)
Environmental performance	EPI	40 indicators into 11 issue categories and three policy objectives are taken into consideration	The index set up as a composite index; different weight has been given to 16 highly aggregated indicators.	EPI report published by World Economic Forum with the collaboration of Yale University and Columbia University.
Sustainable development goals	SDGI	242 detailed indicators	Countries are ranked on considering their overall score on different concerned issues	United Nations Developmental Programme (UNDP) (2022)
Poverty level	Poverty rate	A state of being in which a person's income is insufficient to meet the basic need (food, shelter, and clothing)	It was comparing a person's or family's income in respect to a set of poverty thresholds to meet basic needs.	World Bank (2022)
Social progress	SPI	In 3 dimensions (basic human needs, opportunity, foundation of wellbeing), 53 indicators used to show the rank of the nation	SPI is calculated using the arithmetic average of the three dimensions	Social Progress Imperative (2021)

Computation of wetland loss rate and selection of drivers

The rate of urban wetland loss was not always vividly quantified in all the published articles. Even the timeframe of work was not the same in all the articles. Annual wetland loss rates were calculated in order to avoid this problem. The annual wetland loss rate was accounted by dividing the lost wetland area by the number of years.

From the published literatures, the causes of urban wetland loss were identified, out of which only the main causes are taken up. To present the major drivers of urban wetland loss, frequency of articles was assessed under identified causes and presented in histogram in order to show the major drivers. This was done in reference to the socioecological parameters.

Methods adopted for computing socioecological parameters

However, socioecological and economic indicators were not calculated in the present study. All these indicator-related information were collected from internationally recognized agencies' endorsed sources like United Nations Development Programme, World Economic Forum, World Bank reports, etc., as mentioned in Table 1. However, to give information about these indices and how these were calculated, the basic methods are discussed briefly.

Data related to socioeconomic and ecological status like human development index (HDI), environmental performance index (EPI), social progress index (SPI), sustainable development goals (SDGs), poverty rate, etc. were collected. HDI is the geometric mean of three (life expectancy, education, and income) normalized indices using Eqs. 1–6. The value ranges from theoretical minimum 0 to theoretical maximum 1. On the basis of the score, world ranking is done. Social progress index (SPI) was calculated by averaging the three dimensions and components as mentioned in Table 1 using Eqs. 7–10. Based on this score, the countries' ranking we use to get. Forty performance indicators from 11 issue categories were used to calculate the environmental performance index (EPI). Usually, the percentage of people in a country whose daily income is less than predetermined thresholds constitutes an indicator of poverty.

HDI: In 2010, for calculating HDI, a new method was applied in Human Development Report, UNDP by using three indices.

$$\text{Life expectancy index (LEI)} = \frac{\text{LE} - 20}{85 - 20} \tag{1}$$

$$\text{Mean year of schooling (MYSI)} = \frac{\text{MYS}}{15} \tag{2}$$

$$\text{Expected year of schooling (MYSI)} = \frac{\text{EYS}}{18} \tag{3}$$

$$\text{Education index (EI)} = \frac{\text{MYSI} + \text{EYSI}}{2} \tag{4}$$

$$\text{Income index } (II) = \frac{In\left(GNI_{PC}\right) - In\,(100)}{In\,(75000) - In\,(100)} \tag{5}$$

$$\text{HDI} = \sqrt[3]{\text{LEI.EI.II}} \tag{6}$$

(Here, LEI= life expectancy index, EI = education index, and II = income index).

To calculate the HDI's life expectancy at birth component, 20 years and 85 years are considered. For the calculation of educational index, the expected years of schooling index (EYSI) and mean years of schooling index (MYSI) were taken into account. The MYSI calculates how long a student, who is 25 years of age or older, has been in school. EYSI is an acronym representing the amount of time a child will spend in school beginning at age five. The indicators have been normalized with a minimum value of 0 and a maximum value of 15 and 18 years, respectively. The two indices are combined using the arithmetic mean to construct an education index. The measure of the standard of living is the gross national product per person (GNIpc). The income ranges from $100 (PPP) to $75,000 (PPP).

SPI: The social progress index is determined using five fundamental procedures. In order to make indications comparable in scale, first missing values are addressed before inverting and standardizing. After that, the indicators are combined into a component score using principal component analysis (PCA). Finally, by averaging the components and dimensions, overall social progress index scores were derived.

$$\text{Component value}_c = \sum \left(w_i \times \text{ indicator}_i\right) \tag{7}$$

where c = social progress index component and i = indicator

$$\text{Component score}_c = \frac{X_j - \text{ worst case}}{\left(\text{Best case} - \text{worst case}\right.} \times 100 \tag{8}$$

where X = component value and j = country

$$\text{Dimension}_d = \frac{1}{4}\sum_c \text{component score}_c \tag{9}$$

d = dimension, c = component

$$\text{Social progress index score} = \frac{1}{3}\sum_d \text{dimension}_d \tag{10}$$

where d = dimension

SDGI: According to their overall rating, nations are ranked. The overall score calculates how far the nation has achieved all 17 SDGs. The result can be seen as a percentage of SDG accomplishments. If a score is 100, it signifies achievement of all SDGs.

EPI: The EPI (2022) score is based on how well state policies succeed in environmental performance. Climate change performance, environmental health, and ecosystem vitality are considered when calculating the EPI score. The EPI produces a scorecard that identifies countries' environmental performance and offers helpful advice for nations aspiring to move towards a sustainable future.

Relation between socioecological parameters and rate of wetland loss

In order to assess the relationship between the socioecological indicators and the rate of urban wetland loss, correlation coefficient (Pearson's correlation coefficient) and kernel distribution estimation (KDE) plot (Eq. 11) were used. Considering the normality of data distribution and interval type of data, we used Pearson's method for computing correlation. To determine whether the relation is statistically significant or not, correlation values were statistically tested (at 0.05 and 0.01 level). KDE plot was applied for visualizing the probability density of a continuous variable. Along with scattered plot, frequency distribution through histogram was also shown in KDE plot.

$$\hat{f}_h(x) = \frac{1}{n}\sum_{i=1}^{n} Kh\left(x - x_1\right) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right) \tag{11}$$

where K = kernel is a non-negative function and $h > 0$ is a smoothing parameter called the band width.

The study simultaneously attempted to articulate the process of wetland transformation in reference to several chosen socioecological conditions of different countries. Publication frequency was counted under different identified causes of urban wetland loss (built-up expansion, agricultural encroachment, metal and non-metal pollutants, others) in reference to the socioecological variables. For instance, when the drivers were evaluated with reference to HDI, the sample publications were subdivided into four clusters like (1) very high HDI (> 0.8), (2) high HDI (0.7–0.799), (3) medium HDI (0.55–.699), and (4) low HDI (< 0.55), and frequency of publication was counted. In the same way, other socioecological variables such as the SDG index, social development index, poverty rate, and environmental performance index were taken and analyzed. Classification basis is mentioned in Table 1.

A methodological flow chart was prepared in order to present the subsequent methods to reach the objective (Fig. 1).

Results and discussions

Bibliometric status on urban wetland transformation

Spatial frequency of literature

Spatio-temporal publication frequency in three defined phases (Fig. 2) clarified the fact that the research hot spots are not only confined to USA, Canada, and UK in between 1990 and June 2022; over the advances of time, new hot spots were added to the research scenario. In phase 2, along with the existing hearth, China and Australia were emerged as new epicenters (Fig. 2b). In phase 3, India was also identified as an emerging hot spot. A remarkable research progress was also found in Mexico, Nigeria, India, Sri Lanka, Uganda, Colombia, etc., so-called backward countries (Fig. 2c). Time series publication plot shows a sharp rise in research publication frequency from 2018 onwards (Fig. 2d). All these are very good signs of research progress.

International collaboration and research network

International collaboration in research publication in between 1990–2008 and 2009–2022 is shown in Fig. 3. Research network itself shows that it was simple in between 1990 and 2008 and more intricate in between 2009 and 2022, indicating the fact that between 2009 and 2022, an improved research network was built. For instance, in between 1990 and 2008, a good research network was recognized among the USA, UK, Canada, Sweden, Germany, and France (Fig. 3a). In between 2009 and 2022, more countries were included within the collaborative research scenario more intensively, like China, the UK, Brazil, Germany, Chile,

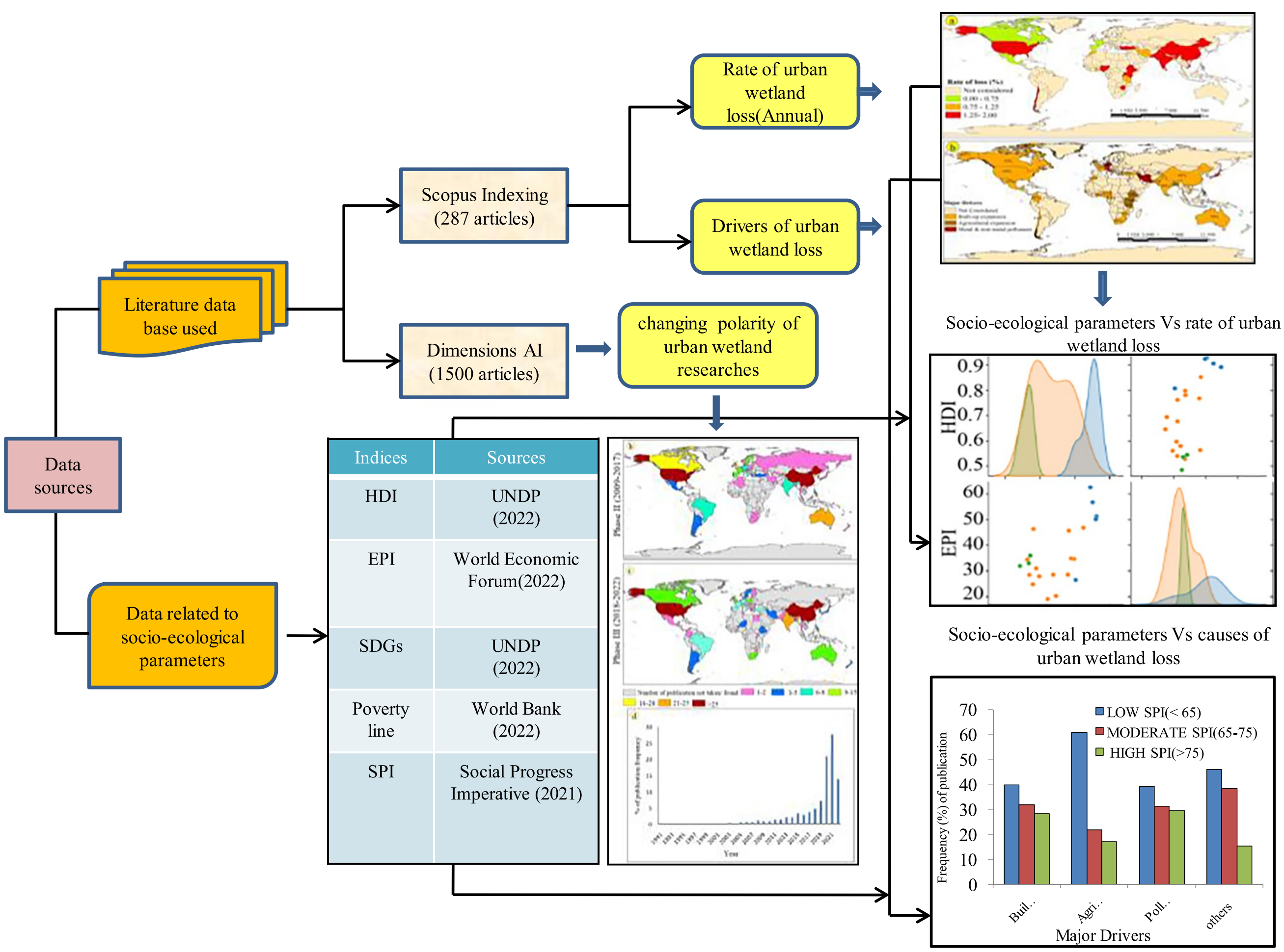

Fig. 1 Methodological flow chart of the work

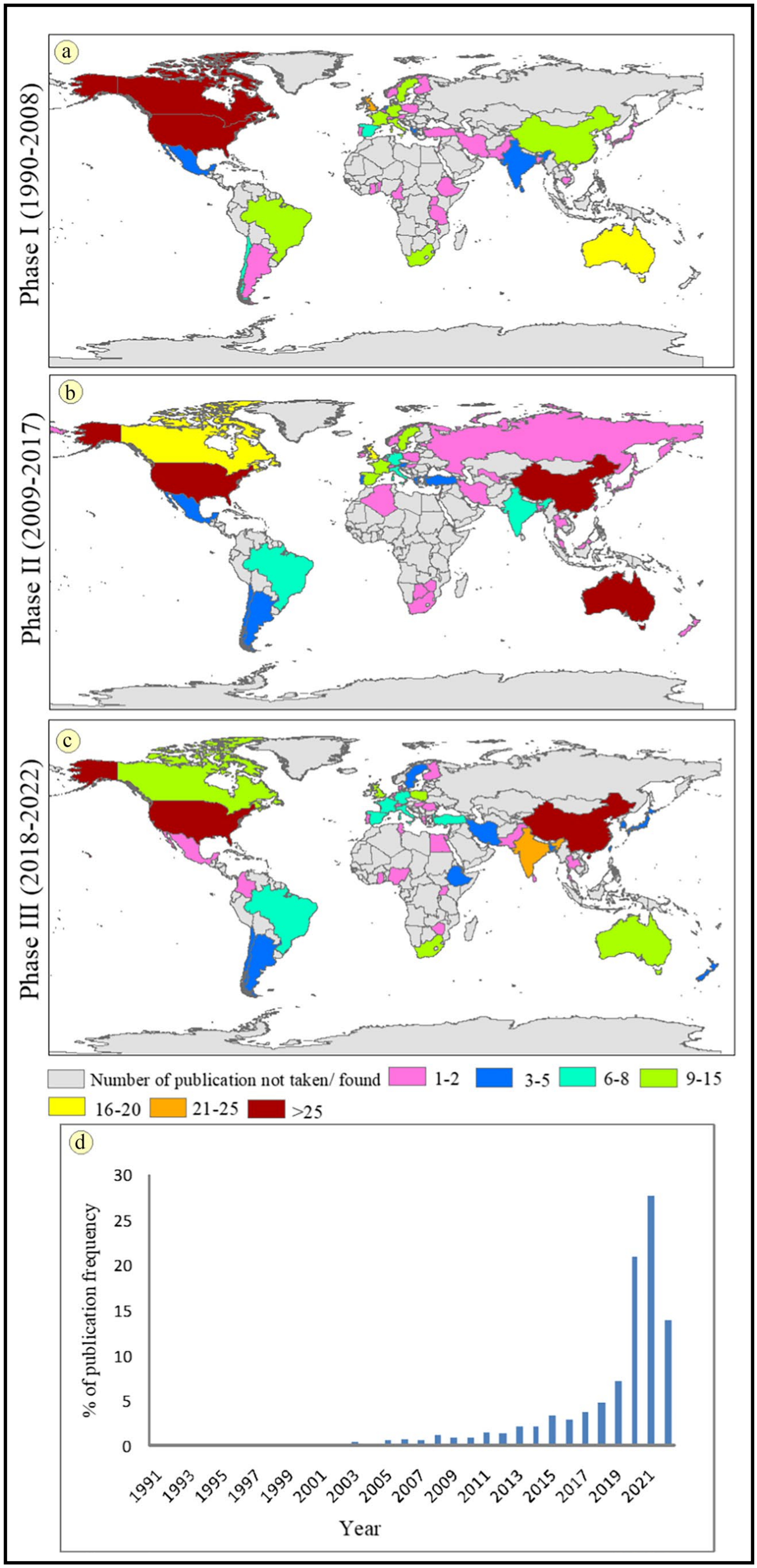

Fig. 2 Publication frequency among randomly taken literatures on urban wetland loss from 1990 to June 2022 subdividing the time spectrum into three time phases **a** 1990–2008, **b** 2009–2017, **c** 2018–2022, and **d** yearly % of publication frequency

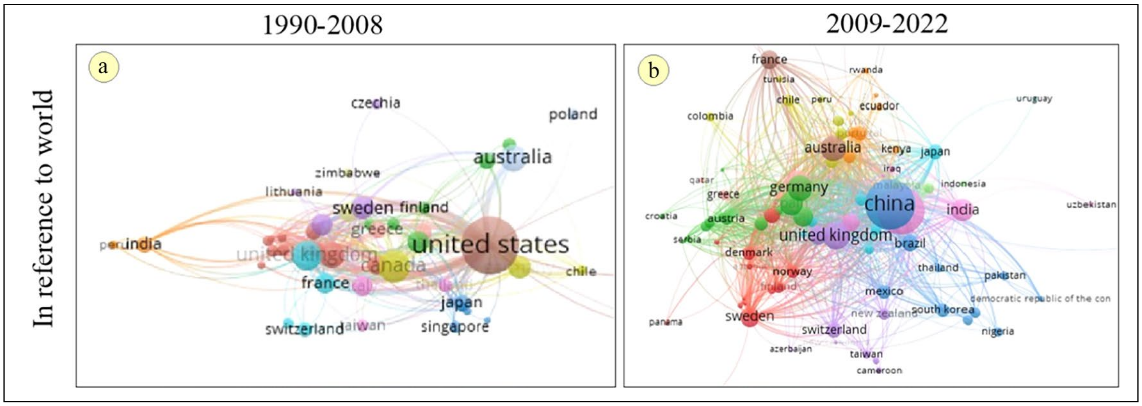

Fig. 3 International collaboration and research network in reference to world. Size of the nodes indicating countries denotes publication frequency, and the lines connecting the nodes indicate collaboration among the countries

Spain, France, Mexico, Bangladesh, Sweden, and Australia (Fig. 3b).

Rate of urban wetland loss

Urban wetland transformation

The world scenario of the rate of urban wetland loss presented a heterogeneous picture (Table 2). Publications from some countries of all the continents were taken. In North America, publications were taken from the USA, Canada, and Mexico. It reveals that in the USA, the annual rate of urban wetland loss varies from 0.26 to 2.09% (Fickas et al., 2016); in Canada and Mexico, it was considerably low (< 0.5%) (Merlin-Uribe et al., 2013). Publications from Chile and Colombia were taken as a representative in South America. Moderate to high rate of loss was found in Chile (1.01%) (Rojas et al., 2019; Rojas et al.,2022). The disparity was reported across the country. However, the average rate was mentioned here for analysis. Spain, France, Italy, Turkey, and Morocco were taken as representatives of Europe. Except Turkey, other countries recorded a low rate of wetland loss. In Africa, a high rate of urban wetland loss mostly observed in Nigeria (1.85%), Ethiopia (1.9%), Rwanda (1.64%), and Uganda (1.30%) except Tanzania (0.8%) (Obia et al., 2015; Hussien et al., 2018). China (2%), Pakistan (2%), Sri Lanka (1.57%), and Bangladesh (1.25%) registered a high rate of annual urban wetland loss in reference to the Asian continent (Chen et al., 2014; Rahman et al., 2021). If it is seen historically, wetland loss in the European continent was far greater than the recent past (Kingsford et al., 2016). If it is analyzed from the economic strength point of view of the countries concerned, a general inference could be derived, i.e., in most of the developing countries and least developed countries, the rate of urban wetland loss was comparably higher than in developed countries (Pauchard et al., 2006; Dewan and Yamaguchi, 2009; Mao et al., 2018; Jiangyi et al., 2020). The spatial distribution of urban wetland loss rate also justified this (Fig. 4a).

Dispersion of urban wetland loss rates

The box plot in Fig. 5 is a graphical rendition of country-specific dispersion of wetland loss rates using the minimum, first quartile, third quartile, and median and maximum rates among the countries concerned. In some countries like Mexico, Spain, Tanzania, and Canada, median urban wetland loss rate was found < 1% annually. On the other hand, > 1% median wetland loss was found in India, China, the USA, Nigeria, Chile, Bangladesh, Ethiopia, Uganda, Rwanda, Sri Lanka, Kenya, and Vietnam. This also shows that except a very few cases, the median rate of wetland loss is higher in developing countries than in developed countries. When country-specific and economic strength-specific dispersion were analyzed, amongst the developed nations, France and Spain accounted very low rate of loss and the lowest rate of dispersion. Here, it is also to be mentioned that all developed countries did not account the low rate of dispersion. Turkey and the USA registered high dispersion. In reference to developing countries, Pakistan and Sri Lanka recorded a very high rate of wetland loss with low dispersion, indicating a consistently high rate of wetland loss across the country. Contrarily, China, India, and Iran recorded the highest spatial variability in urban wetland loss, which is reflected in the box plot. In the least developed countries, the rate of loss was found to be high with a higher rate of dispersion (Fig. 5). When the distribution of urban wetland loss rate was accounted in reference to the country's economic strength, slightly positively skewed distribution was found in the developed nations and negatively skewed distribution was accounted in the developing countries. Completely mixed distribution was recorded in the case of least

Table 2 Rate of urban wetland loss

Literature	Objectives	Study area	Methodology	Findings
Basu et al. (2021)	Quantifying the declination of wetland area	Chatra wetland in eastern india	Urban water index (UWI), urban expansion index, and urban land index (UI) were used to examine changes in wetland area	In 1991, wetland area was 397.17 ha; it reduced by 101.66 ha in 2018, with an annual rate of loss was 2.76%
Athukorala et al. (2021)	Assessing the impact of urbanization on the MMNL region, Sri Lanka	MMNL region, Sri Lanka	LULC and spatial metrics used for landscape configuration and composition	In this region, 1.75% of wetland was lost annually within the time frame from 2007 to 2017
Assefa et al. (2021)	Examining the spatio-temporal pattern of LULC change over 35 years	Wetland in Bahir Dar city, Ethiopia	From 1984 to 2019 changing pattern of the LULC map which derived with the help of Landsat 5 TM (1984, 1994), 7ETM+ (2004), and 8 OLI (2014, 2019)	With a 2.16% rate, wetlands lost between 1984 and 2019
Kabiri et al. (2020)	Investigating the wetland loss	Wetland in Kampala district, Uganda	Landsat TM for 1986 and ETM data for 2016 were used to detect the rate of wetland loss and NDVI for detection of urban agricultural encroachment from 1986 to 2016	Yearly rate of wetland loss is 2.52%
Wizor and Wali (2020)	Identifying and mapping urban wetland loss	Urban wetland in Nigeria	To determine the limit of wetland loss, GIS and satellite imageries were used. It helps to make the LULC map	The size of the wetland was 2352.15 km^2 in 2000, which dissipated to 1266.75 km^2 in 2018. The yearly rate of loss was 2.42%
Wasswa et al. (2019)	Assessing the spatio-temporal wetland change in KMC	Wetland near to Kampala-Mukono corridor, Uganda	Pixel-based comparison procedure used to detect changes in wetland	The wetland area declined from 10,140 km^2 in 1974 to 5410 km^2 in 2013 at a loss rate of 1.19% per year
KAYITESI (2019)	Analyzing urban growth and its outcome on the Rwampara wetland.	Rwampara wetland in Rwanda	Overall LULC change analysis with the help of Landsat™ image (1997) and OLI image (2017)	Rwampara wetland decreased from 24 ha in 1987 to 7.7 ha in 2018, the annual rate of loss was 2.19%
Rojas et al. (2019)	Examining the effect of urban development in wetland	Wetland in South central Chile, Chile	Change of wetland area quantified by LULC map. Urban expansion over the wetland has been quantified using the Strategic Environmental Assessment (SEA)	From 2004 to 2014, wetland loss took place at 10%, with an annual rate of 1.01%
Mao et al. (2018)	Investigating the amount and pattern of wetland loss in china due to urbanization	Wetlands in China	Using TM/ETM image for LULC map from 1990 to 2010. Change identification, field sample, and decision tree method used to show the effect of urbanization on wetland	Urban area increased by 90.9% over the 20 years (1990–2010), whereas China's total wetland area fell by 134.05 km^2 annually
Ghosh et al. (2018)	To assess the spatio-temporal change of East-Kolkata wetland	East-Kolkata wetland in Eastern India, Kolkata	A series of wetland transformation maps prepared with the help of NDWI and NDBI to detect spatio-temporal change in the wetland	The yearly rate of loss of wetland from 2011 to 2017 was 7.34%
Olusola et al. (2016)	Assessing the loss of wetlands in Lagos metropolis	Wetland near to Lagos Metropolis, Nigeria	LULC change detection used	The wetland area was 708.96 ha in 1965, but it shrunk by 7.10 ha by 2005. The annual loss rate was 2.19%

Table 2 (continued)

Literature	Objectives	Study area	Methodology	Findings
Nyamaso and Kihima (2014)	Assessing the pattern of land use change and its impact on wild species	Kimana wetland in Kenya	Land use change pattern analyzed, data taken from Landsat™ image (1980, 1990, 2000, 2010, 2013)	Wetland loss from 1980 to 2013 was 2.08% per year
Merlin-Uribe et al. (2013)	Evaluating the land use dynamics of wetland area during 1989–2006	Xochimilco Wetland system in Mexico City, Mexico	Used LULC change analysis from 1968 to 2006	The yearly rate of wetland loss was 0.36%
Bolca et al. (2014)	Examining the land use change near wetland	Gediz Delta wetland area in Turkey	Used changes of different land use types (1963–2010) using quick bird satellite image	In 1963, the area of the wetland was 7216.112 km^2 that decayed to 5005.491 km^2 in 2010 which indicated an annual rate of loss of 0.651%
M Sufia et al. (2009)	Distinguish the water bodies from pre and post urbanization periods	Wetland Dhaka city, Bangladesh	Satellite imageries and aerial photographs used to detect the aerial change of wetland	Wetland coverage was 133 km^2 in 1968 but dropped to 67 km^2 in 2001, a loss of 1.5% yearly
Evers et al. (1992)	To identify the change in wetland status from 1945 to 1985	Wetland in USA	Changing area detection with LULC map (1945–1985)	The total wetland area was 585.1 km^2 in 1945; it was reduced to 347 km^2 in 1985, so the annual rate of loss of 1.01%

developed countries. Box plot of Nigeria, Ethiopia, Tanzania, and Kenya recorded outliers indicating abnormally high and low rates of urban wetland loss.

The result clearly distinguishes urban wetland loss rate and its dispersion among the developed, developing, and least developed countries. Developed countries dates back to urbanization history. For instance, in the UK, France, Spain, and USA, urbanization rapidly started from the nineteenth century onwards (Fielding, 1989; Puga, 1998; Davis, 2011). As a consequence, the reclamation was started thereafter. In this current time, the rate of urban wetland loss is reported to be low. It does not signify that it was low even during the peak rise of urban expansion in parity with their second and third phases of demographic transition (rising population phases). At this current phase, a cluster of developed nations attained the fourth stage (literally zero population growth). A few countries like Australia, Japan, and Germany reached at fifth stage of demographic transition (negative population growth) as defined by Blacker (1947), Caldwell (1976), Coale (1989), and Sundman and (2011). In these sociodemographic and economic conditions, the requirement for horizontal expansion of urban areas is not as high as in developing countries (Haregeweyn et al., 2012; Handayani et al., 2018). Moreover, the culture of vertical rise of building and apartment residence in developed nations were started far before the developing countries (Rao et al., 2020; Wang et al., 2022). All these partially explain the relatively lower rate of wetland loss. Contrarily, developing countries have been experiencing faster population growth. The urbanization rate is also significantly high (Muema et al., 2018; Basu and Das, 2021). For instance, in India, it was 3.11% (Census of India, 2011), and in China, it was 4.96% annually (Qin and Zhang, 2014). The study also proved that in the coming 50 years, two-thirds of the population would likely to live in urban areas in such countries (Friedmann, 2006; O'Neill et al., 2012; Vishwanathan, 2018). To accommodate such a high population mass in urban areas, both horizontal and vertical expansions of an urban area are going on simultaneously (Grover et al., 2015; Zhang et al., 2018). Often, it is at the cost of replacing agricultural land, vegetated areas, and blue spaces like water bodies of different kinds (Pandey and Seto, 2015; Singh et al., 2017; Ziaul and Pal, 2017).

Influence of economic and socioecological factors on the rate of wetland loss

With the help of KDE (Fig. 6), it was tried to explore the influence of different economic and socioecological parameters and the average rate of urban wetland loss. The correlation matrix among the parameters and rate of urban wetland loss quantified the degree of influence and their levels of significance

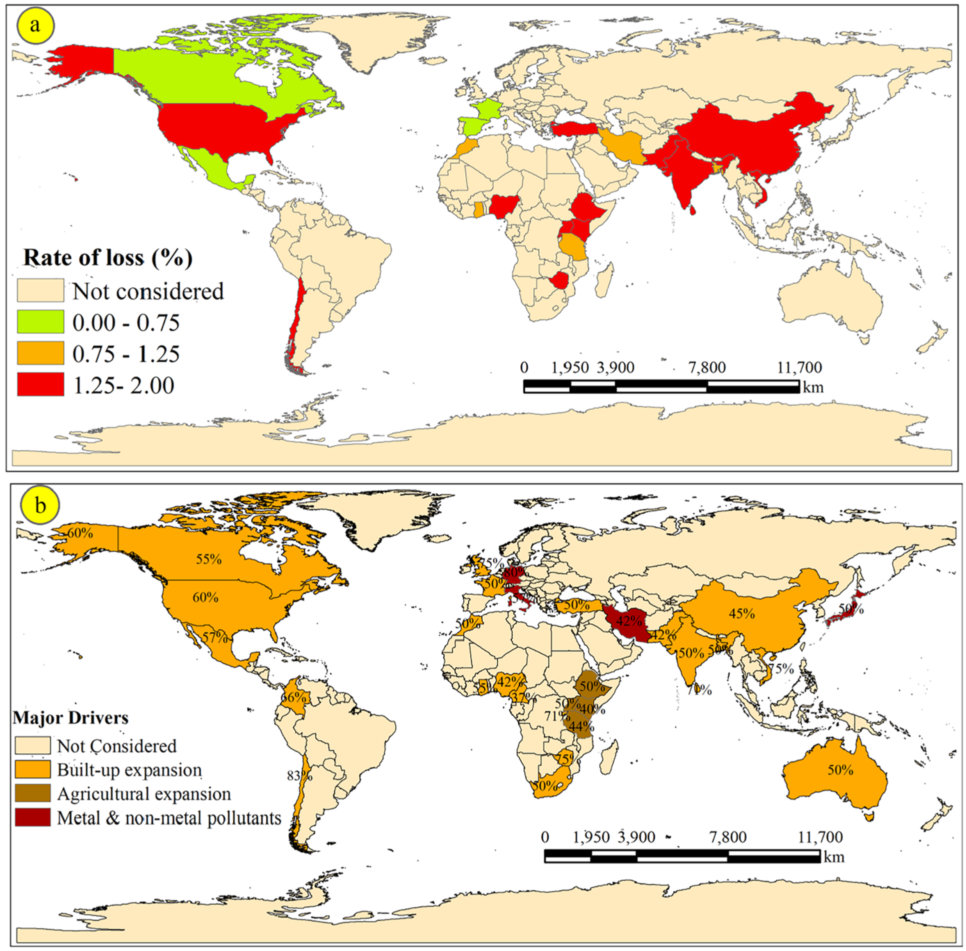

Fig. 4 Annual rate of urban wetland loss (**a**) and major drivers (**b**). The values within the country of **b** indicate percentage of publication claimed the respective drivers as major driver of urban wetland loss of the respective country

(Table 3). A moderate negative correlation between HDI and the rate of urban wetland loss rate (− 0.52) at a significance level of 0.05 was computed. It does indicate that the countries with high HDI have lower rate of urban wetland loss. So, improvement of HDI would be a good holistic alternative to protect the wetland loss. Environmental performance index (EPI) is negatively correlated with the urban wetland loss rate (− 0.63), and the relationship is statistically significant at a 0.01 level of significance. So, the countries worked a lot towards developing their environmental performances and have a low rate of wetland loss. Negative relation was also found between the sustainable development goal Index (SDGI) and average rate of urban wetland loss (− 0.48). It does signify that dedicated works towards achieving SDGs can reduce resource loss, including urban wetland loss. For instance, France is one of the top rankers of SDGI (SDGI = 81.24), and the wetland loss rate is also very low (0.2%) (Rapinel et al., 2018; Vaissière et al., 2021). Social progress index (SPI) has a moderate negative influence on the rate of urban wetland loss (− 0.57). It refers that socially progressed nations are capable to minimize the rate of urban wetland loss (Quétier et al., 2014; Kahil et al., 2016; Dou et al., 2017). Urban wetland loss is positively but insignificantly correlated with the poverty rate (+ 0.02). Poverty is a curse of a nation that not only can hamper people standard of living but also can adversely affect the natural resources and neighboring environment (Barbier and Hochard, 2018; Masron et al., 2019). Positive relation indicates this truth. So poverty eradication, as one of the SDGs' goals, is necessary to reduce the rate of urban wetland loss. When the relationship was tried to assess in reference to developed, developing, and least developed countries, the influencing power of the socioecological factors was found slightly different. In most of the cases, the control was found more in developing nations. Histograms of urban wetland loss rate in developed, developing and least developing countries showed the most contrasting rates of loss with the highest peakness. The least developed countries showed narrower contrast.

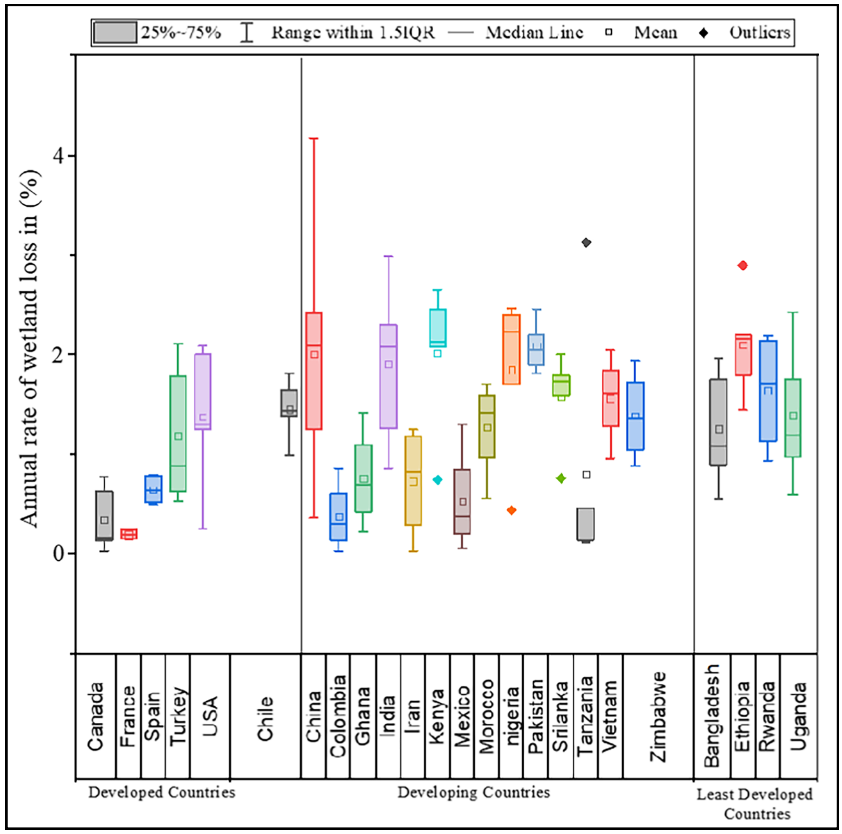

Fig. 5 Dispersion of urban wetland loss rate accounted in reference to countries of different economic status based on the literature survey

Drivers of urban wetland loss and its relation to socioecological and economic perspectives

Drivers of wetland loss

Literature survey regarding finding out the major drivers of urban wetland loss endorsed four main drivers of urban wetland loss, i.e., (1) agricultural encroachment, (2) built-up area expansion, (3) metal and non-metal pollutants, and (4) others (climatic and hydrological factors) (Table 4). The driving process of urban wetland loss is not uniform across all the countries with varying economic strength. For instance, in developed, developing, and least developed countries, metal and non-metal pollution, built-up expansion, and agricultural expansion were, respectively, found as dominant drivers of urban wetland loss. It does not mean that all other drivers have no such significant role. In developing countries like India, China, Nigeria, Chile, Kenya, Ghana, Sri Lanka, Pakistan, and Iran, all the identified drivers are proactive. Other causes like hydrological modification are also found prominent in developing countries. Figure 4b depicts the spatial distribution of dominant reasons across the world. The distribution is also very concomitant with the result highlighted. Some exceptions obviously can be identified. As an example, the USA falls under the category of developed countries; still, the rate of loss is high and built-up expansion acts as the main driver of urban wetland loss (Fig. 4b).

Analyzing drivers in economic and socioecological perspectives

Figure 7 shows the frequency of research works that argues the importance of different drivers for urban wetland loss in reference to different economic and socioecological perspectives like HDI, developmental status of the country, EPI, SDGs, and SPI. In the case of countries with low poverty rate, the pollution effect was recognized as the most dominant driver, followed by built-up expansion, agriculture expansion, and others. In the case of middle poverty rate countries, agriculture, others, built-up, and pollution are the drivers by order. Countries with high poverty rate recorded agricultural expansion as a dominant driver, followed by built-up and others (Fig. 7a).

Similarly, based on developmental and human development status, pollution and built-up expansions were found as the dominant reasons behind urban wetland conversion. In the case of low HDI (≤ 0.55), agricultural expansion was found as a dominant driver (Fig. 7b). When the frequency distribution was assessed in reference to environmental performance index (EPI), it was found that in high EPI (> 50) countries, pollution and built-up expansion are the dominant

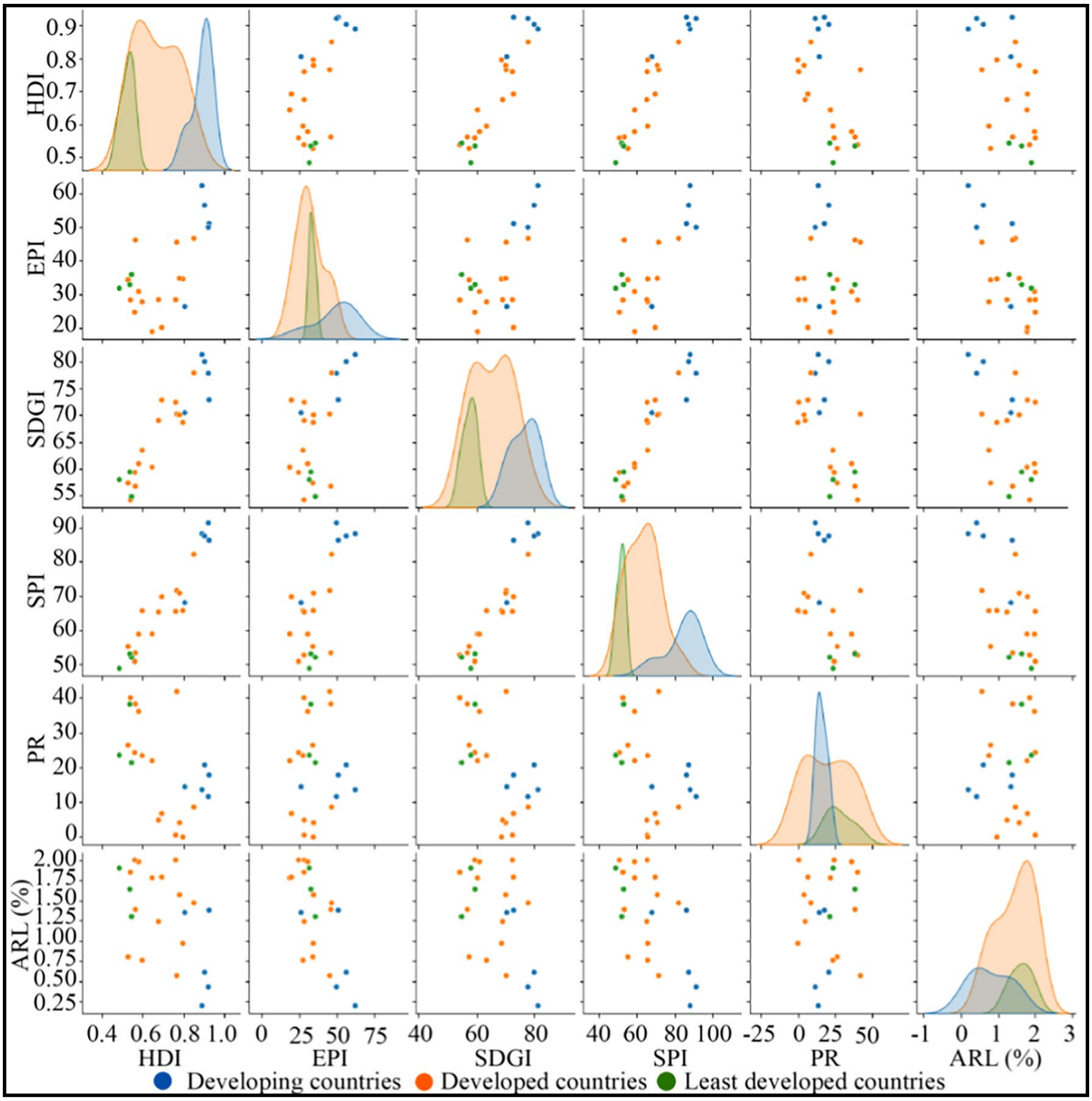

Fig. 6 Kernel density distribution (KDE) plot showing the influence of different socio ecological perspective on rate of urban wetland loss. HDI, human development index; EPI, environmental performance index; SDGI, sustainable development goal index; SPI, social progress index; PR, poverty rate; ARL, annual rate of urban wetland loss

Table 3 Correlation matrix between the socioecological parameters and the rate of urban wetland loss

	HDI	EPI score	Performance by SDGs	SPI	Poverty rate	Average rate of loss
HDI	1.00					
EPI score	0.62**	1.00				
SDGI	0.93**	0.55**	1.00			
SPI	0.95**	0.68**	0.93**	1.00		
Poverty rate	− 0.54**	0.07	− 0.58**	− 0.42*	1.00	
Average rate of loss	− 0.52*	− 0.63**	− 0.48*	− 0.57**	0.02	1.00

*Correlation is significant at the 0.05 level (two-tailed)

**Correlation is significant at the 0.01 level (two-tailed) drivers (Fig. 7d). Agricultural, built-up expansion, and pollution were reported as the main drivers of wetland loss in the countries having middle EPI (30–50), and other causes were found to be dominant in the case of low EPI (< 30).

Sustainable development goals were set for improving environmental and human well-being, and at present, the position of each country is different (SDG range 86.51 to 39.05). So, in this reference, when the drivers' frequency was examined, countries with low SDG are more prone to wetland conversion susceptibility by agriculture expansion and other factors. Conversely, pollution and built-up expansion were the dominant drivers in the countries having high SDG (Fig. 7e).

In reference to social progress, it was found that in the countries having low SPI (< 65), wetlands were highly affected majorly due to agricultural expansion followed by others and built-up expansions (Fig. 7f). On the other side, the countries with high SPI, pollution and built-up expansion were found as the dominant causes of urban wetland loss.

Phases of economic, social, environmental, and SDG achievement of a country create an attitude towards sensitivity on resource management. In the countries like Rwanda, Uganda, Ethiopia, Tanzania, Kenya, Nigeria, Bangladesh, Pakistan, Ghana, and Cameroon, where EPI, HDI, developmental state, SPI, and SDGI are very poor, agriculture, other causes, and built-up expansion were reported the major causes of urban wetland loss. The primary target of those countries is to assure food staff, and that is mainly yielded from the agriculture sector. So, they are more focused on agricultural development than other sectors (Matfess et al., 2015; Dror et al., 2015; Sekabira et al., 2021). Even in the limited urban areas, reclamation of peri-urban water bodies is more prominent due to agriculture than built-up area expansion (Huang et al., 2009; Forkuor and Cofie, 2011; Naikoo et al., 2022). Moreover, the conversion of water bodies by agriculture is cost-effective than built-up development. In developing countries, due to not having a proper implementation of the wetland conservation plan, wetland resources behave like a neutral staff and people are enthusiastic about converting it into agricultural land for making an economic turnover (Tariku and Abebayehu, 2011; Mabwoga and Thukral, 2014; Wang et al., 2019). Draining of wetland water for agriculture purpose (Nabahungu and Visser, 2013; Russi et al., 2013; Prieto, 2015), excess harvesting of river water (Xu et al., 2013; Famiglietti, 2014), steady groundwater harvesting, and lowering of groundwater table (Pal and Akoma, 2009; Saleem et al., 2018) also create water dearth situation even in the wetland leading to ecological distress. Frequent drying out of parts of wetland leads to reclamation of wetland (Junk et al., 2013; Chakraborty et al., 2018). Along with quantitative loss, the presence of agriculture around wetland and sometimes within wetland bed also deposits huge amount of agriculture residues (Pal et al. 2022; Singha and Pal, 2023) which converts many oligotrophic wetland into eutrophic wetland reducing their productivity (Singha and Pal, 2023).

Conversely, in developed nations, the attitude towards environmental resource management was changed considerably. Moreover, since the population size is relatively smaller, its pressure on environmental resources is comparatively lesser. For instance, the man-land ratio in developed countries like Sweden and Australia is, respectively, 0.25 and 1.24 ha per person (World Bank, 2018) which is much greater than the developing nations like India (0.12 ha per person) and China (0.09 ha per person) (World Bank, 2018). Due to having less population pressure and, socioecological awareness, concerned policy implementation, developed nations were found much capable to restrict wetland loss to some extent (Xu et al., 2019). However, over-dependence on the industrial sector and effluents of this sector is often caused for wetland conversion (Asselen et al., 2013). Service and industrial sectors contribute major gross national income of these countries (Behun et al., 2018; Dalenogare et al., 2018). For example, countries like Germany, Italy, the USA, and France contribute 26.6%, 22.6%, 18.4%, and 16.8% in industrial sector and 63%, 65%, 80.1%, and 70.2% in service sector, respectively, of its total GDP (World Bank, 2022). In order to produce huge industrial goods, effluent is a major by-product which often mixes with water bodies of different kinds leading to contamination. Li et al. (2022) reviewed the literatures on heavy metal pollution in coastal wetlands and reported that mercury (Hg), cadmium (Cd), and copper (Cu) are the main causes of such contamination. In consequence of this, soil substrate contamination (Liang, 2017; Yang and Shen, 2020), different types of diseases among the fishes and other species (Leung et al., 2017; Meena et al., 2018), biomagnifications, and ecosystem pollution were found very crucial. Influx of unprocessed or semi-processed effluents is the major cause behind this, and most of the cases are responsible for reduction in service abilities of the wetland (Wang et al., 2013; Pal and Debanshi, 2022). Changes of thermal environment due to industrial effluent are also very important leading to the micro-thermal conditions of fish habitat (Pozzer et al., 2022). Afzal et al. (2019) documented that wetlands and floating vegetations are often used for wastewater treatment but higher contamination beyond its capacity sometimes is caused for wetland degradation. From the above discussion, it is quite evident that in the developed nations, qualitative loss is more prominent at the present time. In developing nations, reclamation is more prominent and in least developed nations, both qualitative and quantitative loss is evident.

Table 4 Data from the world on account of identifying the drivers of urban wetland loss

Literature	Objectives	Study area	Methodology	Findings
Hettiarachchi et al. (2014)	Examining the nature of the socioecological transformation of wetlands and investigating the cause of such transformation	Wetlands of Colombo, srilanka	Techniques from urban ecology, wetland science, and environmental history were combined**.**	The Colombo urban wetland's overall structure and social environment have changed significantly since 1980
Rashid and Aneaus (2020)	Assessing the change of land system in and around wetland	Khushalsar wetland of Srinagar city, India	Used LULC map for both 2004 and 2014, which is derived from Landsat™ 5 for 2004 and Landsat 8 OLI for 2014 imagery (Landsat 8)	The built-up area in and around this wetland has increased by 510% in the last ~5 decades
Rojas et al. (2019)	Examining urban growth, its effect on the area of wetland, geo forms, and previously designated protected areas	Rocuant- Andalien wetland located in South Central Chile, South America	Used LULC change maps from 2004 to 2014, SEA helps to quantify urban growth over the wetland	Urban area increased by 28% between 2004 and 2014. Future increase expected 238%. wetland area decreased 10% from 2004 to 2014 and is expected to decrease by up to 32%
Zhang et al. (2019)	Identifying wetland's variation over space and time and also what is the cause behind it.	Beijing-Tianjing-Hebei (BTH) region, china	High-quality LULC data set for 2000 and 2015 was used to show the distribution and conversion of wetland. The driving forces of changes in wetland identified by aggregated boosted trees (ABTs)	In 2000 (BTH), wetland region experienced 6264.07 km^2 more area than in 2015. Natural wetland changed due to the production of agriculture, artificialization, built-up expansion, and increase of grassland area.
Lin et al. (2018)	Examining the variation of the pattern of landscape in Zhoushan island's wetland from 1985 to 2015	Wetlands of zhouShan island in East china sea	From a Landsat image, wetland distribution for the four time periods 1985, 1995, 2005, and 2015 was calculated using support vector machines and artificial visual interpretation. A landscape matrix describes the spatial organization of a landscape. Statistical information was used to determine the drivers	The natural wetland fell by 6.07 km^2, whereas the artificial wetland raised 78.64 km^2 from 1985 to 2015. Wetland areas that are artificial have surpassed those that are natural. The natural wetland is being gradually fragmented. Wetland transitions from natural to manmade are the most common
Hussien et al. (2018)	Investigating wetland changes between 1984 and 2013 and identifying the main drivers of wetland change	Wetlands in North central Ethiopean highland, Africa	LULC has consecutively analyzed data derived from Landsat satellite imageries of 1984, 1993(TM), 2000, 2013 (ETM+) used to show spatio-temporal change over the last 3 decades	The area size of wetlands decreased from 7.4% in 1984 to 2.6% in 2013; 66% of total wetland was lost within 30 years. Agricultural and urban expansion act as the leading cause of it. The highest rate of wetland loss was recorded in 2000 and 2013
Ghosh et al. (2018)	Identifying the main causes of East Kolkata wetland loss	The East Kolkata Wetland located on Kolkata city, West Bengal, India	NDWI is used to demarcate the surface water extent, NDBI for extracting the built-up area, and WTR represents the gradual change of water body.	Wetland loss rate was not similar over the time. It was 23.55% (1991–2011) and 7.34% (2011–2017). Main drivers of it identified as transformation of land due to built-up area and encroachment of crop land.

Table 4 (continued)

Literature	Objectives	Study area	Methodology	Findings
Jacques et al. (2017)	Studying the effect of urbanization on shape, size, and pattern of wetland	Wetland of New Hampshire	A combination of DOQ, NAIP image, and topographic maps used for change detection.	Urbanization has an impact on wetland size and spatial dispersion. Moving out from the urban core was proven to enhance quantity
Mondal et al. (2017)	Examining the urban wetland shrinkage pattern and accountable factor of it.	East Kolkata wetland, Kolkata, WB.	Quantified land cover changes to investigate the factors and pattern of wetland change. Wetland shrinkage monitoring model (WSM) used to tie between urban growth forces and wetland transition process	Urban growth near to wetland was a responsible factor for wetland shrinkage. Wetland altered to other classes. According to the 2025 wetland transition, 9-km^2 wetland area at a troublesome situation
Fang et al. (2015)	Investigating how urbanization affects the distribution of nutrients and heavy metal in Napahai wetland	Napahai wetland, China	An inductively coupled plasma optical emission spectrometer (optima,7000DV, USA) is used to measure the concentration of heavy metals. How urbanization and other abiotic factors influenced heavy metal distribution exhibited by principal component analysis (PCA)	Urbanization influences the distribution of the primary organic compounds, fulvic acid, and hydrophobic acid. The accumulation of heavy metals leads to qualitative degradation of Napahai Wetland
Ji et al. (2015)	Assessing the urban wetland and its changing pattern at various spatial scales	Kansas city metropolitan region, USA	This study used a series of (SPOT) images from 1992 to 2010 and found that there has been a considerable amount of urban sprawl recently. To enhance the detection capability and accuracy of urban wetland, a knowledge-based image classification approach was used. The cross-scale study utilized to determine wetland dynamics' trend and magnitude	The built-up expansion was primarily affected by small-sized wetland. Urbanizations leads to the squeezing of wetland
McCauley et al. (2013)	Quantifying the impact of urbanization on the number, size, and pattern of wetland	Wetlands in Orange and Seminole countries in Florida, USA	Color infrared image (CIR) was used to analyze wetland individually through decades. To estimate the change of urbanization and its effect on wetland loss, LULC data from 1990 to 2004 has been taken	Over the past 20 years (1984–2004), 26% of wetlands were destroyed or deteriorated, while nearly half of managed forests had deteriorating conditions and were adjacent to land used for agricultural and urban development
Jiang et al. (2012)	Analyzing the changes of spatial distribution and area of urban wetland and identifying the cause of wetland area loss	Wetlands in Bejing, China	The decision tree and threshold method have been taken to depict the boundaries of wetland. Gray correlation analysis (GCA) has been driven to analyze the factors of wetland change and land utilization	Total surface water area gradually decreases from 1996 to 2007. The rate of urbanization and wastewater is major artificial driving factor wetland degradation

Table 4 (continued)

Literature	Objectives	Study area	Methodology	Findings
Zhou et al. (2010)	Detecting the changes of wetland by using post-classification comparison approach	Xixi wetland, china	Urban wetland land cover change was mapped and tracked by using IKONOS images taken from June 2003 to January 2006. A post-classification comparison technique and transformation matrix were employed to determine the wetland's changes	The Xixi wetland's landscape has undergone significant transformation in the last three years. Reduce the size of water bodies while expanding the area of vegetation
Wang et al. (2008)	Addressing probabilities of wetland landscape transformation into the non-wetland landscape	Wetland in Wuhan city, China	To show the transformation of wetland, some specific model has been used, such as the cellular and Markov model	A good number of wetlands were brought under the control of construction in urban areas, and the fragmentation of wetland increased
Bolca et al. (2007)	Studying the changes in land use of Bolcova Delta	Wetlands of Bolcova Delta, Turkey	Changes of land use taking place over time. RS and GIS helped to visualize it. This study used an aerial photograph (1957, 1976, 1996) IKONOS satellite image from 2005 to determine the region's physic-cultural characteristics	This region experienced rapid and unsystematic urbanization that led to a qualitative and quantitative change in wetland
Lee et al. (2006)	Assessing how coastal wetland's function and structure affected by urbanization.	Selected coastal wetland all over the world	A functional model is presented to show the effect of urbanization on the ecosystem of coastal wetland	Urbanization causes a rise in nutrients and pollution, which affect wetlands' hydrological and sedimentation patterns. Thus, the coastal wetland's function changed
Kentula et al. (2004)	Assessing the status of wetland over the last 16 years and effect of urbanization on wetland resources	Portland, northwest Oregon, USA	Used GIS analysis, field survey, and the National Wetland Inventory (NWI) to monitor changes over the previous 16 years	Due to human intervention, the hydrogeomorphic classes of the wetland in 1998 are typical. Nearby research site, undeveloped and agricultural land converted to urban and residential use

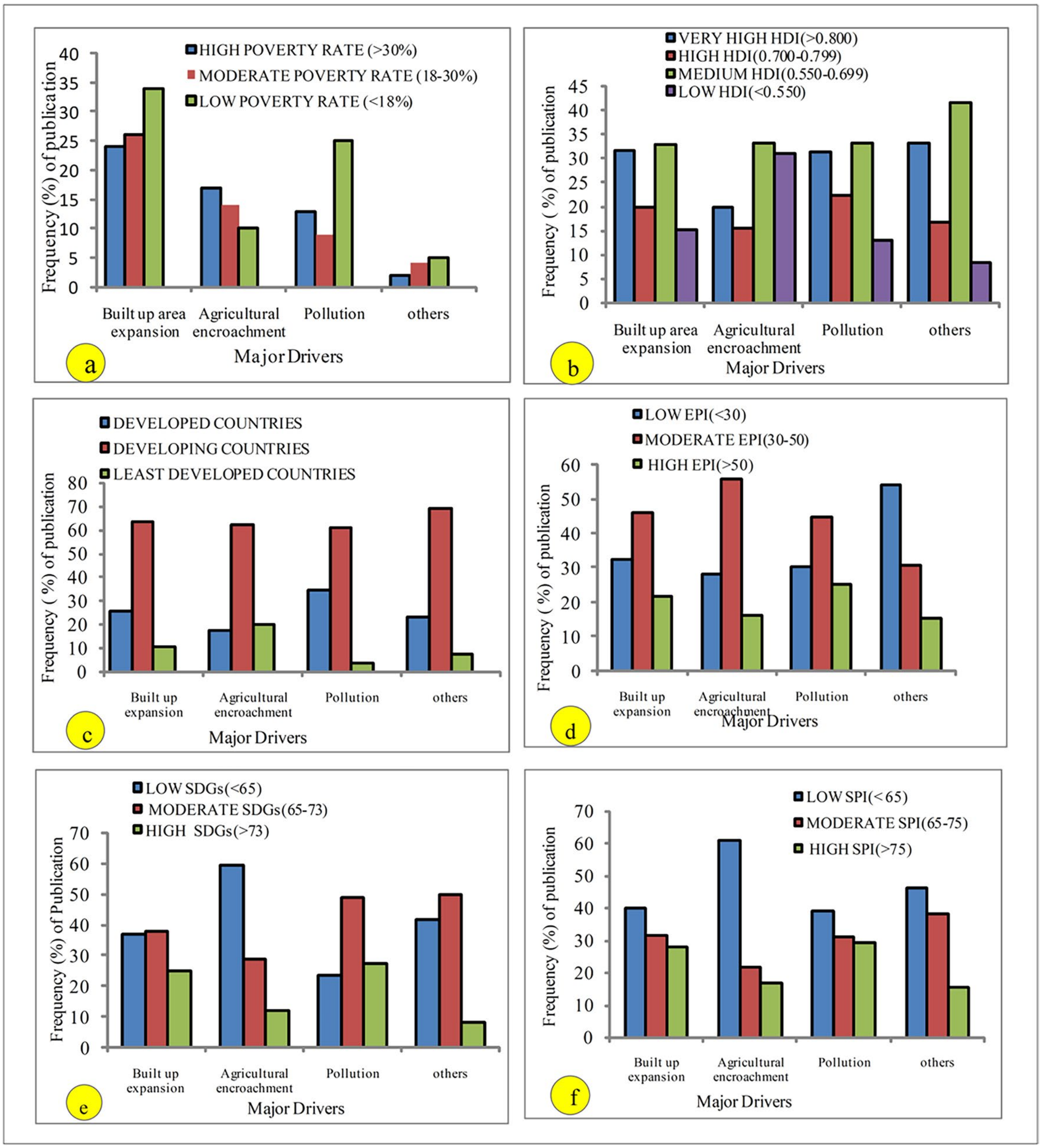

Fig. 7 Publication frequency histogram showing the causes responsible for wetland transformation in reference to different perspectives: **a** poverty rate of the country, **b** human development index (HDI), **c** development status of the country, **d** environmental performance index, **e** sustainable development goals, and **f** social progress index

Conclusion

The study articulated that economic and socioecological parameters have significant influence to determine the rate of urban wetland loss. Developed countries with good HDI, EPI, SDGI, SPI, and developmental status recorded considerably low rate of urban wetland loss. Contrarily, a higher rate of urban wetland loss was identified in the developing and least developed countries where all the mentioned socio-ecological and economic parameters are in relatively weaker states. The poverty rate was found high in these nations, and a positive association with the rate of wetland loss reveals that it may also be caused for resource waste or loss.

Meta-analysis proved that over the progress of time, some countries from developing nations also emerged as new research hearth along with some progressed nations. Moreover, in collaborative research, the former countries also secured an appreciable position.

Local bodies of a country adopt planning for wetland resource management. In developing countries, such approaches were found less effective to make it successful. The progress of world literatures across the world identified different reasons for urban wetland loss, and therefore, for making it successful, driver-centric approaches could be taken. For example, if a wetland is getting lost due to dam-induced water diversion from a river, for saving it, ecological flow release is necessary. If a wetland is affected by pollution, immediately sources of pollution are required to be controlled. Apart from all these regional perspectives, improving the national and global economic and socioecological perspectives would be a good alternative for saving the wetlands from such aggressive anthropogenic interventions. For instance, the study reported that HDI, EPI, SDGI, SPI, and developmental status can significantly reduce the rate of urban wetland loss. So, the improvement of these perspectives could be the savior of wetland loss. It could help to minimize the need for adopting regional-level planning often. Hence, all these perspectives would be equally helpful work in different situations. The study also clearly pointed out the fact that poverty is the curse of wetland loss even in this twenty-first century. So, poverty eradication would be a broad national and international level step to conserve and restore the precious natural capital and kidney of the urban system. The findings at the national and international level would be very instrumental to re-think about the planning towards wetland conservation.

The approach of the present study is novel and found a novel finding of international planning importance. Besides its effectiveness, a few limitations could also be pointed out for showing the further scope of the study. The sample literatures taken could be extended across different other nations, and sample size of each nation could be enhanced. This could help to make the inference more firm.

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Data availability All the data and materials related to the manuscript are published with the paper, and available from the corresponding author upon request (swadespal2017@gmail.com).

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication All the co-authors agreed to publish the manuscript.

Conflict of interest The authors declare no competing interests.

References

Afzal M, Rehman K, Shabir G, Tahseen R, Ijaz A, Brix H (2019) Large-scale remediation of oil-contaminated water using floating treatment wetlands. NPJ Clean Water 2(1):3

Alam MZ, Carpenter-Boggs L, Rahman A, Haque MM, Miah MRU, Moniruzzaman M, Abdullah HM (2017) Water quality and resident perceptions of declining ecosystem services at Shitalakka wetland in Narayanganj city. Sustainability of Water Quality and Ecology 9:53–66

Alikhani S, Nummi P, Ojala A (2021) Urban wetlands: a review on ecological and cultural values. Water 13(22):3301

Asomani-Boateng R (2019) Urban wetland planning and management in Ghana: a disappointing implementation. Wetlands 39(2):251–261

Assefa WW, Eneyew BG, Wondie A (2021) The impacts of land-use and land-cover change on wetland ecosystem service values in peri-urban and urban area of Bahir Dar City, Upper Blue Nile Basin. Northwestern Ethiopia Ecological Processes 10(1):1–18

Asselen SV, Verburg PH, Vermaat JE, Janse JH (2013) Drivers of wetland conversion: a global meta-analysis. PloS One 8(11):e81292

Assessment ME (2005) Ecosystems and human well-being: wetlands and water. World Resources Institute

Athukorala D, Estoque RC, Murayama Y, Matsushita B (2021) Impacts of urbanization on the Muthurajawela Marsh and Negombo Lagoon, Sri Lanka: implications for landscape planning towards a sustainable urban wetland ecosystem. Remote Sens (Basel) 13(2):316

Ballut-Dajud GA, Sandoval Herazo LC, Fernández-Lambert G, Marín-Muñiz JL, López Méndez MC, Betanzo-Torres EA (2022) Factors affecting wetland loss: a review. Land 11(3):434

Barbier EB, Hochard JP (2018) Land degradation and poverty Nature Sustainability 1(11):623–631

Bassi N, Kumar MD, Sharma A, Pardha-Saradhi P (2014) Status of wetlands in India: a review of extent, ecosystem benefits, threats and management strategies. Journal of Hydrology. Regional Studies 2:1–19. https://doi.org/10.1016/j.ejrh.2014.07.001

Basu T, Das A (2021) Systematic review of how eco-environmental transformation due to urbanization can be investigated in the sustainable development of Indian cities. Environmental Challenges 4:100099

Basu T, Das A, Pham QB, Al-Ansari N, Linh NTT, Lagerwall G (2021) Development of an integrated peri-urban wetland degradation assessment approach for the Chatra Wetland in eastern India. Sci Rep 11(1):1–22

Behun M, Gavurova B, Tkacova A, Kotaskova A (2018) The impact of the manufacturing industry on the economic cycle of European Union countries. Journal of competitiveness 10(1):23

Bellezoni RA, Meng F, He P, Seto KC (2021) Understanding and conceptualizing how urban green and blue infrastructure affects the food, water, and energy nexus: a synthesis of the literature. J Clean Prod 289:125825

Blacker CP (1947) Stages in population growth. Eugen Rev 39(3):88

Bolca M, Özen F, Güneş A (2014) Land use changes in Gediz Delta (Turkey) and their negative impacts on wetland habitats. J Coast Res 30(4):756–764

Bolca M, Turkyilmaz B, Kurucu Y, Altinbas U, Esetlili MT, Gulgun B (2007) Determination of impact of urbanization on agricultural land and wetland land use in Balçovas' Delta by remote sensing and GIS technique. Environ Monit Assess 131(1):409–419

Boyer T, Polasky S (2004) Valuing urban wetlands: a review of non-market valuation studies. Wetlands 24(4):744–755

Cai Y, Zhang H, Zheng P, Pan W (2016) Quantifying the impact of land use/land cover changes on the urban heat island: a case study of the natural wetlands distribution area of Fuzhou City. China Wetlands 36(2):285–298

Caldwell JC (1976) Toward a restatement of demographic transition theory. Population and development review:321–366

Carter M (2015) Wetlands and health: how do urban wetlands contribute to community wellbeing? Wetlands and human health. Springer, Dordrecht, pp 149–167

Chakraborty R, Talukdar S, Basu T, Pal S (2018) Habitat identity crisis caused by the riparian wetland squeeze in Tangon River Basin, Barind Region, India. Spat Inf Res 26:507–516

Chandramouli C, General R (2011). In: Census of India 2011 (ed) Provisional Population Totals. Government of India, New Delhi, pp 409–413

Chaudhary S, McGregor A, Houston D, Chettri N (2019) Spiritual enrichment or ecological protection?: a multi-scale analysis of cultural ecosystem services at the Mai Pokhari, a Ramsar site of Nepal. Ecosyst Serv 39:100972

Chen L, Jin Z, Michishita R, Cai J, Yue T, Chen B, Xu B (2014) Dynamic monitoring of wetland cover changes using time-series remote sensing imagery. Eco Inform 24:17–26

Coale AJ (1989) Demographic transition. In: Social economics. Palgrave Macmillan, London, pp 16–23

Corbau C, Zambello E, Rodella I, Utizi K, Nardin W, Simeoni U (2019) Quantifying the impacts of the human activities on the evolution of Po delta territory during the last 120 years. J Environ Manage 232:702–712

Cowardin LM, Golet FC (1979) US Fish and Wildlife Service 1979 wetland classification: a review. In: Classification and inventory of the world's wetlands. Springer, pp 139–152

Dalenogare LS, Benitez GB, Ayala NF, Frank AG (2018) The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of production economics 204:383–394

Dar SA, Rashid I, Bhat SU (2021) Land system transformations govern the trophic status of an urban wetland ecosystem: perspectives from remote sensing and water quality analysis. Land Degradation & Development 32(14):4087–4104

Das A, Basu T (2020) Assessment of peri-urban wetland ecological degradation through importance-performance analysis (IPA): a study on Chatra Wetland. India Ecological Indicators 114:106274

Das R, Pal S (2016) Spatial association of wetlands over physical variants in Barind Tract of West Bengal, India.. Journal of Wetlands. Environ Manag 4(2). https://doi.org/10.20527/jwem.v4i2.99

Davis K (2011) The urbanization of the human population. City Read 5:20–30

Dewan AM, Yamaguchi Y (2009) Land use and land cover change in Greater Dhaka, Bangladesh: using remote sensing to promote sustainable urbanization. Applied geography 29(3):390–401

Dou T, Troesch S, Petitjean A, Gábor PT, Esser D (2017) Wastewater and rainwater management in urban areas: a role for constructed wetlands. Procedia Environmental Sciences 37:535–541

Dror I (2015) Innovation platforms for agricultural development. J. J. Cadilhon, M. Schut, M. Misiko, & S. Maheshwari (Eds.). Taylor & Francis

Ehrenfeld JG (2000) Evaluating wetlands within an urban context. Urban Ecosyst 4(1):69–85

Evers DE, Gosselink JG, Sasser CE, Hill JM (1992) Wetland loss dynamics in southwestern Barataria basin, Louisiana (USA), 1945–1985. Wetlands Ecology and Management 2(3):103–118

Famiglietti JS (2014) The global groundwater crisis. Nature Climate Change 4(11):945–948

Fang H, Xu Y, Ye Z, Zhang Z, Pan S, Deng L et al (2015) Impact of urbanization on nutrients and heavy metal pollution of Napahai Wetland, Shangri-La County, China. International Journal of Sustainable Development & World Ecology 22(2):117–126

Fickas KC, Cohen WB, Yang Z (2016) Landsat-based monitoring of annual wetland change in the Willamette Valley of Oregon, USA from 1972 to 2012. Wetlands ecology and management 24(1):73–92

Fielding AJ (1989) Migration and urbanization in Western Europe since 1950. The Geographical Journal 155(1):60–69

Forkuor G, Cofie O (2011) Dynamics of land-use and land-cover change in Freetown, Sierra Leone and its effects on urban and peri-urban agriculture—a remote sensing approach. International Journal of Remote Sensing 32(4):1017–1037

Frantzeskaki N (2019) Seven lessons for planning nature-based solutions in cities. Environ Sci Policy 93:101–111

Friedmann J (2006) Four theses in the study of China's urbanization. Int J Urban Reg Res 30(2):440–451

Ghosh S, Dinda S, Chatterjee ND, Das K (2018) Analyzing risk factors for shrinkage and transformation of East Kolkata Wetland. India Spatial Information Research 26(6):661–677

Grover A, Singh RB (2015) Analysis of urban heat island (UHI) in relation to normalized difference vegetation index (NDVI): a comparative study of Delhi and Mumbai. Environments 2(2):125–138

Hammer DA, Bastian RK (2020) Wetlands ecosystems: natural water purifiers? In: Constructed wetlands for wastewater treatment. CRC Press, pp 5–19

Handayani HH, Murayama Y, Ranagalage M, Liu F, Dissanayake DMSLB (2018) Geospatial analysis of horizontal and vertical urban expansion using multi-spatial resolution data: a case study of Surabaya. Indonesia Remote Sensing 10(10):1599

Haregeweyn N, Fikadu G, Tsunekawa A, Tsubo M, Meshesha DT (2012) The dynamics of urban expansion and its impacts on land use/land cover change and small-scale farmers living near the urban fringe: a case study of Bahir Dar. Ethiopia Landscape and urban planning 106(2):149–157

Harikumar, P. S., & Jisha, T. S. (2010). Distribution pattern of trace metal pollutants in the sediments of an urban wetland in the southwest coast of India.

Herrera D, Ellis A, Fisher B, Golden CD, Johnson K, Mulligan M et al (2017) Upstream watershed condition predicts rural children's health across 35 developing countries. Nat Commun 8(1):1–8

Hettiarachchi M, Morrison TH, Wickramsinghe D, Mapa R, De Alwis A, McAlpine CA (2014) The eco-social transformation of urban wetlands: a case study of Colombo, Sri Lanka. Landscape and Urban Planning 132:55–68

Huang SL, Wang SH, Budd WW (2009) Sprawl in Taipei's peri-urban zone: responses to spatial planning and implications for adapting global environmental change. Landscape and urban planning 90(1-2):20–32

Hussien K, Demissie B, Meaza H (2018) Spatiotemporal wetland changes and their threats in North Central Ethiopian Highlands. Singapore Journal of Tropical Geography 39(3):332–350

Imperative SP (2021) Social progress index 2021

Jacques, K., Congalton, R. G., & Babbitt, K.(2017). Effects of Urbanization on the Spatial Distribution and Size of Wetlands in New Hampshire.

Ji W, Xu X, Murambadoro D (2015) Understanding urban wetland dynamics: cross-scale detection and analysis of remote sensing. International Journal of Remote Sensing 36(7):1763–1788
Jia H, Ma H, Wei M (2011) Urban wetland planning: a case study in the Beijing central region. Ecological Complexity 8(2):213–221
Jiang W, Wang W, Chen Y, Liu J, Tang H, Hou P, Yang Y (2012) Quantifying driving forces of urban wetlands change in Beijing City. Journal of Geographical Sciences 22(2):301–314
Jiangyi L, Shiquan D, Hmeimar AEH (2020) Cost-effectiveness analysis of different types of payments for ecosystem services: a case in the urban wetland ecosystem. J Clean Prod 249:119325
Jisha KC, Puthur JT (2021) Ecological importance of wetland systems. Current Challenges and Future Strategies, Wetlands Conservation, pp 40–54
Junk WJ (2013) Current state of knowledge regarding South America wetlands and their future under global climate change. Aquatic Sciences 75(1):113–131
Junk WJ, An S, Finlayson CM, Gopal B, Květ J, Mitchell SA et al (2013) Current state of knowledge regarding the world's wetlands and their future under global climate change: a synthesis. Aquatic sciences 75:151–167
Kabiri S, Allen M, Okuonzia JT, Akello B, Ssabaganzi R, Mubiru D (2020) Detecting level of wetland encroachment for urban agriculture in Uganda using hyper-temporal remote sensing. AAS Open Research 3:18
Kahil MT, Albiac J, Dinar A, Calvo E, Esteban E, Avella L, Garcia-Molla M (2016) Improving the performance of water policies: evidence from drought in Spain. Water 8(2):34
KAYITESI, C. (2019). Spatio-temporal analysis of urban growth and its impacts on Rwampara wetland in the City of Kigali Rwanda.
Keho Y (2016) What drives energy consumption in developing countries? The experience of selected African countries. Energy Policy 91:233–246
Kentula ME, Gwin SE, Pierson SM (2004) Tracking changes in wetlands with urbanization: sixteen years of experience in Portland, Oregon, USA. Wetlands 24(4):734–743
Khoshkam M, Marzuki A, Al-Mulali U (2016) Socio-demographic effects on Anzali wetland tourism development. Tour Manag 54:96–106
Kingsford RT, Basset A, Jackson L (2016) Wetlands: conservation's poor cousins. Aquatic Conservation: Marine and Freshwater Ecosystems 26(5):892–916
Kumar A, Sati JP, Tak PC, Alfred JRB (2005) Handbook on Indian Wetland Birds and their Conservation: i-xxvi; 1- 468 (Published by the Director. Zool. Surv, India)
Kumar S, Agarwal A, Villuri VGK, Pasupuleti S, Kumar D, Kaushal DR et al (2021) Constructed wetland management in urban catchments for mitigating floods. Stochastic Environmental Research and Risk Assessment 35(10):2105–2124
Lee SY, Dunn RJK, Young RA, Connolly RM, Dale PER, Dehayr R et al (2006) Impact of urbanization on coastal wetland structure and function. Austral Ecol 31(2):149–163
Let M, Pal S (2023) Socio-ecological well-being perspectives of wetland loss scenario: a review. J Environ Manage 326:116692
Leung HM, Duzgoren-Aydin NS, Au CK, Krupanidhi S, Fung KY, Cheung KC et al (2017) Monitoring and assessment of heavy metal contamination in a constructed wetland in Shaoguan (Guangdong Province, China): bioaccumulation of Pb, Zn, Cu and Cd in aquatic and terrestrial components. Environ Sci Pollut Res 24:9079–9088
Li C, Wang H, Liao X, Xiao R, Liu K, Bai J et al (2022) Heavy metal pollution in coastal wetlands: a systematic review of studies globally over the past three decades. J Hazard Mater 424:127312
Li Y, Shi Y, Zhu X, Cao H, Yu T (2014) Coastal wetland loss and environmental change due to rapid urban expansion in Lianyungang, Jiangsu. China Regional environmental change 14(3):1175–1188
Li Y, Zhu X, Sun X, Wang F (2010) Landscape effects of environmental impact on bay-area wetlands under rapid urban expansion and development policy: a case study of Lianyungang. China Landscape and urban Planning 94(3-4):218–227
Li Z, Jiang W, Wang W, Chen Z, Ling Z, Lv J (2020) Ecological risk assessment of the wetlands in Beijing-Tianjin-Hebei urban agglomeration. Ecol Indic 117:106677
Liang J, Yang Z, Tang L, Zeng G, Yu M, Li X et al (2017) Changes in heavy metal mobility and availability from contaminated wetland soil remediated with combined biochar-compost. Chemosphere 181:281–288
Lin Q, Yu S (2018) Losses of natural coastal wetlands by land conversion and ecological degradation in the urbanizing Chinese coast. Sci Rep 8(1):1–10
Lin W, Cen J, Xu D, Du S, Gao J (2018) Wetland landscape pattern changes over a period of rapid development (1985–2015) in the ZhouShan Islands of Zhejiang province, China. Estuar Coast Shelf Sci 213:148–159
SU MS, TI GM, Zahidul I (2009) Pre-and post-urban wetland area in Dhaka City, Bangladesh: a remote sensing and GIS analysis. Journal of Water Resource and Protection 2009
Mabwoga SO, Thukral AK (2014) Characterization of change in the Harike wetland, a Ramsar site in India, using landsat satellite data. SpringerPlus 3(1):1–11
Malekmohammadi B, Jahanishakib F (2017) Vulnerability assessment of wetland landscape ecosystem services using driver-pressure-state-impact-response (DPSIR) model. Ecol Indic 82:293–303
Mandal MH, Roy A, Siddique G (2021) Spatial dynamics in people-wetland association: an assessment of rural dependency on ecosystem services extended by Purbasthali Wetland, West Bengal. Environment, Development and Sustainability 23(7):10831–10852
Mandishona E, Knight J (2019) Users' perceptions and understanding of two urban wetlands in Harare, Zimbabwe. South African Geographical Journal= Suid-Afrikaanse Geografiese Tydskrif 101(3):326–348
Mao D, Luo L, Wang Z, Wilson MC, Zeng Y, Wu B, Wu J (2018a) Conversions between natural wetlands and farmland in China: a multiscale geospatial analysis. Sci Total Environ 634:550–560
Mao D, Tian Y, Wang Z, Jia M, Du J, Song C (2021) Wetland changes in the Amur River Basin: differing trends and proximate causes on the Chinese and Russian sides. J Environ Manage 280:111670
Mao D, Wang Z, Wu J, Wu B, Zeng Y, Song K et al (2018b) China's wetlands loss to urban expansion. Land degradation & development 29(8):2644–2657
Maparu TS, Mazumder TN (2017) Transport infrastructure, economic development and urbanization in India (1990–2011): is there any causal relationship? Transportation research part A: policy and practice 100:319–336
Marasinghe S, Perera P, Simpson GD, Newsome D (2021) Nature-based tourism development in coastal wetlands of Sri Lanka: an importance–performance analysis at Maduganga Mangrove Estuary. J Outdoor Recreat Tour 33:100345
Masron TA, Subramaniam Y (2019) Does poverty cause environmental degradation? Evidence from developing countries. J Poverty 23(1):44–64
Matfess H (2015) Rwanda and Ethiopia: developmental authoritarianism and the new politics of African strong men. African Studies Review 58(2):181–204
McCauley LA, Jenkins DG, Quintana-Ascencio PF (2013) Isolated wetland loss and degradation over two decades in an increasingly urbanized landscape. Wetlands 33(1):117–127
McInnes RJ (2013) Recognising wetland ecosystem services within urban case studies. Mar Freshw Res 65(7):575–588
Meena RAA, Sathishkumar P, Ameen F, Yusoff ARM, Gu FL (2018) Heavy metal pollution in immobile and mobile components

of lentic ecosystems—a review. Environ Sci Pollut Res 25:4134–4148
Merlín-Uribe Y, Contreras-Hernández A, Astier-Calderón M, Jensen OP, Zaragoza R, Zambrano L (2013) Urban expansion into a protected natural area in Mexico City: alternative management scenarios. Journal of environmental planning and management 56(3):398–411
Mondal B, Dolui G, Pramanik M, Maity S, Biswas SS, Pal R (2017) Urban expansion and wetland shrinkage estimation using a GIS-based model in the East Kolkata Wetland, India. Ecol Indic 83:62–73
Muema JM, Kaluli JW, Gathenya JM, Mwangi BM (2018) Evaluation of wetland loss in Maragua Watershed, Murang'a County, Kenya. Journal of Sustainable Research in Engineering 4(4):160–170
Nabahungu NL, Visser SM (2013) Farmers' knowledge and perception of agricultural wetland management in RWANDA. Land Degradation & Development 24(4):363–374
Naikoo MW, Rihan M, Peer AH, Talukdar S, Mallick J, Ishtiaq M, Rahman A (2022) Analysis of peri-urban land use/land cover change and its drivers using geospatial techniques and geographically weighted regression. Environ Sci Pollut Res:1–19
Nascimento N, Vinçon-Leite B, De Gouvello B, Gutierrez L, Granceri M, Silva T, Costa H (2016) Green blue infrastructure at metropolitan scale: a water sustainability approach in the Metropolitan Region of Belo Horizonte. Brazil, In Novatech, p 2016
Nyamasyo SK, Kihima BO (2014) Changing land use patterns and their impacts on wild ungulates in Kimana Wetland Ecosystem, Kenya
O'Donnell EC, Netusil NR, Chan FK, Dolman NJ, Gosling SN (2021) International perceptions of urban blue-green infrastructure: a comparison across four cities. Water 13(4):544
Obia AE, Itam EB, Archibong AE (2015) Urban development in the third world and threat to wetlands: the case study of Calabar. Nigeria Global Journal of Engineering Research 14(1):33–45
Olusola A, Muyideen A, Abel O (2016) Anassessment of wetland loss in Lagos Metropolis. Nigeria, Developing Country Studies
Omayer, H. M. (2022). Stakeholders' visual preferences relationships of landscape design elements in constructed wetland parks.
O'Neill BC, Ren X, Jiang L, Dalton M (2012) The effect of urbanization on energy use in India and China in the iPETS model. Energy Econ 34:S339–S345
Pal S, Akoma OC (2009) Water scarcity in wetland area within Kandi block of West Bengal: a hydro-ecological assessment. Ethiopian Journal of Environmental Studies and Management 2:1–17
Pal S, Debanshi S (2022) Exploring the effect of wastewater pollution susceptibility towards wetland provisioning services. Ecohydrology & Hydrobiology 23:162–176
Pal S, Sarkar R, Saha TK (2022) Exploring the forms of wetland modifications and investigating the causes in lower Atreyee river floodplain area. Eco Inform 67:101494
Pal S, Talukdar S, Ghosh R (2020) Damming effect on habitat quality of riparian corridor. Ecol Indic 114:106300
Pal S, Talukdar S (2018) Application of frequency ratio and logistic regression models for assessing physical wetland vulnerability in Punarbhaba river basin of Indo-Bangladesh. Hum Ecol Risk Assess Int J 24(5):1291–1311
Pandey B, Seto KC (2015) Urbanization and agricultural land loss in India: comparing satellite estimates with census data. J Environ Manage 148:53–66
Pattison-Williams JK, Pomeroy JW, Badiou P, Gabor S (2018) Wetlands, flood control and ecosystem services in the Smith Creek Drainage Basin: a case study in Saskatchewan, Canada. Ecol Econ 147:36–47
Pauchard A, Aguayo M, Peña E, Urrutia R (2006) Multiple effects of urbanization on the biodiversity of developing countries: the case of a fast-growing metropolitan area (Concepción, Chile). Biol Conserv 127(3):272–281
Pejic Bach M, Tustanovski E, Ip AW, Yung KL, Roblek V (2019) System dynamics models for the simulation of sustainable urban development: a review and analysis and the stakeholder perspective. Kybernetes: The International Journal of Systems & Cybernetics 49(2):460–504
Peteet DM, Nichols J, Kenna T, Chang C, Browne J, Reza M et al (2018) Sediment starvation destroys New York City marshes' resistance to sea level rise. Proc Natl Acad Sci 115(41):10281–10286
Petrişor AI, Hamma W, Nguyen HD, Randazzo G, Muzirafuti A, Stan MI et al (2020) Degradation of coastlines under the pressure of urbanization and tourism: evidence on the change of land systems from Europe. Asia and Africa Land 9(8):275
Pozzer AC, Gómez PA, Weiss J (2022) Volatile organic compounds in aquatic ecosystems—detection, origin, significance and applications. Sci Total Environ:156155
Prasher K (2018) The state of India's disappearing 919 wetlands. The Weather Channel India, https://weather.com/en-IN/india/news/news/2018-11-08-the-case-of-indias- disappearing wetlands. Accessed 25 June 2022
Prieto M (2015) Privatizing water in the Chilean Andes: the case of Las Vegas de Chiu-Chiu. Mountain Research and Development 35(3):220–229
Puga D (1998) Urbanization patterns: European versus less developed countries. Journal of Regional Science 38(2):231–252
Qin B, Zhang Y (2014) Note on urbanization in China: urban definitions and census data. China Economic Review 30:495–502
Quétier F, Regnery B, Levrel H (2014) No net loss of biodiversity or paper offsets? A critical review of the French no net loss policy. Environ Sci Policy 38:120–131
Rahman MM, Szabó G (2021) Impact of land use and land cover changes on urban ecosystem service value in Dhaka. Bangladesh Land 10(8):793
Convention R (1971) The Ramsar Convention. In: Ramsar Center, Rue Mauverney 28, CH 1196, Gland, Switzerland
Convention R (2018) Global wetland outlook: state of the world's wetlands and their services to people. Ramsar Convention Secretariat, Gland, Switzerland
Rao Y, Zhou J, Zhou M, He Q, Wu J (2020) Comparisons of three-dimensional urban forms in different urban expansion types: 58 sample cities in China. Growth Chang 51(4):1766–1783
Rapinel S, Clément B, Dufour S, Hubert-Moy L (2018) Fine-scale monitoring of long-term wetland loss using LiDAR data and historical aerial photographs: the example of the couesnon floodplain. France Wetlands 38(3):423–435
Rashid I, Aneaus S (2020) Landscape transformation of an urban wetland in Kashmir Himalaya, India using high-resolution remote sensing data, geospatial modeling, and ground observations over the last 5 decades (1965–2018). Environ Monit Assess 192(10):1–14
Ricart S, Rico-Amorós AM (2021) Constructed wetlands to face water scarcity and water pollution risks: learning from farmers' perception in Alicante. Spain Water 13(17):2431
Rojas C, Munizaga J, Rojas O, Martínez C, Pino J (2019) Urban development versus wetland loss in a coastal Latin American city: lessons for sustainable land use planning. Land Use Policy 80:47–56
Rojas O, Soto E, Rojas C, López JJ (2022) Assessment of the flood mitigation ecosystem service in a coastal wetland and potential impact of future urban development in Chile. Habitat Int 123:102554
Russi D, ten Brink P, Farmer A, Badura T, Coates D, Förster J et al (2013) The economics of ecosystems and biodiversity for water and wetlands. IEEP, London and Brussels 78:118

SAC (2011) National wetland atlas. Space application center (SAC). In: Indian Space Research Organisation (ISRO), Ahmedabad, India
Saha TK, Pal S (2019b) Exploring physical wetland vulnerability of Atreyee river basin in India and Bangladesh using logistic regression and fuzzy logic approaches. Ecol Indic 98:251–265
Saha TK, Pal S (2019a) Emerging conflict between agriculture extension and physical existence of wetland in post-dam period in Atreyee River basin of Indo-Bangladesh. Environ Dev Sustain 21(3):1485–1505
Saleem M, Hussain A, Mahmood G (2018) A systematic approach for design of rainwater harvesting system and groundwater aquifer modeling. Applied Water Science 8:1–10
Salimi S, Almuktar SA, Scholz M (2021) Impact of climate change on wetland ecosystems: a critical review of experimental wetlands. J Environ Manage 286:112160
Schäfer KVR, Duman T, Tomasicchio K, Tripathee R, Sturtevant C (2019) Carbon dioxide fluxes of temperate urban wetlands with different restoration history. Agric For Meteorol 275:223–232
Schieder NW, Walters DC, Kirwan ML (2018) Massive upland to wetland conversion compensated for historical marsh loss in Chesapeake Bay, USA. Estuaries Coast 41(4):940–951
Sekabira H, Nijman E, Späth L, Krütli P, Schut M, Vanlauwe B et al (2021) Circular bioeconomy in African farming systems: what is the status quo? Insights from, Rwanda, DRC, and Ethiopia
Shah AM, Liu G, Meng F, Yang Q, Xue J, Dumontet S et al (2021) A review of urban green and blue infrastructure from the perspective of food-energy-water nexus. Energies 14(15):4583
Sica YV, Quintana RD, Radeloff VC, Gavier-Pizarro GI (2016) Wetland loss due to land use change in the Lower Paraná River Delta, Argentina. Sci Total Environ 568:967–978
Siddiqui AF, Waseem A, Mamoon D (2017) Did we find alternate to GDP to measure national progress? Analysis of Harvard University's social progress index. Turkish Economic Review 4(4):352–368
Simon D, Goodness J, Lwasa S, Puppim de Oliveira JA, Macedo LV, Kavonic J et al (2021) Urban governance of and for urban green and blue infrastructure. In: Urban Ecology in the Global South. Springer, Cham, pp 403–431
Singh P, Kikon N, Verma P (2017) Impact of land use change and urbanization on urban heat island in Lucknow city, Central India. A remote sensing based estimate. Sustain Cities Soc 32:100–114
Singha P, Pal S (2023) Influence of hydrological state on trophic state in dam induced seasonally inundated flood plain wetland. Ecohydrology & Hydrobiology
Stefanakis AI (2022) Nature-based solutions for water pollution control: promoting environmental education through case studies. In: Enhancing Environmental Education Through Nature-Based Solutions. Springer, Cham, pp 397–411
Stiglitz, J. E., Sen, A., & Fitoussi, J. P. (2009). Report by the commission on the measurement of economic performance and social progress
Sun C, Zhen L, Miah MG (2017) Comparison of the ecosystem services provided by China's Poyang Lake wetland and Bangladesh's Tanguar Haor wetland. Ecosyst Serv 26:411–421
Sundman, M. L. (2011). The Effects of the Demographic Transition on Economic Growth: Implications for Japan
Tariku M, Abebayehu A (2011) The driving forces of Boye wetland degradation and its bird species composition, Jimma, Southwestern Ethiopia. Journal of Ecology and the Natural Environment 3(11):365–369
Thapa S, Wang L, Koirala A, Shrestha S, Bhattarai S, Aye WN (2020) Valuation of ecosystem services from an important wetland of Nepal: a study from Begnas watershed system. Wetlands 40(5):1071–1083
Tiner RW (1999) A guide to wetland identification, delineation, classification, and mapping. CRC Press, Estados Unidos
UNDP (2015) Transforming our world: the 2030 Agenda for Sustainable Development. https://sustainabledevelopment.un.org/post2015/transformingourworld. Accessed 21 June 2022
UNDP (2022) Human Development Report. The next frontier. Human Development and the Anthropocene. United Nations Development Programme, New York
Vaissière AC, Quétier F, Bierry A, Vannier C, Baptist F, Lavorel S (2021) Modeling alternative approaches to the biodiversity offsetting of urban expansion in the grenoble area (France): what is the role of spatial scales in 'no net loss' of wetland area and function? Sustainability 13(11):5951
Villa JA, Bernal B (2018) Carbon sequestration in wetlands, from science to practice: an overview of the biogeochemical process, measurement methods, and policy framework. Ecol Eng 114:115–128
Vishwanathan SS, Garg A, Tiwari V, Shukla PR (2018) India in 2 C and well below 2 C worlds: opportunities and challenges. Carbon Management 9(5):459–479
Wang J, Sui L, Yang X, Wang Z, Ge D, Kang J et al (2019) Economic globalization impacts on the ecological environment of inland developing countries: a case study of Laos from the perspective of the land use/cover change. Sustainability 11(14):3940
Wang N, Chen Z, Li T, Zhen M (2022) Spatiotemporal pattern evolution and influence mechanism of urban vertical expansion: a case study of Jiangsu Province. China Land 11(3):433
Wang S, Li G, Fang C (2018) Urbanization, economic growth, energy consumption, and CO2 emissions: empirical evidence from countries with different income levels. Renew Sustain Energy Rev 81:2144–2159
Wang X, Ning L, Yu J, Xiao R, Li T (2008) Changes of urban wetland landscape pattern and impacts of urbanization on wetland in Wuhan City. Chin Geogr Sci 18(1):47–53
Wang Y, Feng J, Lin Q, Lyu X, Wang X, Wang G (2013) Effects of crude oil contamination on soil physical and chemical properties in Momoge wetland of China. Chin Geogr Sci 23:708–715
Wasswa H, Kakembo V, Mugagga F (2019) A spatial and temporal assessment of wetland loss to development projects: the case of the Kampala–Mukono Corridor wetlands in Uganda. International journal of environmental studies 76(2):195–212
Were D, Kansiime F, Fetahi T, Cooper A, Jjuuko C (2019) Carbon sequestration by wetlands: a critical review of enhancement measures for climate change mitigation. Earth Systems and Environment 3(2):327–340
Wizor CH, Wali E (2020) Geo-spatial analysis of urban wetlands loss in obio/akpor local government area of rivers state, nigeria. Asian Journal of Geographical Research. 3 (1): 35-48, 2020; Article no. AJGR. 54603ISSN: 2582, 2985
World Bank (2018) Country wise arable land per hectares per person. World Bank https://data.worldbank.org/indicator/AG.LND.ARBL.HA.PC?end=2018&locations=IN&start=1961(Accessed August, 2022)
World Bank (2022) The World Bank Annual Report 2022. The World Bank
Wu C, Chen W, Cao C, Tian R, Liu D, Bao D (2018) Diagnosis of wetland ecosystem health in the Zoige Wetland. Sichuan of China Wetlands 38(3):469–484
Xu T, Weng B, Yan D, Wang K, Li X, Bi W et al (2019) Wetlands of international importance: status, threats, and future protection. Int J Environ Res Public Health 16(10):1818
Xu X, Chen M, Yang G, Jiang B, Zhang J (2020) Wetland ecosystem services research: a critical review. Global Ecology and Conservation 22:e01027

Xu X, Huang G, Sun C, Pereira LS, Ramos TB, Huang Q, Hao Y (2013) Assessing the effects of water table depth on water use, soil salinity and wheat yield: searching for a target depth for irrigated areas in the upper Yellow River basin. Agric Water Manag 125:46–60

Yan G, Liu J, Zhu L, Zhai J, Cong L, Ma W et al (2018) Effectiveness of wetland plants as biofilters for inhalable particles in an urban park. J Clean Prod 194:435–443

Yang W, Sun T, Yang Z (2016) Does the implementation of environmental flows improve wetland ecosystem services and biodiversity? A literature review Restoration Ecology 24(6):731–742

Yang Y, Shen Q (2020) Phytoremediation of cadmium-contaminated wetland soil with Typha latifolia L. and the underlying mechanisms involved in the heavy-metal uptake and removal. Environ Sci Pollut Res 27:4905–4916

Zhang L, Zhen Q, Cheng M, Ouyang Z (2019) The main drivers of wetland changes in the Beijing-Tianjin-Hebei region. Int J Environ Res Public Health 16(14):2619

Zhang W, Li W, Zhang C, Hanink DM, Liu Y, Zhai R (2018) Analyzing horizontal and vertical urban expansions in three East Asian megacities with the SS-coMCRF model. Landscape and urban planning 177:114–127

Zhao Y, Ji B, Liu R, Ren B, Wei T (2020) Constructed treatment wetland: glance of development and future perspectives. Water Cycle 1:104–112

Zhou H, Jiang H, Zhou G, Song X, Yu S, Chang J et al (2010) Monitoring the change of urban wetland using high spatial resolution remote sensing data. International Journal of Remote Sensing 31(7):1717–1731

Ziaul S, Pal S (2017) Estimating wetland insecurity index for Chatra wetland adjacent English Bazar Municipality of West Bengal. Spat Inf Res 25(6):813–823

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