Journal of Environmental Management 326 (2023) 116692

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

Socio-ecological well-being perspectives of wetland loss scenario: A review

Manabendra Let[a], Swades Pal[b,*]

[a] Junior Research Fellow, Department of Geography, University of Gour Banga, Malda, India
[b] Professor, Department of Geography, University of Gour Banga, Malda, India

ARTICLE INFO

Keywords:
Meta-analysis
Wetland loss
Drivers
Socio-ecological perspectives and relations in between

ABSTRACT

Previous original research focused on wetland loss and finding out its drivers across different regional units of the world. A few reports also tried to account world's condition on wetland loss. A couple of review articles articulated the causes of wetland loss and services. The present study intended to explore the linkage between wetland loss rate and processes concerning socio-ecological well-being parameters to highlight alternative ways to adopt wetland conservation policies. A total of 132 pieces of Scopus index literature were taken analysing loss rate and drivers of loss from 22 sample countries where publication frequency is relatively high. Meta-analysis was done to explain the publication trend and spatial change in publication polarity. Results distinctly revealed that the rate of wetland loss varies from 0.06% to 4.81% annually, with substantially low in developed countries (DC) than in developing (DeV) and least developed countries (LDC). Six drivers, such as agricultural land expansion, the built-up area, the conversion to grassland area, construction of the dam, climate change and tourism, were the primary drivers. But all these are not equally active across the DC, DeV and LDC. Climate change, tourism development in DC, agriculture and built-up expansions in the Dev and LDC appeared as the major causes behind wetland loss. Socio-ecological well-being parameters like human development, environmental performance, social progression, and economic status were found to be significantly negatively (−0.48 to −0.57), and the poverty rate was positively (0.27) associated with the rates of wetland loss. Drivers also varied with respect to the socio-ecological conditions. These findings are not merely added knowledge to the state-of-arts but are also helpful in re-directing global policies toward wetland conservation.

1. Introduction

Wetlands are the area on the land surface that are inundated either permanently or seasonally. As per the Ramsar Convention (1971), wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed 6 m" It provides a wide range of ecosystem benefits in the form of different functions, characteristics, or processes that directly or indirectly contribute to human well-being (Mitsch and Gosselink, 2000; Gandahi and Hanafi, 2014; Clarke et al., 2021). The crucial functions are wildlife habitat support, water supply, and carbon sequestration (Bernal and Mitsch, 2013; Were et al., 2019; Shiau and Chang, 2022). It also provides foods, medicine and different recreational facilities and simultaneously purifies and filtrates agricultural pollutants (Ricaurte et al., 2014; Sica et al., 2016; Haroon and Kibria, 2017). Given that wetlands, which encircle coastal wetlands, freshwater swamps and marshes, and peatlands encompass about 8% of the earth's terrestrial surface (Mitsch et al., 2018) and account for about 45% of the total economic value of all global ecosystems (Mitsch and Gosselink, 2015).

Despite these vital services, humankind has been draining, converting and in-filling both inland and coastal wetlands for centuries (Davidson, 2014). It has been widely reported that about 50% of the world's wetlands have been lost since 1900 (Davidson, 2014; Yu et al., 2017; Ragavan and Das, 2019). The global wetlands declined dramatically during the last several decades because of climate change and anthropogenic pressures (Dangles et al., 2017; Chen et al., 2018; Goldberg et al., 2020). It has been estimated that about 35% of global wetlands have been lost since 1970 (Darrah et al., 2019), having a loss rate over three times faster than that of forest (Ramsar Convention on Wetlands, 2018). The scenario is more or less similar everywhere; for example, global coastal wetlands are getting eroded at a rate of 1% per year (Alongi, 2012).

This loss of wetlands continues, the responsible drivers being agricultural (Reis et al., 2017) and industrial production (Ballut-Dajud et al.,

* Corresponding author.
E-mail addresses: manabendralet20@gmail.com (M. Let), swadespal2017@gmail.com (S. Pal).

https://doi.org/10.1016/j.jenvman.2022.116692
Received 24 August 2022; Received in revised form 26 October 2022; Accepted 1 November 2022
Available online 23 November 2022
0301-4797/

2022), increasing urbanisation (Sundar et al., 2015; Hartig and Bennion, 2017; Seifollahi-Aghmiuni et al., 2022) and infrastructure development, changes in water use and availability (Niu et al., 2012) climate change, disease control and aquaculture (Richards and Friess, 2016; Duan et al., 2021). Among all these factors, a good number of the literatures revealed that agricultural activities are the leading anthropogenic causes of wetland loss (Song et al., 2020; White et al., 2022). Now the question is that, is it uniform all across the world irrespective of their processes and rate of development? One of the objectives of this review is to find the answer to this question.

The rate and process of wetland loss in our world are diverse (Birch et al., 2022) and this is visible both on the areal and temporal scale concerned (Chamberlin, 2022). And this diversified rate and process are regionally driven by a set of natural and artificial factors. If it is tried to explain the global perspective, it can be done in light of socio-ecological well-being perspectives. To show this, a wide range of socio-ecological well-being measuring indices were devised like the Human Development Index (HDI), Environmental Performance Index (EPI), performance by Sustainable Development Goal Index (SDGI), Poverty rate and Social Progress Index (SPI). All these were devised considering different socio-ecological and well-being perspectives indicators. Each country has been passing through different economic, social, ecological and human development phases. Therefore, resource development is varied across.

Wetland loss and its causes change in different countries with varied social progression levels. Socially progressed countries are likely to be experienced better societal coordination, social capital as well as ecological balance (Mandishona and Knight, 2022). Similarly, human development status conventionally measured using the Human Development Index (HDI) is another major issue determining social and economic functions. Good HDI usually refers to a high literacy rate, per capita income, and life expectancy. All these factors are related to environmental management practice as reflected in their national and regional policies. It could be expected that the good educational status of the country will help design ecologically viable policies (Ahmed et al., 2020). Hence, wetland as a natural capital demands protection in this situation with other environmental resources. Good human health in a high HDI country is also a good indicator of ambient ecological conditions. So, it could be presumed that the country is environmentally rich too, and wetland, a vital environmental component, is protected. In this argument, a link between wetland loss and human development status could be found. Poverty is another essential issue regionally sometimes condemned as a cause of resource waste and loss. Poverty initially provokes people to collect their basic needs, particularly food, for survival at any coast without thinking much about the sustainability of resources. It may often harm the resources. So, the countries with greater hunger and poverty may be prone to enhanced loss of resources, including wetland (Gordon et al., 2010; Lamsal et al., 2015). The backward countries largely depend on primary activities like agriculture, fishing etc. are more sensitive to enhanced stress on wetlands since it is one of the significant sources of nutrients (Brander et al., 2013).

Similarly, environmental performances measure how well the environment and ecosystem are in a given time. It comprised two significant components (environmental health and ecosystem vitality) and 40 indicators (11 issue categories and three policy objectives) per EPI report 2022. ***Environmental Health*** measures environmental stresses to human health, and ***Ecosystem Vitality*** measures ecosystem health and natural resource management. Both these components are closely associated with each other. So, good EPI of a region stakes thinking that there is a high possibility of good environmental health and a low chance of imparting pressure on natural ecosystem resources. If only wetland loss is considered, a country's high EPI may positively impact sustaining the wetland resources.

The functions and services performed by wetlands stand at the core of the United Nations Sustainable Development Goals (SDGs) (Ramsar Convention on Wetlands, 2018). To acquire sustainable development that balances natural ecosystem protection, social condition and economic growth, the United Nations (UN) drafted the 2030 agenda and proposed 17 sustainable development goals incorporating 169 targets and 262 indicators. As the world is striving to achieve 17 distinctly set sustainable development goals (SDGs) like eradication of poverty (SDG 1), erasing hunger (SDG 2), clean water and sanitation (SDG 6), sustainable cities and communities (SDG 11), organise climate action (SDG 14). Wetland, as a natural capital, can help to achieve these goals. For instance, more than one billion people depend directly and indirectly on this resource for their livelihood (CBD, 2016). So, sustenance of this resource can ensure livelihood and equality and thereby help to erase hunger of the marginal people, poverty and health well-being of the people concerned. Debanshi and Pal (2022) also reported an immense role of wetlands on carbon balance and climatic mediation. So, conserving such resources can be a step forward for effective climate action. Due to anthropogenic intervention, wetland loss and quality degradation have become very threatening. Both these issues can adversely affect attaining SDGs. On the way, the SDG index is computed to reveal the posting of one country towards achieving the SDGs. For the countries where the situation is in a good state concerning the SDG index, it could be expected that those countries are not only economically sustainable but also ecologically. Ecologically sustainable countries by nature will try to preserve ecological resources like wetlands. So, in this context, the present study hypothesized that SDG index is negatively correlated with wetland loss and drivers of loss by their influence rates differ across different SDGs.

According to Hakimdavar et al. (2020) understanding wetlands' extent, trend, and probable causes in ecosystem sustainability are essential, particularly for SDGs 6.6 and 15.1, which highlight the need for conservation and restoration of wetlands. Most previous literature also recommended this (Zhang et al., 2021; Epele et al., 2021). Original research on wetlands across the world majorly focused on wetland inventory (Ling et al., 2018; DeLancey et al., 2022), monitoring (Darrah et al., 2019; Fekri et al., 2021; Ficken et al., 2022), hydrological transformation (Pal and Sarda, 2020; Khatun et al., 2021), habitat character modification (Cavallaro et al., 2019; Pal and Talukdar, 2019; Pal and Debanshi, 2022), ecological modification (Wu et al., 2018; Pal and Sarda, 2020), its service abilities (Barbier, 2019; Xu et al., 2020), natural change and human interventions and wetland loss (Zhang et al., 2019), wetland area, depth simulation, prediction (Debanshi and Pal, 2020; Saha et al., 2021), conservation and restoration issues (An and Verhoeven, 2019; Kumari et al., 2020). Review articles on wetlands mainly focused on drivers of wetland losses. Dallut-Bajudetal (2022) elucidated that all over the world, major anthropogenic activities affecting the wetlands were agriculture (25%), urbanisation (16.8%), aquaculture (10.7%) and industry (7.6%). On the other hand, they confirmed that mangroves (25.7%), lagoons (19.11%) and marine waters (11.7%) were the most vulnerable wetland type among other categories. Adeli et al. (2020) highlighted the current incident regarding threats and solutions for wetland monitoring using SAR sensors. Most of the works stressed that the wetland loss rate is highly variable in different parts of the world, and agricultural expansion and intensification is the primary reason behind this. Apart from this, expansion of the built-up area, damming induces water diversion, overgrazing, climate change, pollution issues, salinisation, groundwater level lowering etc., are other significant causes at different regional scales (Pal and Talukdar, 2018). However, all the drivers are not found equally active worldwide. Millennium Ecosystem Assessment (MEA) report (MEA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB) report (TEEB, 2012) also reported the same at a broader geographical scale.

But these studies hardly focused on how different socio-ecological well-being perspectives are associated with wetland loss. Are these caused for insisting on a particular driver or a set of drivers of wetland loss? Considering this, the present study intended to explore (1) the relationship between different socio-ecological well-being perspectives and wetland loss and (2) how socio-ecological aspects are related to drivers of wetland loss. All of these were aimed to explore considering the literature between 1990 and 2022.

2. Materials

For meta-analysis of the bibliometric information total, 132 publications under the Scopus index and published in English were analysed. The period of the study was considered from 1990 to 2022. To search the articles, Dimensions and Google scholar databases were used. Numerous articles on wetlands were found in the database, but 132 sample articles from well spread 22 countries worldwide directly reported the rate of wetland loss and major drivers were taken into consideration.

Since the study intended to explore the linkage between socio-ecological well-being and wetland loss, in a world scenario, five such indices, namely (1) Human Development Index (HDI), (2) Environmental Performance Index (EPI), (3) Sustainable Development Goal Index (SDGI), (4) Social Progress Index (SPI), and (5) Poverty rate were selected, and the index value of the concerned countries was taken from different sources (Table 1).

Table 1
Sources of different socio-ecological parameters.

Socio-ecological parameters	Indices	Number of indicators taken	Methods for computation	References/ source
Human development	HDI	Three dimensions, viz. Standard of living, health and education	Equally weighted geometric mean	Human development report published by
Environmental Performance	EPI	Forty indicators into 11 issue categories and three policy objectives are considered.	The index is constructed as a composite index based on sixteen highly aggregated indicators weighted differently	EPI report published by World Economic Forum with the collaboration of Yale University and Columbia University (2022)
Sustainable Development Goals	SDGI	242 detailed indicators	Countries are ranked by considering their overall score on different concerned issues	Sustainable Development Report published by United Nations Developmental Programme (UNDP (2022))
Poverty level	Poverty rate	A state of being in which a person lacks the income to meet basic needs, such as food, shelter and clothing	Poverty is measured by comparing a person's or family's income to a set poverty threshold to meet basic needs	The global poverty rate data published by World Bank (2022)
Social Progress	SPI	Fifty-three indicators in the areas of basic human needs, foundations of well-being, and opportunity to progress show the relative performance of the nation	SPI is calculated using the arithmetic average of the three dimensions, viz. basic human needs, foundations of wellbeing and opportunity	Social Progress Index report published by Social Progress Imperative (2021)

3. Method

3.1. Method regarding metadata analysis

To show the time series change in publication frequency across different parts of the world, both year-specific publication frequency and phase-wise Spatio-temporal views were highlighted to explore the changing publication polarity over time. The total period was subdivided into two phases (1) phase I (1990–2012) and (2) phase II (2013–2022). The equal period in both phases was not considered because of time series skewness in publication.

To show international collaboration in research, a network view map was prepared, showing the nature of the research network and collaboration in phases I and II. It was also made in particular reference to India.

3.2. Computation of wetland loss rate and selection of drivers

All the published articles on wetland loss didn't always quantify the rate of wetland loss vividly. Moreover, those were quantified, and the time scale was not uniform. So, to make this uniform, annual wetland loss was computed from the published articles dividing the lost area by the number of years. A box plot was created to show the dispersion of wetland loss rate, including median, 1st and 3rd quartile, whisker and outlier (if any) in each country taken.

While figuring out the drivers of wetland loss from the published literature, only the most dominant cause they mentioned was considered. Frequency distribution and histogram approach were pursued to present the major drivers of wetland loss in reference to different socio-ecological conditions.

3.3. Methods adopted for computing socio-ecological parameters

Although the present study didn't compute the socio-ecological well-being indices like HDI, EPI, SDGI, PR, SPI etc. All these were taken from different reliable international sources, as mentioned in Table 1. However, the primary methods were briefly mentioned in order to understand how these were computed.

The Human Development Index (HDI) was calculated using the geometric mean of normalised indices for each of the three dimensions, viz. Standard of living, health and education for each country. Based on obtained results, world rankings were done. The Ecological Performance Index (EPI) was constructed as a composite index based on sixteen highly aggregated indicators weighted differently and assessed against absolute targets. The Social Progress Index (SPI) was calculated using the arithmetic average of the three dimensions (basic human needs, foundation of wellbeing and opportunity). Based on the obtained score, world rankings were done. Country-wise poverty is typically measured by determining the percentage of people whose daily income falls below specific baseline amounts, such as $10 per day. These baselines remain the same for every country.

3.4. Relation between socio-ecological parameters and rate of wetland loss

In order to explore the linkage (if there is any) between different socio-ecological indices and the rate of wetland loss, correlation matrix (Pearson's correlation coefficient) and kernel distribution estimation (KDE) plots were computed and presented. Correlation matrix values were statistically tested to determine whether the correlation was statistically significant (at least at 0.05 confidence level). KDE plot depicts the probability density function of the non-parametric and continuous data variable (single or multiple). KDE plot and scattered plot also show the relation between target variables. Here, along with the distribution pattern, the scattered plot between socio-ecological indices values and the rate of wetland loss was demonstrated.

Simultaneously, to explore the process of wetland transformation focusing on drivers, the study aimed to articulate different selected socio-ecological indices. The frequency approach was adopted to count publication frequency with varying wetland loss rates in reference to the degree of the socio-ecological status as expressed in the computed indices. Apart from the major drivers, another category named Other was defined including different other causes than the major considered drivers. For instance, on account of HDI when the drivers were analysed, the sample publication belonging to the country was categorised into four clusters (1) very high HDI (>0.8), (2) high HDI (0.7–0.799), (3) medium HDI (0.55–0.699) and (4) low HDI (<0.55). This classification of countries based on HDI was made based on the UNDP classification (2022). The frequency analysis of the drivers concerned under each HDI class was presented in a histogram to analyse the primary driver of wetland loss. Considering the economic status and HDI of the country, United Nations has made three clusters of all the nations, i.e., developed, developing and least developed countries. The drivers were presented similarly in reference to these economic country clusters to analyse the drivers of wetland loss. In the same way, drivers were interpreted regarding other socio-ecological indices like SDG index, social progress index, poverty rate and environmental performance index.

4. Result

4.1. Bibliometric status on wetland transformation

4.1.1. Spatial frequency of literature

A total of 4100 sample publications randomly taken from the Dimension database in phase 1 (1990–2012) and phase 2 (2013–2022) were presented on the world map to represent the spatial distribution of publication frequency and time series changes of publication polarity. Fig. 1 (a and b) shows that in phase 1, highly developed countries like the USA, UK, Australia, Canada, and Scandinavian countries recorded high publication frequency. But over time, along with these countries, some new hot spots were identified, like China and India; neighbouring Scandinavian countries and some Latin American countries like Brazil, Mexico and Chile. Many Asian and African countries that recorded no publication in phase 1 appeared in publication scenario of phase 2.

The yearly publication frequency record revealed a sharp rise in publication frequency on wetland transformation (Fig. 1c). Average publication in two defined phases also exhibited that in phase 2, the frequency was incomparably higher than in phase 1. This fact indicates remarkable research progress over time.

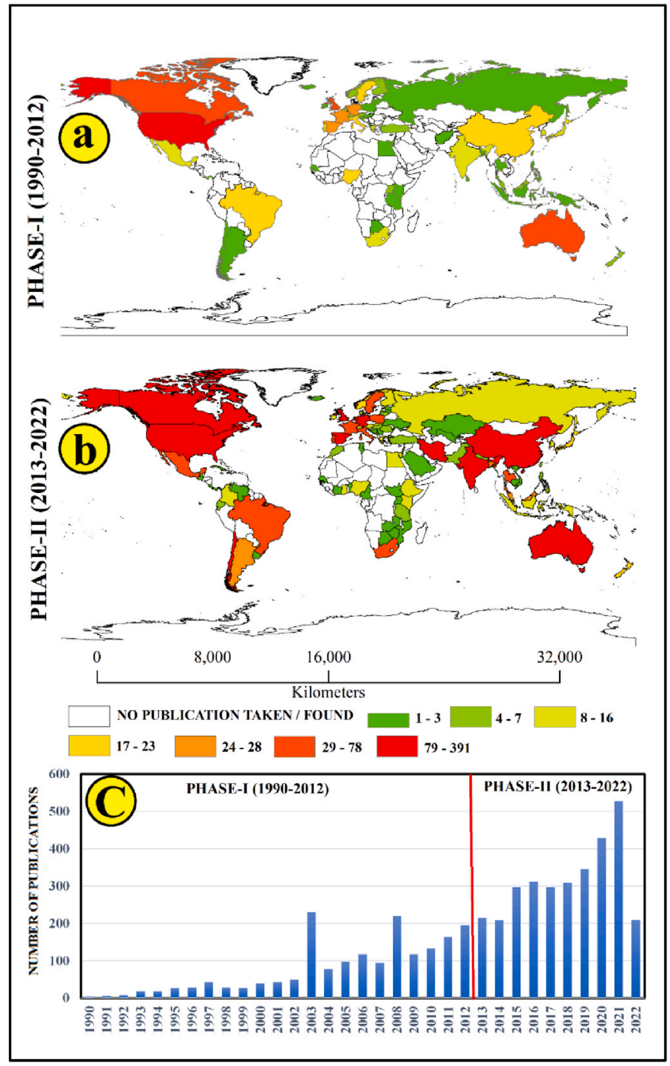


Fig. 1. Publication frequency among randomly taken literature on wetland transformation from 1990 to June 2022 (a) country-wise publication frequency in 1990–2012 and (b) 2013–2022 (c) yearly publication frequency.

4.1.2. International collaboration and research network

The history of international research collaboration is ancient, but its intensity and network sprawl considerably increased over time. For instance, in phase I, international collaboration was very prominent in countries like the USA, the UK, Australia, and Canada. Still, more countries like Germany, China, India, Brazil, South Africa, Netherlands, Italy, Portugal, France, etc., were come ahead and built a widespread research network in phase II. Only in reference to India, it was found that in the early phase, international collaboration was mainly with a few countries like the USA, UK, Canada, Germany, China, Australia, Sweden, and Japan. Still, in the later phase, such a network was widened. Currently, India works with many countries, as shown in Fig. 2 (b and d).

4.1.3. Wetland loss

The rate of wetland loss around the world exhibited a unique picture. There was a wide disparity in rates across all the countries. The continent-wise results showed some typical characteristics concerning the same. In the African continent, we considered the publications from countries like Tanzania, Uganda, Ethiopia and Nigeria. All these African countries witnessed a higher rate of wetland loss (0.46%–4.89% annually) compared to other continents (Xu et al., 2018). In the African continent, Ethiopia experienced a very high rate of wetland loss. In the continent of Asia, the sample countries of wetland loss were India, Bangladesh and China. Among these countries, the rate was higher in Bangladesh (Rahman et al., 2022). The United States and Canada accounted for the relatively low rate of wetland loss, the rate being below 1% per year (Serran et al., 2018). The continent of South America displayed moderate to high wetland loss rates, as found in Brazil and Argentina (Kandus et al., 2018). The rate of wetland loss also varied in response to changing nature of wetlands. Wetlands in continental and coastal zones recorded different rates (Novoa et al., 2020). Some countries like the US, Canada, Australia, the United Kingdom etc., possess a higher rate of coastal wetland loss than continental wetlands (Hopkinson et al., 2019; Sapkota et al., 2021). On the contrary, countries like India, Nigeria, Tanzania, and Bangladesh revealed wetland loss more in continental zones than in coastal zones (Wang et al., 2012; Xi et al., 2021). Some countries like Brazil, Argentina, etc., displayed more or less similar loss rates in continental and coastal wetlands (Hopkinson et al., 2019).

The Box plot in Fig. 4 presented a clear view of the median value concerning the rate of wetland loss and the degree of dispersion in different selected countries under the category of developed, developing and least developed countries. It is evident from the presentation that the median value of the wetland loss rate in all the counties is not uniform. Even this rate is not uniform in countries with a specific economic

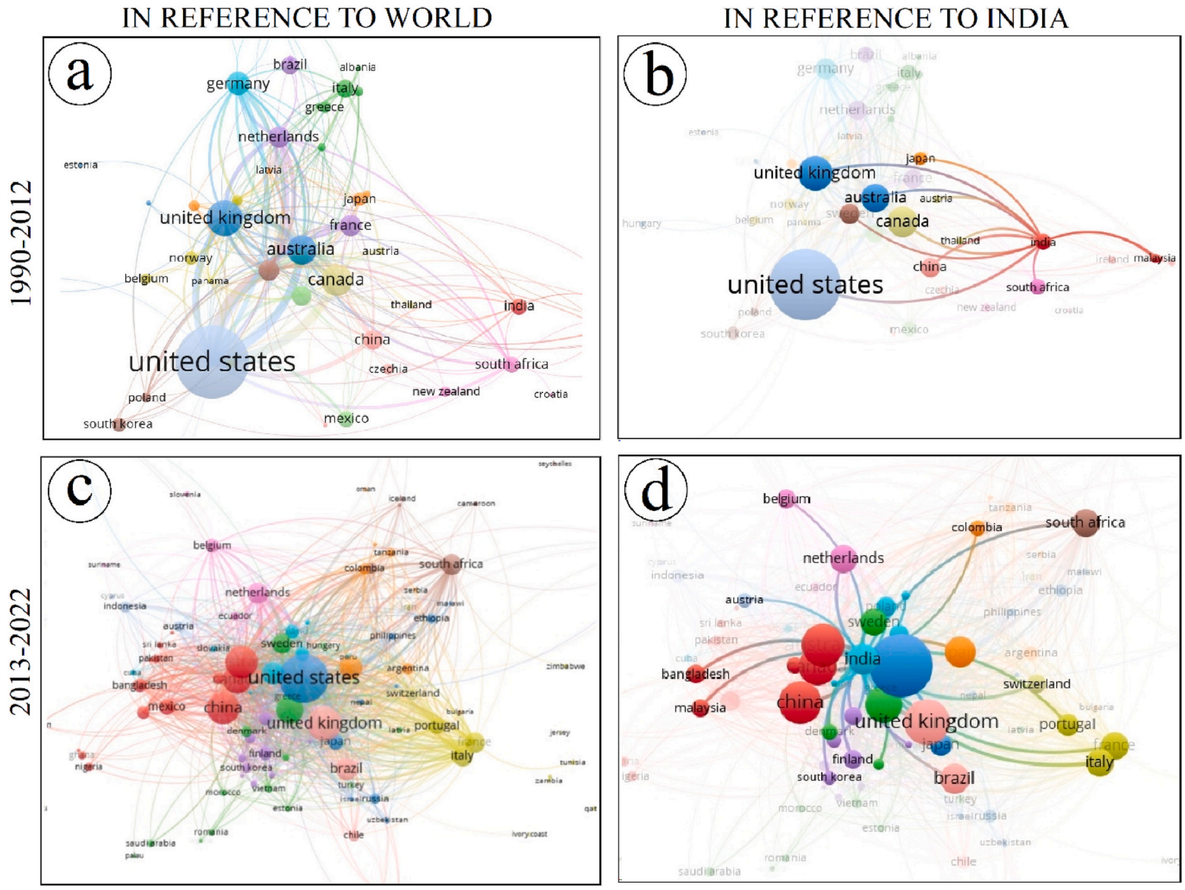


Fig. 2. Network view map showing international collaboration and research network concerning the world and India. The nodes' size indicates countries' publication frequency, and the lines connecting the nodes indicate collaboration among the countries.

domain (White et al., 2022). However, the degree of dispersion was found to be comparatively low in developed countries than in others (Nicholls, 2004). A high rate of wetland loss and very high dispersion were accounted for in the case of least developed countries (McGranahan et al., 2007; Ghosh and Das, 2019). A positively skewed loss rate was found in the countries like the United States, Australia, Argentina, Brazil, Vietnam etc. On the other side, a negatively skewed loss rate was found in the countries like Switzerland, England, Nigeria, Bangladesh etc. From the diagram, it is further observed that two countries, namely Vietnam and Nigeria, possessed outliers indicating abnormally high and low loss rates, respectively.

Wetland loss occurs worldwide, but the rate varies in different parts of the world (Finlayson, 2013). Obtained results from this work clearly show that the average annual rate of wetland loss is generally higher in the least developed countries in comparison to developing and developed countries (Pauchard et al., 2006). This is because of rapid population growth and the resultant pressure on resources like wetlands (Kirwan and Megonigal, 2013; Ghosh et al., 2018) and other natural resources (Wassie, 2020; Khan et al., 2021). In the countries, such as Ethiopia, Uganda, Bangladesh, and Tanzania higher rate of wetland loss was the result of the expansion of agricultural land and built-up area triggered by heavy population growth (Nicholls, 2004; Van Rees and Reed, 2014). In developing countries rate of wetland loss is not as high as in the least developed countries. However, in Brazil and India average rate of wetland loss exceeds 2% annually. It shows these two countries pose severe threats to wetlands. On the other side, a low loss rate was registered in developed countries like Canada, France, Greece etc., which may be primarily because of relatively lesser population size and high man-land ratio. Further, people in developed countries are more sensible, making them aware of the need and importance of wetlands (Everard et al., 1995; Ye and Sun, 2021). In the United States and Spain, the rate of wetland area loss stands above the rest of the developed countries. Economic strength and sensibility toward natural resources enabled them to build often proper planning for wetland conservation and restoration (Chen et al., 2019). Here it could be further mentioned that even though US and Spain come under the category of developed countries, wetland area still witnessed relatively faster rate of loss in these countries. These rates are displaying so due to the conversion of the coastal regions (Lin and Yu, 2018; Sapkota and White et al., 2022).

Dispersion of wetland loss rate was found maximum in the least developed countries because of varying anthropogenic pressure across different parts of a nation. Such countries are also trying to protect their wetland, but due to not having enough economic strength, expertise, and sensitivity, it has not been widely applied and found satisfactory results (Huq et al., 2011; Sterzel et al., 2020). In some parts where the planning is successful, the rate was found to be less in comparison to other areas without any conservation plan or plan failed (Xi et al., 2021). Contrarily, in developed countries, the scenario is quite opposite. Relatively less dispersion was found due to low human interventions and widely applied planning for wetland conservation (Chen et al., 2019).

4.1.4. *Drivers of wetland loss*

Supplementary Table 2 depicts a glimpse of the drivers of wetland loss worldwide. So many other pieces of literature were also taken for inference. From the literature, more than fifteen causes like agriculture, urbanisation, industrialisation, aquaculture, grassland expansion, dam construction, climate change, tourism, water quality change, groundwater declination, pollution, forest fires, illegal hunting and poaching, mining activity etc., were identified. Lead pollution is becoming a crucial cause of water quality deterioration in the water body as well as soil, and it is again responsible for aquatic ecosystem pollution (Bilen and Turan, 2022; Rasool et al., 2022; Tauqeer et al., 2022). Khalil et al. (2022) also reported that daily household used chemicals in different forms also impart pollution to the different components of the environment. Moreover, microcontaminants like pesticides, biocides, pharmaceuticals, personal care products etc., play a role towards contaminating neighbouring environmental components (Abbas et al., 2022). Among different causes reported by the predecessors, six are very dominant. The dominant causes by the order are (1) expansion of agricultural land, (2) expansion of built-up area, (3) conversion to grassland area, (4) construction of dam, (5) climate change, and (6) tourism development.

If spatiality is analysed, agriculture expansion and built area expansion were identified in developing countries like India, China, Brazil etc. (Fig. 5a). Tourism and conversion to grassland were identified as significant drivers of wetland loss in the case of developed countries. Here it is to be mentioned that this boundary is not always very distinct in the case of all countries of the individual economic domain. The exception was also reported. For instance, irrespective of being a developed country, Canada's primary driver of wetland loss is the expansion of agricultural land (Fig. 3b). Similarly, even though Chile is a developing country, its rate of wetland loss is very low.

Every country passes through the economic and socio-ecological development phases to be developed (Eisenmenger et al., 2020). So, if time series driver analysis could be done, the above statement would be more explicit. For instance, publications in early 1990 show a relatively higher rate of wetland loss in both developed and developing countries than time around 2020 (Davidson, 2014).

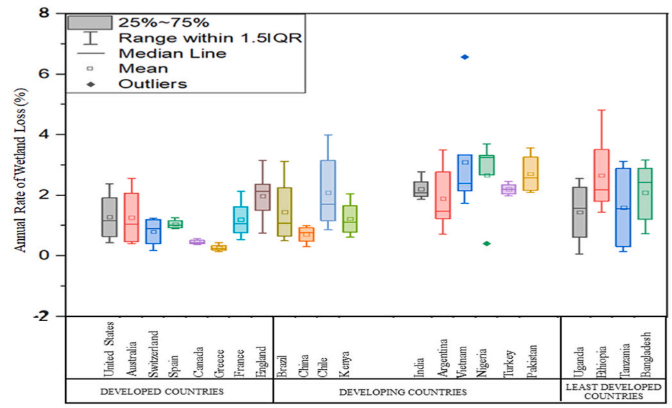


Fig. 4. Dispersion of wetland loss accounted with reference to countries of different economic status based on the literature survey.

4.1.5. Dominance of drivers with reference to socio-ecological perspectives

In this section, the study tried to explain the nature of drivers of wetland loss concerning the socio-ecological well-being indices like the Human Development Index (HDI), Income level, Environmental Performance Index (EPI), Social Progress Index (SPI), poverty rate and Sustainable Development Goals Index (SDGI).

Fig. 5a endeavoured to show the main drivers of wetland loss considering developed, developing and least developed countries. In developing countries, a maximum number of publications (55%) revealed that expansion of agricultural land was the main driver of wetland loss, followed by built-up land sprawling (Rebelo et al., 2009;

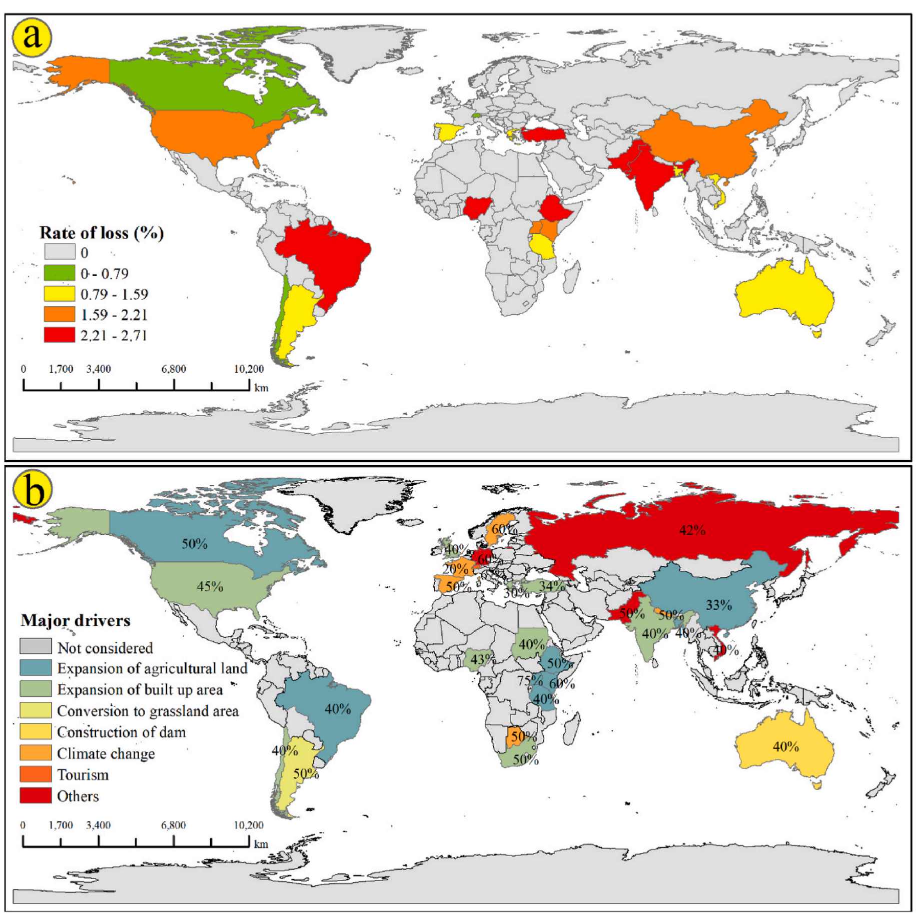
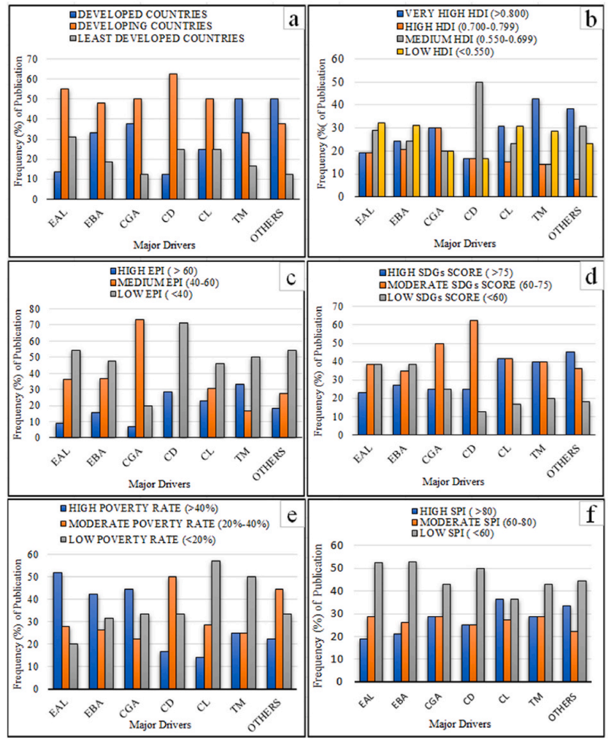


Fig. 3. Showing annual rate of wetland loss (a) and significant drivers (b). The values shown indicate the percentage of publications claiming the driver as the country's main driver (b).



Note: EAL (Expansion of agricultural land), EBA (Expansion of built-up area), CGA (Conversion to grassland area), CD (Construction of dam), CL (Climate change), TM (Tourism development)

Fig. 5. Percentage publication frequency histogram showing the causes responsible for wetland transformation regarding different perspectives (a) economic status of the countries to which publication belongs (b) human development index (HDI) perspective (c) environmental performance index (EPI), (d) sustainable development goals (SDGs) score, (e) poverty rate and (f) social progress index (SPI).

Kingsford and Basset, 2016). These two causes are also active in the least developed and developed countries, but their intensities are relatively lower.

Frequency distribution of the publication revealing major drivers was done in response to four different HDI categories entitled very high HDI, high HDI, Medium HDI and low HDI. Result (Fig. 5b) shows that in the countries with very high HDI values, maximum publications reported that tourism development and climate change were the major drivers of wetland loss. Similarly, conversion of wetlands to grassland areas and expansion of built-up areas were found to be the main reasons for countries with high HDI values. In the case of medium HDI countries, most publications documented that damming and associated hydrological control were the main drivers behind the loss of wetlands. Agricultural and built-up area expansions were found as the primary drivers of wetland loss in the low HDI countries.

Environmental Performance Index (EPI) specific drivers' status was presented in Fig. 5c. From this, it is clear that tourism and dam construction were mainly responsible for wetlands loss in countries with high EPI. Conversion of wetland into grassland and the built-up area was found in the countries with medium EPI. Construction of dams and agricultural land expansion was found majorly responsible for wetland loss in the countries with low EPI.

Regarding SDGI, top rankers' countries (>75) reported that climate change and tourism were the main drivers of wetland loss. So, these are the immediate challenges against them to reach higher SDG or sustain it. On another side, agricultural and built-up area expansions toward wetland areas were found as the principal challenges against the countries (mainly developing and least developed countries) far away from achieving the SDG (Fig. 5d). In the second case, the challenge is associated with the fundamental need of people (Silvius et al., 2000; Gómez-Baggethun et al., 2019). In reference to the current policy context and trend of the developing country like India, it is very clear that for improving the accessibility to the facilities amenities, development of smart cities, and sustainable growth of cities etc. are very common policy features. It promotes rural-urban migration (Koley, 2020). Mianabadi et al. (2022) reported that among different push and pull parameters, changes in natural environments like droughts, water scarcity in respect to global climate change is also another crucial cause for such high rate of migration and urbanization. Considering different other aspects, United Nation Organization (2018) projected that by 2050, 68% people of the globe will live in the urban area. If such rate increases, built up expansion, climate change may also be emerged as a dominant cause of wetland loss in the developing countries. It may withstand such countries against attaining some specific goals of SDGs.

When the drivers were analysed on account of the country's poverty level, the countries with low poverty levels revealed that climate change was the primary reason for wetland loss. In the case of countries with high poverty rates, expansion of agricultural land was found as the main driver (Fig. 5e). The countries where agriculture is dominated, it is often claimed that wetland reclamation by agrarian land is very serious (Mao et al., 2021; Fang et al., 2019). More than 50% of publication has supported this. Nevertheless, the construction of dams and others were the primary drivers in connection with moderate poverty rate induce countries.

Based on Social Progress Index (SPI), countries were grouped into three classes, i.e., high score (SPI value > 80), moderate score (SPI value 60–80), and low score (SPI value < 60). The figure (Fig. 5f) shows that countries with high SPI scores condemned climate change and other causes as the major drivers of wetland transformation. On the other hand, in countries with weak social progression rates, agricultural land expansion and built-up area expansions were accounted as the drivers of wetland loss. 52% of publications expressed this view.

4.1.6. Socio-ecological influence on the rate of wetland loss

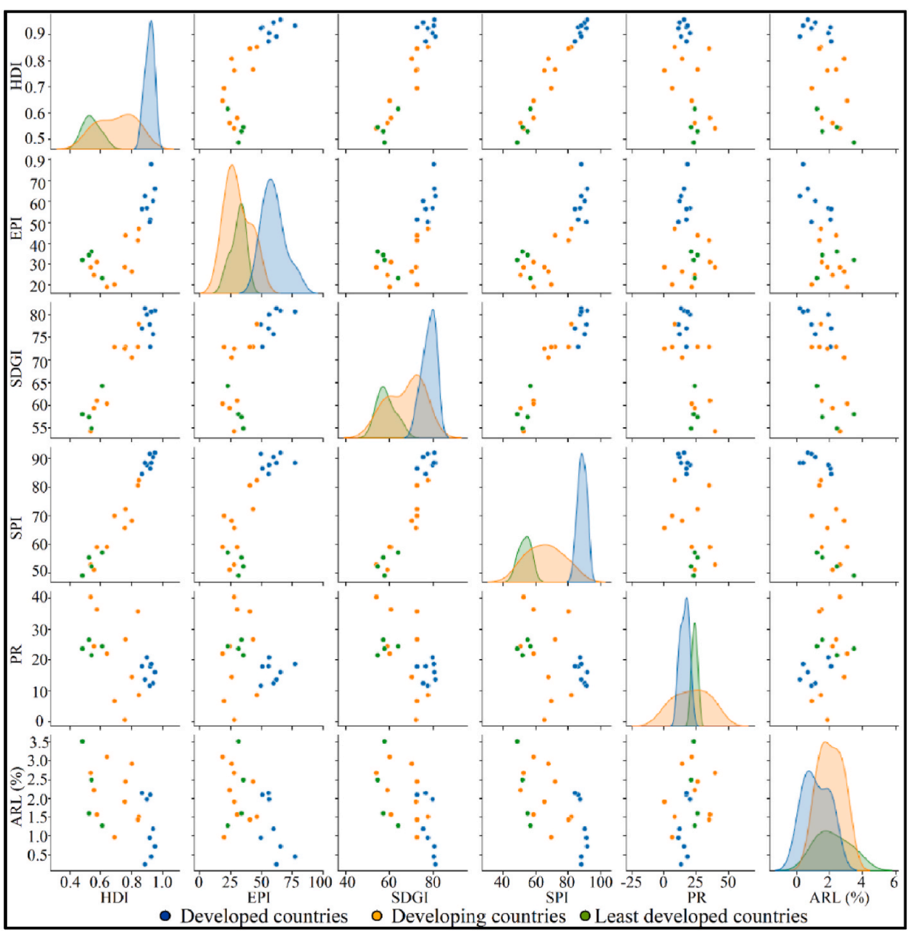
Fig. 6 (KDE plot) correlates socio-ecological well-being parameters with the rate of wetland loss separately in developed, developing and least developed countries. Table 2 also depicts the correlation matrix to obtain the degree of relation with its statistical significance. From Fig. 6 it is clear that HDI is negatively associated with the rate of wetland loss ($r = -0.48$), and the relationship is statistically significant at 0.05 level. Secondly, the environmental performance index (EPI) is also negatively associated with the rate of wetland loss (−0.49) at 0.05 level of significance. It means the countries where environmental health and ecosystem vitality are in a good state; the loss rate is low. The association between Sustainable Development Goals (SDGI) index and wetland loss rate also shows a negative correlation (−0.59) at 0.01 significant level. It indicates the countries nearer to achieving the SDGs are less prone to wetland loss than those far away from reaching the SDGs. A negative correlation (−0.57) does exist between the Social Progress Index value and the rate of wetland loss, with a significance level of 0.01. With increasing social progression, the conversion rate was found dwindled. However, there is a positive correlation (0.27) between the poverty rate and the rate of wetland loss. It reveals that the rate of loss increases with the increasing poverty rate.

Table 2
correlation matrix of socio-ecological wellbeing parameter with the rate of wetland loss.

	HDI	EPI	SDGI	SPI	Poverty rate	Annual rate of loss (%)
HDI	1					
EPI	0.76**	1				
SDGI	0.93**	0.71**	1			
SPI	0.97**	0.81**	0.93**	1		
Poverty Rate	−0.47*	−0.18	−0.56**	−0.42*	1	
Annual rate of wetland loss (%)	−0.48*	−0.49*	−0.59**	−0.57**	0.27	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

KDE plot shows the scattered plot of this relation concerning different economic domains. In all the cases, the relation trend is almost uniform, as the correlation matrix revealed, but its degree is not consistent among developed, developing and least developing countries. The nature of the scattered plot and density plot show this (Fig. 6).



Note: Used abbreviations and their full forms - HDI (Human Development Index), EPI (Environmental Performance Index), SDGI (Sustainable Development Goals Index), SPI (Social Progress Index), PR (Poverty Rate), ARL (Annual rate of loss).

Fig. 6. Kernel density plot shows the influence of different socio-ecological perspectives on the rate of wetland loss.

Relatively stronger relationship is found in the case of developed countries followed by developing and least developed countries. Kernel density plot also shows the broader spectrum of the rate of wetland loss in the case of least developed countries than in developing and developed countries. The distribution pattern is quite similar between developing and developed countries but is highly different in the least developed countries (Fig. 6).

5. Conclusion

This work distinctly revealed that the rate of wetland loss widely varies across countries, with a generalised distinction between developed, developing and least developed countries. A very low rate of wetland loss was found in developed countries, followed by developing and least developed countries. Six major drivers were found: expansion of agricultural land, expansion of the built-up area, conversion to grassland area, construction of the dam, climate change and tourism development. Tourism development, climate change in the developed countries, agricultural land and built-up area expansion in the least developed and developing countries were the main drivers. Socio-ecological well-being parameters are significantly associated with wetland loss to a varying degree. Except for the poverty rate, all other five indices are negatively associated with the wetland loss rate. Moreover, these parameters also drive the process of wetland conversion. Meta-analysis revealed that the frequency of publication increases over time, and new poles of publication appeared in developing countries, apart from the existing poles of developed countries. Even in this scenario, the study selected a smaller number of sample publications for this study. Including a more significant number of relevant studies could provide more improved results.

The findings of this study since showing the linkage between socio-ecological well-being parameters and wetland loss rate and drivers of loss; this study presented a summary of the wetland loss scenario of the world with varying socio-ecological perspectives. It will add knowledge to the state-of-arts. Apart from the case-specific planning of wetland conservation, this study also highlighted that socio-ecological wellbeing parameters are crucial for deterring the fate of the wetland in a broad sense. Loss of wetland areas as a beneficial blue space, particularly in the urban areas, may degrade the livability state of the urban areas where people are agglomerating now a day for better accessibility to facilities and job opportunities. Such a situation may diminish the environmental performances which are against sustainable human well-being. When the entire world is trying to achieve SDGs by 2030, the present scenario of rapid, unecological urban growth, urban in-migration and consequent loss of natural capital is not expected. So, this issue also entails a further scope of research in this connection. The present study result could effectively be used for wetland restoration, and conservation since drivers were denoted for different countries. Moreover, the obtained effective result on the linkages between socio-ecological well-being and wetland loss, this study could be treated as a good policy tool for wetland sustainability as well as the sustainability of the human being.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgement

For this study, we would like to extend our gratitude to Rajesh Sarda, Satyajit Paul, Ripan Ghosh, and Susmita Ghosh for helping us with different purposes.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2022.116692.

References

Abbas, M.A., Iqbal, M., Tauqeer, H.M., Turan, V., Farhad, M., 2022. Microcontaminants in wastewater. In: Environmental Micropollutants. Elsevier, pp. 315–329.

Adeli, S., Salehi, B., Mahdianpari, M., Quackenbush, L.J., Brisco, B., Tamiminia, H., Shaw, S., 2020. Wetland monitoring using SAR data: a meta-analysis and comprehensive review. Rem. Sens. 12 (14), 2190.

Ahmed, Z., Asghar, M.M., Malik, M.N., Nawaz, K., 2020. Moving towards a sustainable environment: the dynamic linkage between natural resources, human capital, urbanization, economic growth, and ecological footprint in China. Resour. Pol. 67, 101677.

Alongi, D.M., 2012. Carbon sequestration in mangrove forests. Carbon Manag. 3 (3), 313–322.

An, S., Verhoeven, J.T., 2019. Wetland functions and ecosystem services: implications for wetland restoration and wise use. In: Wetlands: Ecosystem Services, Restoration and Wise Use. Springer, Cham, pp. 1–10.

TEEB, 2012. The Economics of Ecosystems and Biodiversity for Water and Wetlands. Institute for European Environmental Policy (IEEP) & Ramsar Secretariat, London and Brussels, p. 78.

Ballut-Dajud, G.A., Sandoval Herazo, L.C., Fernández-Lambert, G., Marín-Muñiz, J.L., López Méndez, M.C., Betanzo-Torres, E.A., 2022. Factors affecting wetland loss: a review. Land 11 (3), 434.

Barbier, E.B., 2019. The value of coastal wetland ecosystem services. In: Coastal Wetlands. Elsevier, pp. 947–964.

Bernal, B., Mitsch, W.J., 2013. Carbon sequestration in freshwater wetlands in Costa Rica and Botswana. Biogeochemistry 115 (1), 77–93.

Bilen, S., Turan, V., 2022. In*Practical Handbook On Agricultural Microbiology*. In: Enzymatic Analyses in Soils. Humana, New York, NY, pp. 377–385.

Birch, W.S., Drescher, M., Pittman, J., Rooney, R.C., 2022. Trends and predictors of wetland conversion in urbanizing environments. J. Environ. Manag. 310, 114723.

Brander, L., Brouwer, R., Wagtendonk, A., 2013. Economic valuation of regulating services provided by wetlands in agricultural landscapes: a meta-analysis. Ecol. Eng. 56, 89–96.

Cavallaro, M.C., Main, A.R., Liber, K., Phillips, I.D., Headley, J.V., Peru, K.M., Morrissey, C.A., 2019. Neonicotinoids and other agricultural stressors collectively modify aquatic insect communities. Chemosphere 226, 945–955.

CBD, 2016. Convention on Biological Diversity. http://www.cbd.intislandwhymatters/. (Accessed 14 November 2022).

Chamberlin, J., 2022. Chinook Salmon Use of Tidal Delta Habitats: Synthesis for Snohomish Recovery Plan Revision.

Chen, D., Gu, X., Zhu, W., He, S., Huang, J., Zhou, W., 2019. Electrons transfer determined greenhouse gas emissions in enhanced nitrogen-removal constructed wetlands with different carbon sources and carbon-to-nitrogen ratios. Bioresour. Technol. 285, 121313.

Chen, L., Ren, C., Zhang, B., Li, L., Wang, Z., Song, K., 2018. Spatiotemporal dynamics of coastal wetlands and reclamation in the Yangtze Estuary during past 50 years (1960s–2015). Chin. Geogr. Sci. 28 (3), 386–399.

Clarke, B., Thet, A.K., Sandhu, H., Dittmann, S., 2021. Integrating Cultural Ecosystem Services valuation into coastal wetlands restoration: a case study from South Australia. Environ. Sci. Pol. 116, 220–229.

Convention, Ramsar, 1971. The Ramsar Convention. In: Rue Mauverney, vol. 28. Ramsar Center, Gland, Switzerland. CH 1196.

Dangles, O., Rabatel, A., Kraemer, M., Zeballos, G., Soruco, A., Jacobsen, D., Anthelme, F., 2017. Ecosystem sentinels for climate change? Evidence of wetland cover changes over the last 30 years in the tropical Andes. PLoS One 12 (5), e0175814.

Darrah, S.E., Shennan-Farpón, Y., Loh, J., Davidson, N.C., Finlayson, C.M., Gardner, R.C., Walpole, M.J., 2019. Improvements to the Wetland Extent Trends (WET) index as a tool for monitoring natural and human-made wetlands. Ecol. Indicat. 99, 294–298.

Davidson, N.C., 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. Mar. Freshw. Res. 65 (10), 934–941.

Debanshi, S., Pal, S., 2020. Wetland delineation simulation and prediction in deltaic landscape. Ecol. Indicat. 108, 105757.

Debanshi, S., Pal, S., 2022. Assessing the role of deltaic flood plain wetlands on regulating methane and carbon balance. Sci. Total Environ. 808, 152133.

DeLancey, E.R., Czekajlo, A., Boychuk, L., Gregory, F., Amani, M., Brisco, B., Hird, J.N., 2022. Creating a detailed wetland inventory with sentinel-2 time-series data and Google earth engine in the prairie pothole region of Canada. Rem. Sens. 14 (14), 3401.

Duan, H., Yu, X., Xia, S., Zhang, G., 2021. Waterbird habitat loss: fringes of the yellow and bohai seas along the east asian–australasian flyway. Land Degrad. Dev. 32 (15), 4174–4182.

Eisenmenger, N., Pichler, M., Krenmayr, N., Noll, D., Plank, B., Schalmann, E., et al., 2020. The Sustainable Development Goals prioritize economic growth over sustainable resource use: a critical reflection on the SDGs from a socio-ecological perspective. Sustain. Sci. 15 (4), 1101–1110.

Epele, L.B., Grech, M.G., Manzo, L.M., Macchi, P.A., Hermoso, V., Miserendino, M.L., et al., 2021. Identifying high priority conservation areas for Patagonian wetlands biodiversity. Biodivers. Conserv. 30 (5), 1359–1374.

Everard, M., Denny, P., Croucher, C., 1995. SWAMP: a knowledge-based system for the dissemination of sustainable development expertise to the developing world. Aquat. Conserv. Mar. Freshw. Ecosyst. 5 (4), 261–275.

Fang, C., Wen, Z., Li, L., Du, J., Liu, G., Wang, X., Song, K., 2019. Agricultural development and implication for wetlands sustainability: a case from Baoqing County, Northeast China. Chin. Geogr. Sci. 29 (2), 231–244.

Fekri, E., Latifi, H., Amani, M., Zobeidinezhad, A., 2021. A training sample migration method for wetland mapping and monitoring using sentinel data in Google earth engine. Rem. Sens. 13 (20), 4169.

Ficken, C.D., Connor, S.J., Rooney, R., Cobbaert, D., 2022. Drivers, pressures, and state responses to inform long-term oil sands wetland monitoring program objectives. Wetl. Ecol. Manag. 30 (1), 47–66.

Finlayson, B.A., 2013. The Method of Weighted Residuals and Variational Principles. Society for Industrial and Applied Mathematics.

Gandahi, A.W., Hanafi, M.M., 2014. Bio-composting oil palm waste for improvement of soil fertility. Composting for Sustainable Agriculture 209–243.

Ghosh, S., Das, A., 2019. Urban expansion induced vulnerability assessment of East Kolkata Wetland using Fuzzy MCDM method. Remote Sens. Appl.: Society and Environment 13, 191–203.

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

Goldberg, L., Lagomasino, D., Thomas, N., Fatoyinbo, T., 2020. Global declines in human-driven mangrove loss. Global Change Biol. 26 (10), 5844–5855.

Gómez-Baggethun, E., Tudor, M., Doroftei, M., Covaliov, S., Năstase, A., Onără, D.F., et al., 2019. Changes in ecosystem services from wetland loss and restoration: an ecosystem assessment of the Danube Delta (1960–2010). Ecosyst. Serv. 39, 100965.

Gordon, L.J., Finlayson, C.M., Falkenmark, M., 2010. Managing water in agriculture for food production and other ecosystem services. Agric. Water Manag. 97 (4), 512–519.

Hakimdavar, R., Hubbard, A., Policelli, F., Pickens, A., Hansen, M., Fatoyinbo, T., et al., 2020. Monitoring water-related ecosystems with earth observation data in support of Sustainable Development Goal (SDG) 6 reporting. Rem. Sens. 12 (10), 1634.

Haroon, Yousuf, Kibria, G., 2017. Wetlands: biodiversity and livelihood values and significance with special context to Bangladesh. In: *Wetland Science*. Springer, New Delhi, pp. 317–346.

Hartig, J.H., Bennion, D., 2017. Historical loss and current rehabilitation of shoreline habitat along an urban-industrial river—detroit river, Michigan, USA. Sustainability 9 (5), 828.

Hopkinson, C.S., Wolanski, E., Cahoon, D.R., Perillo, G.M., Brinson, M.M., 2019. Coastal wetlands: A synthesis. In: *Coastal Wetlands*. Elsevier, pp. 1–75.

Huq, A.Z., Tyler, T.R., Schulhofer, S.J., 2011. Why does the public cooperate with law enforcement? The influence of the purposes and targets of policing. Psychol. Publ. Pol. Law 17 (3), 419.

Imperative, S.P., 2021. Global Index 2021.

Kandus, P., Minotti, P., Morandeira, N., Grimson, R., González Trilla, G., Gonzalez, E., Gayol, M., 2018. Remote sensing of wetlands in South America: Status and challenges. Int. J. Rem. Sens. 39, 993–1016. https://doi.org/10.1080/01431161.2017.1395971.

Khalil, A., Abdelli, M.E.A., Mogaji, E., 2022. Do digital technologies influence the relationship between the COVID-19 crisis and SMEs' resilience in developing countries? Journal of Open Innovation: Technology, Market, and Complexity 8 (2), 100.

Khan, S., Shaheen, H., Aziz, S., Nasar, S., 2021. Diversity and distribution of Genus Primula in Kashmir region: an indicator genus of the western Himalayan mountain wetlands and glacial forelands. Biodivers. Conserv. 30 (6), 1673–1688.

Khatun, R., Talukdar, S., Pal, S., Kundu, S., 2021. Measuring dam induced alteration in water richness and eco-hydrological deficit in flood plain wetland. J. Environ. Manag. 285, 112157.

Kingsford, R.T., Basset, A., Jackson, L., 2016. Wetlands: conservation's poor cousins. Aquat. Conserv. Mar. Freshw. Ecosyst. 26 (5), 892–916.

Kirwan, M.L., Megonigal, J.P., 2013. Tidal wetland stability in the face of human impacts and sea-level rise. Nature 504 (7478), 53–60.

Koley, S., 2020. Challenges in sustainable development of smart cities in India. Sustain. J. Rec. 13 (4), 155–160.

Kumari, R., Shukla, S.K., Parmar, K., Bordoloi, N., Kumar, A., Saikia, P., 2020. Wetlands conservation and restoration for ecosystem services and halt biodiversity loss: an Indian perspective. In: Restoration of Wetland Ecosystem: A Trajectory towards a Sustainable Environment. Springer, Singapore, pp. 75–85.

Lamsal, P., Pant, K.P., Kumar, L., Atreya, K., 2015. Sustainable livelihoods through conservation of wetland resources: a case of economic benefits from Ghodaghodi Lake, western Nepal. Ecol. Soc. 20 (1).

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.

Ling, J.E., Casanova, M.T., Shannon, I., Powell, M., 2018. Development of a wetland plant indicator list to inform the delineation of wetlands in New South Wales. Mar. Freshw. Res. 70 (3), 322–344.

Mandishona, E., Knight, J., 2022. Historical changes in wetland management legislation and practices in Zimbabwe, and their implications. Wetl. Ecol. Manag. 1–15.

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. Manag. 280, 111670.

McGranahan, G., Balk, D., Anderson, B., 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environ. Urbanization 19 (1), 17–37.

MEA, 2005. Ecosystems and human well-being: wetlands and water synthesis.

Mianabadi, A., Davary, K., Kolahi, M., Fisher, J., 2022. Water/climate nexus environmental rural-urban migration and coping strategies. J. Environ. Plann. Manag. 65 (5), 852–876.

Mitsch, W.J., Gosselink, J.G., 2000. The value of wetlands: importance of scale and landscape setting. Ecol. Econ. 35 (1), 25–33.

Mitsch, W.J., Gosselink, J.G., 2015. Wetlands. John Wiley & Sons.

Nicholls, R.J., 2004. Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. Global Environ. Change 14 (1), 69–86.

Niu, Z., Zhang, H., Wang, X., Yao, W., Zhou, D., Zhao, K., et al., 2012. Mapping wetland changes in China between 1978 and 2008. Chin. Sci. Bull. 57 (22), 2813–2823.

Novoa, V., Rojas, O., Ahumada-Rudolph, R., Sáez, K., Fierro, P., Rojas, C., 2020. Coastal wetlands: ecosystems affected by urbanization? Water 12 (3), 698.

Pal, S., Debanshi, S., 2022. Exploring the connection of physical habitat health of the wetland with its gas regulating services. Ecol. Inf. 69, 101686 https://doi.org/10.1016/j.ecoinf.2022.101686.

Pal, S., Sarda, R., 2020. Damming effects on the degree of hydrological alteration and stability of wetland in lower Atreyee River basin. Ecol. Indicat. 116, 106542.

Pal, S., Talukdar, S., 2018. Drivers of vulnerability to wetlands in Punarbhaba river basin of India-Bangladesh. Ecol. Indicat. 93, 612–626.

Pal, S., Talukdar, S., 2019. Impact of missing flow on active inundation areas and transformation of parafluvial wetlands in Punarbhaba–Tangon river basin of Indo-Bangladesh. Geocarto Int. 34 (10), 1055–1074.

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.

Ragavan, M.L., Das, N., 2019. Optimization of exopolysaccharide production by probiotic yeast Lipomycesstarkeyi VIT-MN03 using response surface methodology and its applications. Ann. Microbiol. 69 (5), 515–530.

Rahman, M.A., Rahaman, M.H., Yasmeen, S., Rahman, M.M., Rabbi, F.M., Shuvo, O.R., 2022. Phytoremediation potential of Schumannianthus dichotomus in vertical subsurface flow constructed wetland. Environ. Challenges 9, 100631.

Ramsar Convention on Wetlands, 2018. Global wetland outlook: state of the world's wetlands and their services to people. Gland.

Rasool, F., Parveen, S., Manzoor, K., Mahmood, S., 2022. Correlation of planktonic biomass with other physico-chemical parameters of water quality in fertilized fish ponds. International Journal of Applied and Experimental Biology 1 (1), 39–47.

Rebelo, L.M., Finlayson, C.M., Nagabhatla, N., 2009. Remote sensing and GIS for wetland inventory, mapping and change analysis. J. Environ. Manag. 90 (7), 2144–2153.

Reis, V., Hermoso, V., Hamilton, S.K., Ward, D., Fluet-Chouinard, E., Lehner, B., Linke, S., 2017. A global assessment of inland wetland conservation status. Bioscience 67 (6), 523–533.

Ricaurte, M., Dicharry, C., Renaud, X., Torré, J.P., 2014. Combination of surfactants and organic compounds for boosting CO2 separation from natural gas by clathrate hydrate formation. Fuel 122, 206–217.

Richards, D.R., Friess, D.A., 2016. Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012. Proc. Natl. Acad. Sci. USA 113, 344–349.

Saha, T.K., Pal, S., Sarkar, R., 2021. Prediction of wetland area and depth using linear regression model and artificial neural network based cellular automata. Ecol. Inf. 62, 101272.

Sapkota, Y., White, J.R., 2021. Long-term fate of rapidly eroding carbon stock soil profiles in coastal wetlands. Sci. Total Environ. 753, 141913.

Seifollahi-Aghmiuni, S., Kalantari, Z., Egidi, G., Gaburova, L., Salvati, L., 2022. Urbanisation-driven land degradation and socioeconomic challenges in peri-urban areas: insights from Southern Europe. Ambio 51 (6), 1446–1458.

Serran, J.N., Creed, I.F., Ameli, A.A., Aldred, D.A., 2018. Estimating rates of wetland loss using power-law functions. Wetlands 38 (1), 109–120.

Shiau, Y.J., Chang, E.H., 2022. Microbial community development in tropical constructed wetland soils in Taiwan. Sci. Total Environ. 812, 152563.

Sica, Y.V., Quintana, R.D., Radeloff, V.C., Gavier-Pizarro, G.I., 2016. Wetland loss due to land use change in the Lower Paraná River Delta, Argentina. Sci. Total Environ. 568, 967–978.

Silvius, M.J., Oneka, M., Verhagen, A., 2000. Wetlands: lifeline for people at the edge. Phys. Chem. Earth - Part B Hydrol., Oceans Atmos. 25 (7–8), 645–652.

Song, F., Su, F., Zhu, D., Li, L., Li, H., Sun, D., 2020. Evaluation and driving factors of sustainable development of the wetland ecosystem in Northeast China: an emergy approach. J. Clean. Prod. 248, 119236.

Sterzel, T., Lüdeke, M.K., Walther, C., Kok, M.T., Sietz, D., Lucas, P.L., 2020. Typology of coastal urban vulnerability under rapid urbanization. PLoS One 15 (1), e0220936.

Sundar, K.S., Chauhan, A.S., Kittur, S., Babu, S., 2015. Wetland loss and waterbird use of wetlands in Palwal district, Haryana, India: the role of agriculture, urbanization and conversion to fish ponds. Wetlands 35 (1), 115–125.

Tauqeer, H.M., Basharat, Z., Ramzani, P.M.A., Farhad, M., Lewińska, K., Turan, V., Iqbal, M., 2022. Aspergillus niger-mediated Release of Phosphates from Fish Bone Char Reduces Pb Phyto Availability in Pb-Acid Batteries Polluted Soil, and Accumulation in Fenugreek. Environmental Pollution, 120064.

UNDP, 2022. *Human Development Report. The next frontier. Human Development and the Anthropocene*. United Nations Development Programme, New York.

Van Rees, C.B., Reed, J.M., 2014. Wetland loss in Hawai'i since human settlement. Wetlands 34 (2), 335–350.

Wang, Z., Wu, J., Madden, M., Mao, D., 2012. China's wetlands: conservation plans and policy impacts. Ambio 41 (7), 782–786.

Wassie, S.B., 2020. Natural resource degradation tendencies in Ethiopia: a review. Environmental systems research 9 (1), 1–29.

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 Syst. Environ. 3 (2), 327–340.

White, E.E., Ury, E.A., Bernhardt, E.S., Yang, X., 2022. Climate change driving widespread loss of coastal forested wetlands throughout the North American coastal plain. Ecosystems 25 (4), 812–827.

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.

Xi, Y., Peng, S., Ciais, P., Chen, Y., 2021. Future impacts of climate change on inland Ramsar wetlands. Nat. Clim. Change 11 (1), 45–51.

Xu, X., Chen, M., Yang, G., Jiang, B., Zhang, J., 2020. Wetland ecosystem services research: a critical review. Global Ecol. Conserv. 22, e01027.

Xu, X., Jiang, B., Tan, Y., Costanza, R., Yang, G., 2018. Lake-wetland ecosystem services modeling and valuation: Progress, gaps and future directions. Ecosyst. Serv. 33, 19–28.

Ye, C., Sun, F., 2021. Development of a social value evaluation model for coastal wetlands. Ecol. Inf. 65, 101417.

Yu, Y., Jia, T., Chen, X., 2017. The 'how'and 'where'of plant micro-RNA s. New Phytol. 216 (4), 1002–1017.

Zhang, Y., Li, W., Sun, G., King, J.S., 2019. Coastal wetland resilience to climate variability: a hydrologic perspective. J. Hydrol. 568, 275–284.

Zhang, J., Fu, B., Stafford-Smith, M., Wang, S., Zhao, W., 2021. Improve forest restoration initiatives to meet Sustainable Development Goal 15. Nat. Ecol. Evol. 5 (1), 10–13.