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Assessment of Wetland and their Eco-system Services

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Abstract:

Wetland contributes uncountable ecosystem services and goods to humans as well as other organisms. It is considered the nursery of life due to its unique features. It provides several services such as provisional, regulating, cultural, and supportive services. Despite numerous benefits, it is degrading day by day due to direct and indirect impacts such as anthropogenic factors, conversion of land into agricultural land, etc. Studies carried out in the last 10 years of originally published papers were examined. We reviewed about 75 papers and critically analyzed 19 papers for the estimation of economic value and land use/ cover change of wetlands. It has been estimated that an average of 80% of wetland areas were reduced and used for other purposes. It is estimated that the value of the wetland ecosystem services from both human-made and natural inland wetlands is 6467.21 USD ha/year and 1130.74 USD ha/year respectively. The evaluated data of this paper will provide an effective context about wetland ecosystem services to the researchers and government authorities for the sustainable use of wetlands and their conservation importance.

Key words: - Wetland, Land Use Change, Economic Evaluation of Wetlands, Eco-System Services

1. Introduction

Globally wetlands account for approximately 12.1 million sq. km, each with unique characteristics and a vast array of uncountable ecosystem services and goods to both humans and other organisms on earth (Roy et al., 2022). Wetlands are often called "nurseries life", because of their unique features that provide habitat, shelter, and other services for numerous species of aquatic, plants and animals (Diller et al., 2022). It is an important part of our daily livelihood but is not given due importance. It has a contamination-purification feature that purifies unwanted toxic substances generated from anthropogenic factors like agriculture, and industries, and as such is called a "Natural Filter" (Adeeyo et al., 2022). Wetlands were categorized as Marine and coastal, natural inland wetlands, and human-made wetlands (Ramsar Convention 2018). It has been providing various direct and indirect values and functions such as flood control & prevention, habitat regulation, water supply & regulation and nutrient retention, etc. towards humans and other organisms without charging a penny. Knowing the numerous benefits and services it provides, world leaders conserve wetlands through Ramsar Convention on wetlands in 1971 at Ramsar, Iran, so they can be used sustainably.

Wetlands are defined as areas of marshes, fen, peat lands or water, whether natural or artificial, permanent or temporary with water that static or flowing fresh brackish or salt, involving areas of marine water the depth of which at low tide does not overpass six meters (Ramsar convention) It contributes a lot to the country's economy. In terms of valuation, it has use value and non-use values furthermore it is sub-categorized as direct value, indirect value, option value, and existence value Kauffman (2022).

Humans and other organisms acquiring many goods, services, and functions directly or indirectly from nature for free are called ecosystem service (Cheng et al., 2022), which is classified into 4 categories (provisioning service, cultural service, supporting service, and regulated service) and sub-categorized into 11 services (Xie et al., 2015) like water supply, food and fibre, flood regulation and control, habitat regulation, biodiversity, medicine, nutrient cycle, and aesthetic regulation, etc. Wetlands service depends upon water quality and soil, directly or indirectly that not only influence the aquatic ecosystem but also its productivity. However, the climate shifts and their associated parameters also play a key role in gaining more net primary productivity that makes wetlands more capable of delivering ecosystem service (Zhang et al., 2022). To realize the various potentials of wetlands, it is required to understand the net primary productivity evaluation because inundation ensures nutrients and other organisms are exchanged with neighbouring water bodies for sustainable ecosystem functions (Molinari et al., 2022). After this, it has an influence on vegetative composition which impacts the productivity and services provided by wetlands.

NPP is referred to as the total organic matter produced by plants per unit time and unit area by utilizing light through photosynthesis, the output fixed energy used during the performance of their respiration (Yang et al., 2022). Net primary productivity is different in every corner of the whole water body according to the nutrient supply and is highly manipulated by soil and water itself. Due to anthropogenic or human activity and other natural causes, the wetland areas seem to be lost very significantly.

2. Materials and Methods

In this study literature was obtained online from the "Scopus" (https://www.scopus.com/) website, due to its multidisciplinary feature. The papers were identified on the basis of key words such as "ecosystem evaluation" or "Land use/ land change" or "wetland productivity" and classified according to the "Evaluation" & "Land use/ Land change". Furthermore the data was assessed for confirmation and a total of 275 papers were obtained. In addition we run the same in the "web of science" (https://www.webofscience.com/) for more accuracy. A total of 25 papers were found, which make a total 300 samples. In the first screening, the tittles and abstracts were thoroughly read to remove duplicate and theoretical papers (150 in total). As a result, 150 papers reviewed in the second screening which resulted with 75 papers. Among these papers, only 19 papers were found suitable for our objective. The land use/ land change were estimated using 7 papers and 12 papers were used for the monetary value estimation. The data of 12 monetary evaluations were converted in the base year of 2022 accordingly by using the inflation formula (I.R= ((B-A)/A) ×100, (where A= Starting cost and B= Ending cost) to investigate the generated cash value in the current year. Information provided in this paper will help the researcher to gain knowledge on various ecosystem services and land use changes of wetlands.

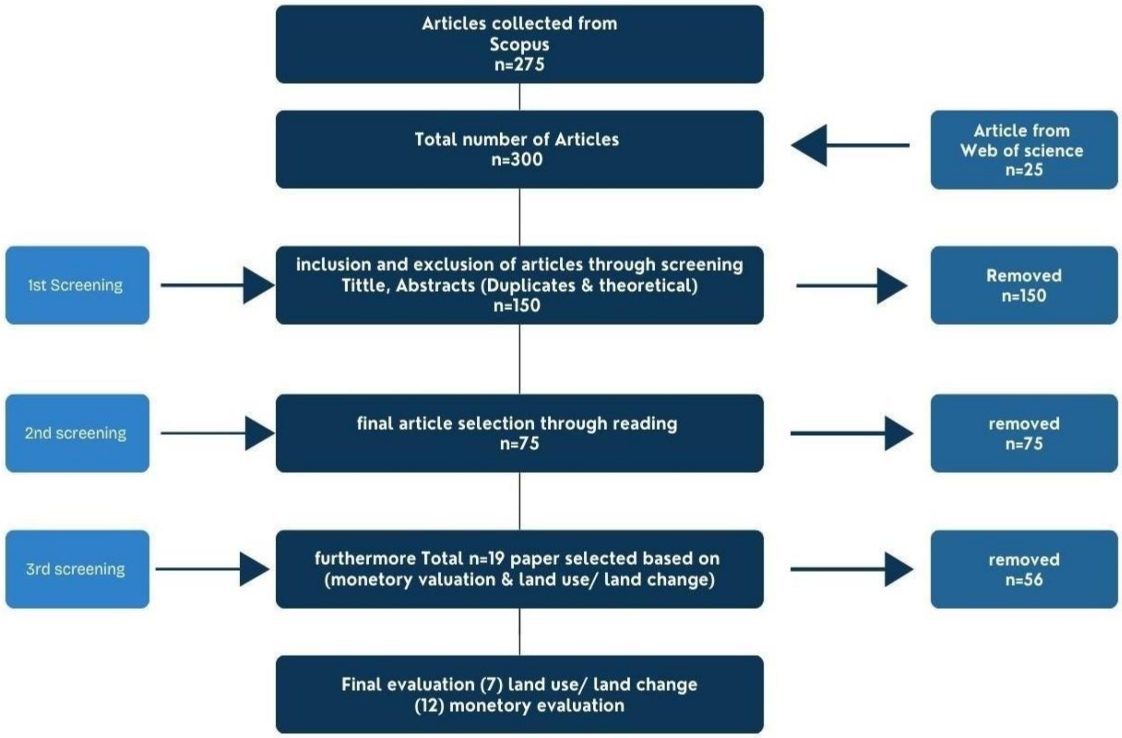

Figure 1: Flowchart (adopted from Manley et al., 2022)

3. Result and Discussion

3.1. Eco-system services

Wetland ecosystem services are profits or benefits that are procured from nature, which are named Provisional service, regulating service, Cultural service, and supporting service. A total of 22 inland wetlands and 15 artificial lakes were taken into consideration. Different methods for evaluation and their ecosystem services were listed based on existing literature. It was found that regulating services like flood control and mitigation were among the major services provided by the wetland. Both the wetlands provide services including sedimentation, paddy fields, nitrogen retention, ecotourism, grazing, food, water purification, habitation, etc. Here both natural inland wetlands and human-made wetlands are discussed below (Table 1).

***Table 1. List of ecosystem services provided by wetland and their evaluation methods in various countries**.*

Inland Natural wetland					
Sl. No.	***Wetland category***	***Methods for evaluation***	***Ecosystem service (P, R, C, S)***	***Area (square km)***	***Reference***
1	Deepor beel fresh water lake (India)	Modified Normalized Difference Water Index (MNDWI), The Mann–Kendall statistical test, The Sen's method, Contamination factor (CF). Potential ecological risk (PER).	Sedimentation (S) Paddy field(P) Flooding (R)	4	Dash et al., 2021, Ahmed et al., 2021
2	Ruamahanga Basin (New Zealand)	high-resolution Land Use Capability Indicator model	Agricultural field(P) Nitrogen retention(S) Flood control(R)	3289	Tomscha et al., 2019
3	Flanders river valley (Belgium)	Flemish Soil Map (ALBON 2014) Biological Valuation Map Flood Hazard Map of 2014	Flood regulation(R) Food production(P)	13522	Decleer et al., 2016
4	Fenland floodplain (United Kingdom)	Toolkit for Ecosystem Service Site-based Assessment (TESSA)	Ecotourism(C) Flood control(R) Grazing(P)	7.13	Peh et al., 2014
5	Driefontein wetland floodplain (Zimbabwe)	Questionnaires, interview,	Food(P), Water purification(R) Spiritual enhancement(C)	6.23	Maramban yika et al., 2021
6	Sawa lake (Iran)	Point-Counts methodology	Food-shelter (P)(S)	5	Abed (2017)
7	South west costal marine area (Benin)	Line transects and stationary point count methods.	Food-shelter(P)(S)	5240	Azonningb o et al.,2018, Sossou and Adjakpa (2020)
8	Lukanga swamp (Zambia)	Transect surveys	Food-shelter(P)(S)	2600	Chabwela et al., 2017
9	Lake cluster (Nepal)	group discussions, key informant interviews, and household (HH) surveys	Landscape(C) Food(P) Habitat protection(S) Flood control(R)	261.06	Pathak et al., 2021

10	Nyando wetland floodplain, swamp (Kenya)	stratified random sampling, quantitative, descriptive statistics and Chi-square test	Fuel and fiber(P), climate regulation(R), spiritual(C), soil formation(S)	30	Maithya et al., 2021
11	Donana marshes (Spain)	multidisciplinary scientific panel and semi-structured interviews	Salt production(P) Climate regulation(R) Aesthetic value(C)	2207	Miras et al., 2013
12	Usumachinta floodplain (southern Mexico)	water quality and stable isotopes, analysis of land use and land cover change, spatial analysis and characterization of oil palm. Semi structured interviews.	Flood control(R) Food(p) education(C) biodiversity(S)	73195	Cazzanelli et al.,2021, Camacho-Valdez et al., 2022, Camacho-Valdez et al., 2020
13	Biwa shiga lake wetland (Japan)	nature-based solutions (NBSs), quantitative analysis	Flood control(R) land reclamation(S)	647	Huang et al., 2021
14	Hakaluki hoar shallow basin (Bangladesh)	Livelihood assessment index (LAI)	Flood regulation(R) Fishing (P)	183.86	Tikadar et al., 2022
15	Mississippi upper river delta freshwater swamp (U.S.A)	Land Use Trend Analysis, Indicators of Hydrologic Alteration (IHA)	Flood regulation(R) Habitat regulation(S) Food (P)	1092.62	Schramm et al., 2015, Yasarer et al., 2020
16	Des moine lobe a pothole wetland (USA)	InVEST Modeling, Amphibian Habitat, Grassland-Bird Habitat	Pollination(R) Biodiversity(S)	770000	Mushet and Roth (2020)
17	Sudd permanent swamp and seasonally flooded wetland (South Sudan)	Interview, group discussion, secondary data	Microclimate regulation(R) Domestic water supply(P) Transportation service(C) Habitat regulation(S)	57000	Mulatu et al., 2022
18	Lake Victoria basin (Uganda, Kenya, Tanzania, Rwanda, and Burundi)	Earth observation data analysis, Reference Data Collection and Accuracy Assessment, physio-chemical, meteorological data analysis	Livestock keeping(P) Transportation(R)	184200	Mugo et al., 2020, Olokotum et al., 2021

19	Nguru permanent fresh water lake (Nigeria)	Interviews, Focus Group Discussions (FGD), questionnaires, and field observations.	Fuel wood(P) Breeding ground(S) Groundwater regulation (R)	8000	Ayeni et al., 2019
20	Upper blue nile basin (Ethiopia)	market price approach, cost-based approach and production function approach, travel cost method, and hedonic pricing, contingent valuation method	Raw material(P) Climate regulation(R) Nutrient cycling (S) Recreation (C)	175000	Assefa et al., 2021
21	Indawgyi natual fresh water lake (Myanmar)	Interview, questionnaires, random sampling, market price valuation method	Agriculture (P) Habitat regulation (S) Recreational(c)	478.84	Htay et al., 2022, Ko et al., 2020
22	Nylsvley Wetland floodplain (South Africa)	Tukey's posthoc Analysis, Kruskal–Wallis analysis, Bayesian Stable Isotope Analysis.	Flood regulation(R) Nutrient regulation (S)	242.5	Dalu et al., 2022
		Human- made / Artificial lake			
Sl. No	***Wetland category***	***Methods for evaluation***	***Ecosystem service(P,R,C,S)***	***Area (square km)***	***Reference***
1	Red river delta natural reserve and mangrove swamp (Vietnam)	Contingent valuation method (Non-parametric, parametric), benefit transfer and replacement cost methods	Habitat regulation(S) Shrimp cultivation(P) Carbon storage (R) Tourism (C)	1372.61	Trung et al., 2020, Dung and Phuong Le(2022)
2	Ayder arnasay lake (Uzbekistan)	Historical, comparative, and statistical methods	Ecotourism(C) Habitat regulation(S) Fish(P) water quality regulation(R)	5271	Burkhanovich and Tairovna(2018) Groll et al.,2016
3	Moeyungyi Wetland Wildlife Sanctuary Lake and seasonal flooding (Myanmar)	Toolkit for Ecosystem Service Site-based Assessment (TESSA)	Paddy field(P) Climate regulation(S) Tourism (C)	103.59	Aung et al., 2021, Peh et al., 2014
4	Dongting lake basin (China)	Land-use conversion matrix using the ArcGIS 10.6 software. Remote sensing images.	Paddy field (P) Waste treatment(R) Soil formation and retention (S)	1900	Yang et al.,2022 Li et al.,2022

5	Zambezi river delta floodplain (Zambia)	Interview Schedule, Key Informant Interviews, Participatory Rural Appraisal (PRA), Simple random sampling, Field Observations, Quantitative Data Analysis, Qualitative Data Analysis	Fish(P) Flood regulation(R)	31711.72	Banda et al., 2022
6	Lake kuyuchuk (Turkey)	Normalized difference water index (NDWI), Landsat data	Breeding ground(S)	4.16	Ergen (2019)
7	Druzno lake (Poland)	TRIM (TRends & Indices for Monitoring data) software,	Artificial breeding ground (S)	30.68	Slepowronska et al., 2022
8	Bundalla salt exploitation site (Sri Lanka)	Group discussion, Participatory Rural Appraisal (PRA)**,** Transact method along with GIS	Fishing and paddy farming(P) Shorebird habitat(S)	62.1	Dharmawardhana et al.,2019, Suraweera and Dahanayaka (2017), Bellio and Kingsford (2013)
9	Wu river national park seasonal river (China)	Market value method, Replacement cost method, Contingent value method	Water supply(P) Water regulation(R)	10.99	Zhang et al., 2013
10	Ili river delta and lake balkhas reservoir (Kazakhstan)	Spatiotemporal analysis (climate change analysis, land use change analysis) Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model	Climate regulation (R) Habitat regulation(S) Fish and agriculture (P)	9766.3	Li et al., 2021, Duan et al., 2020, Pueppke et al., 2018
11	Jagadishpur reservoir (Nepal)	Contingent valuation method, benefit transfer method, revealed price method.	Medicinal and roofing materials(P) Tourism(C) Species conservation (S) Flood and landslide control (R)	196	Baral et al., 2016
12	Punarbhaba river basin (Bangladesh)	Seasonal discharge gap, NDVI, chi-square test, simple linear regression	Flood regulation(R)	5265.93	Talukdar and Pal (2017)

13	La Tembladera flood plain and reservoir (Ecuador)	water temperature (T), potential hydrogen (pH), turbidity, electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD5), chloride ions (Cl–), sulfates (SO42–), nitrates (NO3−)	Water supply(P)	14.7119	Ordonez (2020)
14	Aragauri reservoir (Brazil)	Physio-chemical parameter, multiple regression analysis,	Flood regulation(R)	17.7	Silva et al., 2020
15	Raja artificial reservoir wetland (Pakistan)	Point count method, Krus-kal–Wallis one-way analysis of variance (ANOVA) and Tukey's Honest Significant Difference (HSD) test	Habitat regulation (S) Water supply (P)	.9793	Rajpar et al., 2022

*****P- Provisional service, R- Regulating service, C- Cultural service and S- Supporting service

3.2. Land use/ cover change of wetland: -

Wetland is considered the most productive ecosystem on the earth; however, it is vulnerable to various parameters. Conversion of wetland areas into agricultural land or any other land can rapidly inject profit (Li et al., 2019) but affects other parameters like water quality, habitat fragmentation, ecosystem services, etc. Built-up areas, farmland, agricultural land, or any anthropogenic activities were considered the main cause of wetland loss (Kuule et al., 2022). Some of the land use change evaluations are listed below. The degradation of wetlands is not limited to a country but can be observed globally. In Table 2, the land conversion (percentage) in other land use systems can be seen worldwide, where the Ruamahanga basin has substantially lost 98% of its area followed by Flander – 95%, and 92.87% for Usmachinta flood plains and Deepor Beel 84.38%, which indicates ongoing urbanization in those areas. The high demand of the population may be the reason for wetland degradation.

Table 2. List of land use change in various countries and applied methodology

Sl. No.	***Work done / country***	***Year***	***Services (P,S,C,R)***	***Remaining wetland area (%)***	***Land used change/conversion of land (%)***
1	Lake water volume calculation using time series LANDSAT satellite data a geospatial analysis of Deepor Beel Lake, Guwahati (India) (Ahmed et al., 2021)	2019	Paddy field(P) Flooding (R)	15.62	84.38

2	Assessment on no wetland drainage in the Ruamahanga Basin by using high resolution land use capability modal by mapping nitrogen retention and sediment retention and agricultural production. (New Zealand), (Tomscha et al., 2019)	2019	Agricultural field(P) Nitrogen retention(S) Flood control(R)	2	98
3	Mapping of wetland lose, potential restoration by evaluate ecosystem services of flanders (Belgium) (Decleer et al., 2016)	2014	Flood regulation(R) Food production(P)	5	95
4	Assessment of land use system effect on ecosystem service of donana marshland (Europe) (Miras et al., 2013)	2006	Salt production(P) Climate regulation(R) Aesthetic value(C)	29.5	70.5
5	Assessment of land use change of wetland regarding palm cultivation near aquatic ecosystem by using Landsat 7 ETM+, Landsat 8 OLI Images on Usumacinta flood plain (Mexico) (Valdez et al., 2020)	2017	Flood control(R) Food(p) education(C) biodiversity (S)	7.13	92.87
6	Evaluation of trends and divers of land use change of Lake Victoria (Kenya) (Mugo et al., 2020)	2014	Livestock keeping(P)	66.74	33.26
7	Impact of wetland land use/ change on peri and urban area of Bahir Dhar City (Ethiopia) (Assefa et al., 2021)	2019	Raw material(P) Climate regulation(R) Nutrient cycling (S) Recreation (C)	13.08	86.92
Mean± SEM				19.867± 22.570	80.132±22.570

***P-** Provisional service, R- Regulating service, C- Cultural service and S- Supporting services

3.3. Economic evaluation of wetland ecosystem services: -

Estimation of wetland ecosystem services is the most appropriate way to recognize wetland health and the benefits acquired. Different methods have been used for evaluation for a long time. But the “valuation” and “evaluation” both signify different meanings with evaluation signifying both process and result (Ignatyva et al., 2022). We calculated the estimated monetary valuation in 2022 for the listed wetlands based on the data published by respective researchers in that year (Tables 3 and 4). An increase in their valuation was observed for all the wetlands. It is expected to increase in the future. This reveals that the value of the services is increasing and hence wetlands need to be conserved.

Table 3. List of inland natural wetland monetary evaluation.

Sl. No.	*Work done / country*	*Year*	*Services*	*USD ha/yr.*	*USD/ha /yr. (2022)*	*Referenc e*
1	Long term initiative to convert intensively farm arable land to wetland for sustainable biodiversity conservation on fenland floodplain (United Kingdom)	2014	Ecotourism(C) Flood control(R) Grazing(P)	199	250.51	Peh et al., 2014
2	Evaluation of invasive species impact on ecosystem services of wetland by stakeholder analysis on Ramsar site lake cluster (Nepal)	2019	Landscape(C) Food(P) Habitat protection(S) Flood control(R)	347	404.49	Pathak et al., 2021
3	Assessment of local people’s perception of ecosystem services and overlapping with socioeconomic and biodiversity indicators of Usumschinta floodplains (Mexico)	2019	Flood control(R) Food(p) education(C) biodiversity(S)	1969.5	2295.78	Valdez et al., 2020
4	Evaluation of stakeholders role and interest on ecosystem services for the sustainable wetland management of nile basin sudd wetland and machar marshes (Sudan)	2019	Microclimate regulation(R) Domestic water supply(P) Transportation service(C) Habitat regulation(S)	35.93	41.88	Mulatu et al., 2022
5	Evaluation of provisioning service provided by Nguru Wetland for future and current priorities (Nigeria)	2013	Fuel wood(P) Breeding ground(S) Ground water regulation (R)	605	773.95	Ayeni et al., 2019

6	Impact of wetland land use/ change on peri and urban area of bahir dhar ciry (Ethiopia)	2019	Raw material(P) Climate regulation(R) Nutrient cycling (S) Recreation (C)	2302.17	2683.57	Assefa et al., 2021
7	Assessment of dependency of local people on direct use value of Indawgyi Lake Wildlife Sanctuary (Myanmar)	2020	Agriculture (P) Habitat regulation (S) Recreational(c)	1272.3	1465.01	Ko et al., 2020

*****P- Provisional services, R- Regulating services, C- Cultural services and S- Supporting services

Table 4. List of human-made inland wetland monetary evaluation

Sl. No.	***Work done / country***	***Year***	***Services (P,S,C,R)***	***USD ha/yr.***	***USD ha/yr. (2022)***	***Reference***
1	Evaluation of monetary value of northern part of wetland in (Vietnam)	2019	Habitat regulation(S) Shrimp cultivation(P) Carbon storage (R) Tourism (C)	1.04	1.21	Dung and Phuong Le (2022)
2	Evaluation of rice production impact on Moeyungyi Wetland Wildlife Sanctuary by using Toolkit for Ecosystem Service Site-based Assessment (TESSA) (Myanmar)	2015	Paddy field(P) Climate regulation(S) Tourism (C)	2130	2678.14	Aung et al., 2021
3	Assessment of ecosystem service and their driving factors of Dongting Lake eco-economic zone (China)	2018	Paddy field (P) Waste treatment(R) Soil formation and retention (S)	1941.9	2303.50	Li et al., 2022
4	Evaluation of ecosystem service of national wetland park through market value, replacement cost and contingent value methods (China)	2010	Water supply(P) Water regulation(R)	19970	27292.53	Zhang et al., 2013
5	Economic evaluation of Jagadishpur reservoir wetland (Nepal)	2015	Medicinal and roofing materials(P) Tourism(C) Species conservation (S) Flood and landslide control (R)	48.254	60.67	Baral et al., 2016

*****P- Provisional services, R- Regulating services, C- Cultural services and S- Supporting services

4.0. Status of wetland: -

Eco-system service provided by the wetland is essential for communities especially in under-developed areas. Land use land cover changes were directly proportional to loss of ecosystem services and habitat fragmentation, which causes poor wetland health and stress (Torbick et al., 2006). Furthermore, it squeezes the habitat and may cause poor diversity within the ecosystem Pal and Saha (2018). In addition, the migration of people from one place to another causes more stress to water bodies, because the strike of unemployment and unbalanced livelihood may force them to encroach on undisturbed wetland basins (Sankar et al., 2016). Wetlands are known to mitigate climate change. It acts as a carbon sink particularly; coastal wetlands can trap huge amounts of carbon (Maxwell et al., 2017). Moreover, peat lands, mangrove forests, salt marshes, and sea grass beds store an astounding 20% of the carbon in organic ecosystems on Earth while making up only 1% of the earth's surface (Temmink et al., 2022). Therefore, it is high time to acknowledge the potential of wetlands in carbon sequestration like forests.

5.0. Research Gaps: -

- Most of the monetary evaluation of wetlands has been achieved by the quantitative method, rather than using qualitative and quantitative methods altogether, which creates a barrier to understanding, justification, and decision-making process.
- According to (Mengist et al., 2020), although ecosystem services have lots of benefits, there were several knowledge gaps or limitations such as RES (regulatory ecosystem services). The study focuses only on tangible benefits that are linked with human well-being and less on RES functions which include climate regulation, pest and disease regulation, human safety, etc.

6.0. Conclusion: -

Nature's contribution to humankind is irreplaceable but the pressure built by various human activities is not an old phenomenon. The purpose of this work was to illustrate a scenario in which wetlands can enhance the socio-economic status of a certain location or country. However, the conversion of land for human use purposes affects the biodiversity-linked ecosystem service of wetlands. Major populations from Asia and a few African countries solely depend upon natural resources for their livelihood. Organisms living inside the wetlands both plant and animal species have different functions to support the human-induced stress. We believe this work may have reflected its positive influence on conservation for sustainable use. Wetland plant species play an essential role in supporting the function of the wetland ecosystem, particularly in the context of mitigating climate change to counteract the effects of human-induced climate change. A comprehensive framework that takes into account institutional, social, and ecological influences is required.

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