Anthropogenic Impacts on Wetlands of Kerala, India: A Review of Literature

ABSTRACT

Kerala is blessed with numerous wetlands including rivers, streams, mangroves, backwaters, estuaries, canals, paddy fields, reservoirs, lakes and ponds. Wetlands are an integral part of the state and they endow man with numerous ecosystem services like purification of water, provision of food, flood protection, shoreline stabilization, support to biodiversity, recharge of underground water etc. At present wetlands are under threat as they are victims of population pressure, rapid urbanization and negligent land use pattern. Wetlands of Kerala have become polluted, fragmented and reclaimed for other purposes. If this trend continues man is endangering not only humans but also other creatures on earth. Scientists and environmental conservationists realized the importance of wetlands and have studied the adverse effects of human activities on wetlands and have also suggested mitigation measures to conserve these fragile ecosystems. This paper is a review of published literature on the anthropogenic impacts on anthropogenic of Kerala and measures for their conservation.

Keywords: Human impacts, Reclamation, Conservation, Ecosystem, Rivers, Lakes , and wetlands.

1. INTRODUCTION

Wetlands are essential ecosystems which play a crucial role in sustenance of life on earth. According to the Ramsar Convention on Wetlands[1] , wetlands are "areas of marsh, fen, peat land 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 six meters". Ever since the dawn of human civilization, Man has depended on nearby wetlands for most of his activities. Great civilizations evolved on the banks of mighty rivers. Apart from providing livelihood to millions of people, they play a major role in ground water recharge, flood mitigation, carbon sequestration, water purification, biodiversity sustenance, enhancement of aesthetic value etc. However, with the development of human race, wetlands are facing threat from anthropogenic activities. The ecosystem services provided by wetlands are overlooked and they are being converted to other land uses, fragmented, polluted and destroyed.

Kerala, situated in the southernmost tip of India, extends from 8° 17′and 12°48′ north latitude and 74° 51′ and 77° 20′ east longitudeand covers an area of 38864 sq. km. Located between the Western Ghats on the east and Arabian Sea on the west, Kerala is endowed with numerous wetlands of varying dimensions and characteristics. The state has natural wetlands like rivers, streams, backwaters, estuaries, paddy wetlands, mangroves, lakes and ponds and man-made wetlands such as reservoirs, canals and tanks. According to the National Wetland Atlas 2011[2] the total wetland area of Kerala is 160590hectares while that of India is 15.26 million hectares.Kerala has witnessed rapid change in land use pattern during the past few decades. Break-up of joint family system along with remuneration from abroad led to springing

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up of palatial houses. The state also witnessed rapid urbanization and a boom in construction activities. Wetlands are the main victim of land reclamation for building houses and commercial spaces.

2. RESULTS AND DISCUSSION

2.1. Ramsar Sites:

A look into the published literature shows that Vembanad –Kole wetland is one of the most extensively studied wetland of Kerala. The Vembanad-Kole wetland was included in Ramsar list of Wetlands of International Importance in 2002. Other two wetlands of Kerala in the list are Ashtamudi lake and Shasthamkotta lake. According to the Information Sheet on Ramsar site[3], Vembanad-Kole covering an area of 151250 hectaresis the largest brackish, humid tropical wetland ecosystem in the Southwest coast of India. Though the Vemabanad-Kole is treated as one single wetland in the Ramsar list, researchers, scientists and environmentalist have often treated it as two distinct wetlands- the Vembanad lake or backwaters and the Kole Paddylands. Thus we find separate literature for the Vembanad and the Kole. Ample studies exist regarding biodiversity of this wetland, but for this particular paper only those studies focussing on anthropogenic impacts on Vemanad-Kole have been included.

2.1.1. ***Vembanad Lake***: As early as 1983 Gopalan et al [4] gave a detailed historical account of the vertical and horizontal shrinkage of Vembanad lake. In 1834 the lake covered an area of 36 Km^2. Thereafter upto 1950 almost 10269 hectares was reclaimed mainly for agriculture. Reclamation for harbour and urban development began from 1920 with the development of Cochin port. Vertical shrinkage of Vembanad backwaters was mainly due to siltation which was accelerated by human activities like deforestation, construction of dams, reservoirs and barriers. Gopakumar et al [5] analysed the bathymetry and spatial changes to the Vembanad lake from 1917 to 1990 using geospatial technology and reported that from 1917 to 1970 the aereal extent of the lake reduced by 26.67% mainly for polders and expansion of Wellington island. In 1990 the lake further reduced by 13.95 km^2 due to construction of TM Barrage. Bathymetric analysis revealed that elevation of lake bottom varied from -9.9mMSL to 2mMSL. Krishnadas [6] also reported reclamation of Vembanad wetland which reduced in area from 266.63km^2 in 1966 to 238.05 km^2 in 2012. The Vembanad lake is getting polluted day by day, which was demonstrated by Mani et al [7] through a study on spatial variation in diffuse pollution. Parameters such as iron, acidity, hardness, chloride and sulphate were significantly high during the dry season as compared to wet season due to closure of Thanneermukkam Bund in the dry season. Also, dry season being the tourism season saw increased waste discharge from house boats and resorts. The impact of backwater tourism on this tourist hotspot was analysed by Vincy et al [8]. Water samples collected from 2008 to 2012 revealed that maximum water temperature (33°C) was during the tourism season and post tourism season due to increased faecal contamination. BOD levels were high during the post tourism period. Phosphate level and calcium hardness exceeded permissible limits in all seasons.

2.1.2. ***Kole Wetlands***: The Kole paddy wetlands spreads across the districts of Thrissur and Malappuram. This major rice granary of Keralahas also been extensively studied. John [9] analysed the impact of human activities on the ecology of the Muriyad wetlands which is part of the Kole wetland. The wetland is a victim of sand mining and reclamation which adversely affected the ground water recharge and the flora and fauna. Raj and Azeez [10] highlighted the threat posed by the real estate sector to paddy wetlands including the Kole. Low-lying areas usually fetch low prices, so agencies acquired these wetlands to promote real estate projects to earn huge margins. As suchtotal rice cultivable land area in Thrissur district declined from 37,012 hectares in 2001-02 to 34,158 hectares in 2003-04. The real estate sector also shifted the labour away from agriculture. Srinivasan [11] described the Kole lands as a Multiple Use Wetland Ecosystem and used a Driver Pressure State Impact Response (DPSIR) framework to describe activities undertaken on the wetlands, sustainability of these activities and threats to the ecosystem. Land use change is a main driver leading to pressure on Kole wetland. Mining, construction, subdivision and fragmentation of holdings as a result of Land Reforms Act in 1964 adversely affected the Kole lands. Vimod and Kishore [12] openly showcased the reclamation of the Kole wetland in Kolazhy grama panchayat for a gated township, ignoring the rules of the Land Utilization Order of 1967.The authors proposed the setting up of a web GIS platform – The People's Paddy Register (PPR) to have a continuously updated data base on paddy fields in order to monitor their health.Jenin and Bhaskara [13] examined the pollution level of Kokkala stream which flow into the Kole wetlands from Thrissur railway station. Due to urban sprawl, municipal waste water consisting of domestic and industrial waste water flow to the Kokkala canals as storm water. This ultimately reach the Kole lands and contaminated the agricultural wetland as suspended matter, oils and grease became high and above irrigation standards.

Apart from the Kole wetlands, paddy cultivation and integrated paddy-shrimp cultivation is practiced in waterlogged paddy fields all across Kerala. Jayan and Sathyanathan [14] studied threats faced by water-logged paddy fields of Kerala- Kole, Kuttanad, Kaipad and Pokkali. Reclamation of land and change in land use pattern like conversion of paddy fields to coconut, arecanut and banana, increase in new constructions, conversion of the wetland to brick-kilns, large scale poaching and trapping of birds and fishing, shift to monoculture of prawns etcwere some of the threats mentioned. The researchers pleaded for better management of waterlogged areas through application of sub-soil drainage system, scientific cultivation, mechanization, crop diversification, community participation etc. Sreejith [15] described the history of human intervention in Kuttanad wetland from 1880s to 2010. The Kuttanad Development Scheme affected the ecosystem. Various anthropogenic threats include discharge of sewage, mining, obstruction to navigation, habitat destruction, depletion of aesthetic value etc. Suggestions for saving this biodiversity paradise included legal protection of fragile areas, promotion of eco-friendly tourism, promotion of social awareness, implementation of large-scale eco-restoration programmes etc.

2.1.3.*Sasthamcotta Lake*: Sasthamcotta Lake is a freshwater lake. Sreekumari et al [16]showcased how human interference is leading to the drying up of the Sasthamcotta lake. Sand mining, both instream and floodplain mining is rampant in Ashtamudi basin and the Kallada river which flows close to the lake. Groundwater replenishment of the lake was reduced due to riverbed lowering because of instream sand

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mining and due to the conversion of around 3.57 km^2 land of Kallada river flood plain into fallow lands. An embankment which was originally constructed to protect the lake from agricultural pollutants has completely isolated the lake and prevented flood pulse contribution of monsoon water. Water level of the lake showed a decreasing trend since 2007 even though the rainfall and water discharge through Kallada river were almost same. Divya and Kani [17]assessed the water quality of Sasthamcotta lake during the years 2017 and 2018. Analysis of physico chemical properties showed that water quality of lake was poor. Human activities like discharge of domestic waste and formic acid contained waste water from rubber estates and other acidic runoff contributed to lowering of pH value and to the high value of total dissolved solids. A reason for high BOD was food waste dumped into the lake by houses and hotels. High total coliform counts was due to human fecal contamination, animal waste and chemical waste because of nearby human settlements.

2.2 Other Lakes: Kerala is studded with lakes of varying dimensions and at present these lakes are also under threat.Dharmapalan [18] has illustrated the degradation of Vellayani lake in Thiruvananthapuram district. The lake got reduced in areal extent from 750 hectares in 1926 to 450 hectares due to encroachment for cultivation and construction, and is also subjected to pollution and sand mining rendering the water unfit for drinking and altering the biodiversity. Geethu et al [19]assessed the water quality of Polachira lake from April2013 to March 2014 and found thatwater quality parameters like pH, BOD, nitrite and conductivity were not satisfactory. High value of chloride recorded in the month of July was attributed to municipal, industrial and animal waste. Lakshmi and Tessy [20]assessed the impact of poultry and aquaculture pollution on the water quality of Vallivattom Wetland in Thrissur district. Analysis of physico chemical parameters of surface water samples collected from sites near poultry farm and prawn culture field in 2012 showed that the water quality at these sites was degraded. 32 phytoplankton genera were identified, of which 18 were pollution indicators. The addition of poultry wastes stimulated luxuriant growth of algae in water which reduced the oxygen content in the water.The Environment Impact Assessment of ecotourism in Pookote lake, Wayanad was done by Thomas et al [21] using Rapid Impact Assessment Method. Negative impacts of tourism outweighed positive aspects. The lake was threatened by excessive weed growth, deforestation in the catchment area, replacement of natural vegetation by plantations etc. Boundary of the lake being feeble, caused soil deposition in the lake. Mitigation measures suggested include biological control of weed (Cabomba furcate) by introduction of weevil, use of rock filter dams and silt mats to trap sediments, afforestation in catchment area, reduction of use of fertilizers and pesticides in catchment area, mass awareness programs etc.

2.3 Rivers:44 rivers flow through Kerala of which 41 flow westward and 3 eastward. These river are a victim of population pressure, rapid urbanization and pollution. Numerous studies exist on the evaluation of physico chemical characteristics of rivers of Kerala. However this review paper includes only those studies in which the results of water quality parameter analysis have been explained as a consequence of human interventions.

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Kallarackal [22] explained the hydrological impact of replacing natural vegetations with plantations like eucalyptus, rubber, teak, coffee, softwood etc in the Western Ghats. Unlike in land covered by natural vegetation, lack of humus content and reduced infiltration of rainwater in areas covered by plantations adversely affected water table recharge and stream flow. Water yield from a catchment is determined by the type of species of plantation because of varying evapotranspiration properties of different species. Replacing grass and scrub with fast growing trees decreases dry season water yield. Plantation trees consume more water during the active growing season thereby decreasing stream flow. Chattopadhyayet al [23] analysed the physico-chemical characteristics of water samples spread over five land use types in the study area between the Poringalkuttu reservoir and the confluence of Chalakudy river and the Periyar river and found that water under urban land use showed poor quality throughout the year.

Muraleedharan et al [24] analysed the effect of land use change on selected biophysical and socio-economic aspects of Karuvannur river basin. The analysis showed that conversion of forest land to agricultural land by almost 50% from 1960-61 to 2004-05 reduced water availability in the area. Degradation of forests and frequent shifts in cropping pattern resulted in sedimentation in Peechi Dam. Jennerjahn et al [25] studied effect of land use on the biogeochemistry of dissolved nutrients and suspended and sedimentary organic matter in Kallada river and Ashtamudi estuary. Increased nutrient concentrations were seen during the rainy season sometime after the major fertilizing. Though nitrate concentration was low owing mainly to moderate use of nitrogen fertilizer and efficient absorption by crops, phosphate content was high due to high phosphate fertilizer application as acidic laterite soils are deficient in phosphate. Arun Raj and Vasudeo [26] showcased how human activities like river bed sand dredging and navigable channel dredging contributed to salinity intrusion by taking Valapattanam river in Kannur district as a case study. Rajan and Keerthika [27] also dealt with Valapattanam river and analysed seasonal variations of physico-chemical parameters and salinity intrusion in the river. The river water quality was degraded mainly due to waste discharge from housing area, sewage, detergents and automobile oil waste. Harikumar [28] reported that land reclamation, unscientific tourism, sand mining, faulty agricultural practices along catchment area, urbanization, waste disposal threatened the biodiversity of Kavvayi wetland ecosystem. The wetland was contaminated with organic chlorine pesticide, iron, manganese, copper, lead, cadmium, zinc, nickel etc. Khalid et al [29] screened and quantified emerging contaminants in Periyar river using high resolution mass spectrometry. Water samples collected during 2014 and 2015 revealed 37 compounds included under the category of pharmaceuticals and personal care products, UV filters, steroids, and surfactants. This pollution was attributed to unscientific waste disposal from hospitals, industries, residential and municipal areas because there aren't many pharmaceutical industries near the sampled sites. Mohan and Krishnakumar [30] examined concentration of major and trace elements in the sediments of Kallada river basin. Industrial waste and sewage caused accumulation of copper in river sediments. Waste from metal manufacturing industries led to zinc pollution and zirconium pollution. High levels of potassium was

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observed due to deterioration of plants and animals, industrial spills etc. Paint pigments caused high titanium levels. Sonu et al [31]emphasized that adoption of ecological boundary based planning in place of administrative boundary based planning could solve many environmental problems. The hydrologic modeling of Kuttanad and Meenachil river basin using SWAT and HEC-RAS validated that the increasing built-up and wasteland coupled with the decrease in vegetation would accelerate the surface runoff rate, decrease infiltration into aquifers and enhance the intensity of floods. Land use land cover maps projected for 2025 also corroborated that increase in impervious surface will contribute to flooding, landslides and other disasters. Saha and Paul [32] analysed spatiotemporal trends of 22 physicochemical parameters of the water in the Chaliyar River inn 2017 and 2018 and found that water in the upstream stretches and middle stretches of the river were in ‘‘good’’ status and ‘‘moderate’’ status respectively whereas the lower stretch was in ‘‘very poor’’ to ‘‘unsuitable’’ status with severe anthropogenic stress.

2.4 *Estuaries and Backwaters*:The coastal state of Kerala has many estuaries and backwaters. Nair and Azis [33] in their study of ecology of Ashtamudi estuary showed that effluents from paper mills and dredging for sand did not allow large-scale colonization by benthic fauna during pre-monsoon and post-monsoon periods.The impact of coconut husk retting on environmental factors and fish seed availability was studied by Ambika Devi [34] by evaluating the physico-chemical properties of retting wells in Cochin backwaters. High concentration of sulphides, phosphates and organic carbon, high BOD values and low pH values were observed. Crustaceans were absent in the extremely polluted site. In the retting areas species diversity of polychaetes and crustaceans, population density of zooplankton and animal population were low as compared to non-retting areas. Bijoy [35] studied impacts of coconut husk retting in Kadinamkulam backwater in Thiruvananthapuram district. Kumary et al [36]demonstrated how pollution from domestic waste and coconut husk retting influenced quality of water of Adimalathura estuary. Samples of water were collected during 1995-96. The western bank of the estuary was densely populated and sewage and sullage were disposed into the estuary. Therefore water samples collected from the site located near waste disposal site showed low concentration of oxygen, maximum concentration of nitrate, high levels of nitrite, phosphate and silicate-silicon.

Jayachandran et al [37] analysed how anthropogenic activities affected the water quality of Kodungallur-Azheekode estuary by collecting water samples monthly from July 2009 to June 2010. Agricultural runoff, influx of silt content and sewage increased the level of turbidity, dissolved oxygen and carbon dioxide in the estuary. Sand mining, faulty agricultural practices and poor urban planning caused high concentration of allochthonous and autochthonous nutrients. Extensive sand mining increased the mean depth of the estuary from 2m to 3.6m.John et al [38]reported environmental degradation of Paravur estuary. Sand extraction in theParavur estuary and Ithikkara river which flows into the estuary disrupted the drainage network, lowered the river bed in the storage zone and caused water logging. From 1920 to 2014, 1.29km^{2}of the estuary was reclaimed for agriculture, construction etc. Improper maintenance of the Flood Water Outlet System altered the sediment balance of the coastal zone and led to the formation of a flood

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tide island. Suggestions for proper management of the estuary includes EIA of all development projects near coastal wetlands, environmental auditing during post project period, preparation of a restoration plan to revive Paravur estuary, environmental auditing before granting permission for mining, awareness campaigns regarding services provided by estuaries etc. Premodh and Srinivasan [39]analysed the impact of house boat tourism on Alappuzha backwaters. Toilet waste, plastic and oil are discharged directly into the backwater. Coliform bacteria is high in the water causing skin infections and jaundice among the local residents. There is shortage of drinking water. Discharge of oil from engines affect the aquatic life. Paddy fields located nearby are also affected as they are irrigated by polluted backwater and agricultural labourers are reluctant to work in these polluted fields.

2.5. *Mangroves*:Mangroves are unique wetlands which provide ecosystem services like coastal stabilization, carbon sequestration, supporting biodiversity, storm protection etc. Mangroves of Kerala are under serious threat due to human activities as illustrated in many research studies.

Khaleel and Jaleel [40]studied environmental challenges to the mangrove wetlands of North Malabar. They were challenged by human activities likeillegal reclamation, building of water based recreational facilities, and conversion of natural ponds for aquaculture. Human actions upstream of catchment area affected mangroves indirectly. Suggestions for sustainable development included designing of coastal structure near mangroves to avoid excess sedimentation or erosion, avoiding waste disposal near mangroves, preparation of an inventory of mangroves, continuous monitoring of reaction of mangroves to extraction of forest and fishery products, practice of non-destructive aquaculture, afforestation, promotion of ecotourism etc. Sheela [41] identified mangroves and mangrove associates of Thrissur district and reported that threats faced by mangroves include faulty agricultural practices, encroachment, aquaculture, pollution etc. In Chettuva sand mining is prominent which destroy mangroves. In Mullassery panchayat school students and environmentalists have started a mass movement for conservation and afforestation of mangroves.

Distribution, diversity, stand structure and challenges of mangroves in Kerala were studied by Vidyasagaran and Madhusoodanan [42] Sreelekshmy et al [43] and Surya [44]. The mangroves of Trivandrum district is under threat from reclamation of Veli backwaters for housing and developmental activities. Unscientific land use pattern and real estate activities caused the loss of mangrove vegetation in Kozhikode district. In Thrissur district Chettuvai and Kodungallur mangroves are victims of ecotourism and real estate activities respectively.In Kollam district Asramam mangrove site got degraded due to conversion and real estate activities. In Kottayam district tourism damaged mangroves in Kumarakom. Development projects in Cochin are the culprit in Ernakulam district. Vidyasagaran and Madhusoodanan [42]reported that area under mangroves in Kerala declined from 700 km^2 to 17 km^2. Chandran et al [45] estimated the distribution and diversity of mangroves in Ernakulam district and found that mangrove vegetation in Ernakulam is now restrained largely to river mouths and tidal creeks. The

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mangrove ecosystem underwent serious alterations mainly due to commercial exploitation, land reclamation for agriculture, aquaculture and housing, mining etc. While enumerating the aquatic and semi aquatic macrophytic flora of Kodungallur bachwaters and Azheekode estuary, the Vaheeda and Simon[46] found that the area is lacking in diversity of mangroves. Though the range of salinity of water is ideal for mangrove growth, factors such as human intervention, nature of substratum, invasive species prevent the growth of mangroves. Anthropogenic impacts such as waste disposal, sand mining, encroachment, coir retting, disruption of natural flow of water etc have adversely affected mangroves of this area.Sneha [47]mapped and monitored the change in Nettoor mangroves in Kochi from 1992 to 2019 by calculating Normalized Difference Vegetation Index. These mangroves were also threatened by human intervention.

2.6. *Canoli Canal*: Canoli Canal is part of the National waterway III of India. Hamno and Petterson [48] reported that indiscriminate encroachments, dumpling of liquid waste from residential areas and hospitals and solid waste from industries and hoses threatened the Canoli canal. The impact of waste disposal on the aquifers surrounding canoli canal in Kozhikode district was studied. Vulnerability of aquifers was also predicted. Samples of water were taken from wells, from the canal, from the sea and from precipitation. Results of analysis showed that correlation existed between chemical composition of ground water and distance from canoli canal. Bacteriological analysis revealed that coliform bacteria content decreased as distance from the canal increased. 75% of the samples contained Ecoli. Chloride levels were high and phosphate content increased with distance from the canal. Groundwater in the region was not suitable as drinking water

2.7 *Reservoirs:*Published literature on reservoirs of Kerala mainly pertained to analysis of physico-chemical properties, biodiversity, and the role of reservoirs in the 2018 Kerala flood. Studies on anthropogenic impacts on reservoirs were scant. However John et al [49] demonstrated how accelerated soil erosion due to anthropogenic activities reduced the storage capacity of reservoirs in the Bharatapuzha River basin. Using Revised Universal Soil Loss Equation (RUSLE) the impact of land use–land cover and climatechanges on soil erosion was analysed and prediction of soil erosion was done for years 2020 and 2035. The river basin experiences rapid increase in impervious surfaces and bare land and a reduction in vegetation from 1990 to 2017. Projected land use for 2035 shows that this trend in land use land cover will intensify and soil erosion will increase leading to reduction in storage capacity of reservoirs

2.8. *Region-wise studies*:There are also studies pertaining to wetlands of a particular district or region. Kokkal et al [50] conveyed the message that man-made destruction to wetlands in turn affects human life adversely apart from destroying biodiversity. As only those fish species which could withstand below par water quality conditions could survive in polluted waters, commercially important fishes disappeared affecting the socioeconomic condition of the rural fishermen. Agricultural land reduced due to conversion and reclamation of wetlands like the Kuttanad, Kole, Pokkali and Kaipad areas. Choking of

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drainage channels increased siltation and affected drainage capacity of channels resulting in flash floods. Uncontrolled water runoff and reduced ground water recharge lead to severe drought conditions in the summer season. The authors suggested that central, state, municipal and customary laws should be geared up to protect wetlands.Jayadev[51] identified the cause of wetland destruction in Kollam district. From 1974 to 2004 wetland area decreasedbyover 50%. The paddy fields also decreased by 18000 hectares. The major threat to the wetlands are from land use changes like wetland reclamation for housing, industrial and infrastructural development, changing pattern of agriculture and aquaculture, retting of coconut husk, waste disposal, sand mining etc. Future land use change prediction using Markovian chain analysis showed that paddy fields will continue being converted to other land use types in the future. Dipson [52] studied spatio temporal changes in wetlands of Cochin City using remote sensing and GIS. From 1973 to 2011, wetlands shrunk by 11.76%. The Pokkali fields declined by 13.72%. NH-47 Bye-pass construction and development of Infopark contributed to the reduction of fields during 1990-1998 and 1998-2007 respectively. Suraj and Neelakantan [53] demonstrated the impact of sand mining on paddy wetlands of Thrissur district focussing on Nenmanikkara panchayat of Mukundapuram taluk. Paddy wetlands of Thrissur district being rich in clay suitable for clay brick and tiles are mined extensively, deteriorating this wetland. After mining these paddy fields are left waterlogged, unsuitable for paddy cultivation and the biodiversity is also affected. In 2010, 0.46% of total geographical area of the study area was waterlogged due to clay mining. Paddy wetlands decreased by 238.08 km2 from 1966 to 2010. Measures suggested for proper land management include refilling of mining pits, utilization of waterlogged mining pits for pisciculture and floriculture, using fly ash bricks produced from thermal power plants as alternative to clay bricks. Prasanth [54] demonstrated the impact of industries on the quality of soil and water in Koratty region in Thrissur district. Water in wells, ponds and water courses of Koratty were acidic and contaminated with oil, grease, heavy metals iron, manganese and zinc. Dissolved oxygen (DO) levels were lesser than the desirable level. Coliform bacteria was recorded at very high levels in many of the wells and ponds. Bindu and Mohamed [55] reported that wetlands of Kodungallur town were a victim of rapidly changing land use pattern and land transformation due to increased urban land values, waste disposal, dredging, mining, eutrophication, siltation, salt water intrusion etc. Measures suggested for sustainable development of Kodungallur include rainwater harvesting, planting mangroves, eco-restoration of waterbodies, watershed management etc.

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3. CONCLUSION

Wetlands are crucial for the survival of every region. Degradation and destruction of wetlands spell destruction of life and environment. Unscientific land use including destruction of wetlands adds to the fury of disasters like floods, draughts and cyclonesThough numerous studies exist regarding threats faced by wetlands and measures for their revival and conservation have been suggested, most of the time these recommendations remain in paper only and are not implemented. Though attempts have already been made towards protection of these ecosystems, more needs to be done. Apart from creating awareness among general public regarding the importance of wetlands and the ecosystem services rendered by them, the Government must give priority to conservation of wetlands while framing developmental projects. Various non-governmental organisations can also play a major role towards this cause.

REFERENCES:

1) Ramsar Convention Secretariat. The Ramsar convention manual: a guide to the convention on wetlands (Ramsar, Iran, 1971),Ramsar Convention Secretariat, Gland, Switzerland. 6th ed. 2013; 7.
2) SAC. National Wetland Atlas: Kerala. Space Applications Centre (ISRO), Ahmedabad, India. 2010; 19-21.
3) Information Sheet on Ramsar Wetlands (RIS) https://rsis.ramsar.org/RISapp/files/RISrep/IN1214RIS.pdf
4) Gopalan UK, Vengayil DT, Udayavarma VP, Krishnankutty M. The shrinking backwaters of Kerala. Journal of the Marine Biological Association of India, Cochin. 1983; 25(1): 131-141.
5) Gopakumar R,TakaraK. Analysis of bathymetry and spatial changes of Vembanad Lake and terrain characteristics of Vembanad Wetlands using GIS. IAHS Publication. 2009; 331:402-411
6) Krishnadas H. Assessment of Land Reclamation of Wetlands: A case of Vembanad Wetland, Kerala. International Conference on Urban and Regional Planning. 2014;1-18
7) Mani K, Gopalan R, Suraj KD. Spatial Distribution of Non-Point Source Pollution of Vembanad Lake, Kerala, South India. . International Journal of Engineering Research & Technology. 2013; 2 (11): 787-793.
8) Vincy MV, Rajan B, Pradeep Kumar AP. Water quality assessment of a tropical wetland ecosystem with special reference to backwater tourism, Kerala, South India. International Research Journal of Environment Sciences. 2012; 1(5): 62-68.
9) John TK. Muriyad wetlands: ecological changes and human consequences human consequences. [Project report]. Thiruvananthapuram, Kerala Research Programme on Local Development: Centre for Developmental Studies; 2003.
10) Raj PN, Azeez PA. Real estate and agricultural wetlands in Kerala. Economic and Political Weekly. 2009: 63-66. Assessed 23 July 2018
Available: http://www.jstor.org/stable/40278461
11) Srinivasan J. 2010. Understanding the Kole lands in Kerala as a multiple use wetland ecosystem. Research Unit for Livelihoods and Natural Resources, Working Paper No. 5. 2010. Assessed 12 February 2020
Available: https://www.researchgate.net/publication/228854373
12) Vimod KK, Kishore A. Impact of Urban Sprawl on Land Use in Kole Wetlands of Thrissur. 2015. Assessed 11 January 2018

Available: westernghats-aspn.osgeo.in

13) Jenin JS, Bhaskara K. Study on Kokkala canal water in Kole lands near Thrissur Corporation and its effects on paddy fields. International Journal of Engineering Research and Modern Education. 2017; 299-302.

14) Jayan PR, Sathyanathan N. Overview of farming practices in the water-logged areas of Kerala, India. International Journal of Agricultural and Biological Engineering. 2010; 3(4): 28-43.

15) Sreejith KA. Human impact on Kuttanad wetland ecosystem-an overview. International Journal of Science and Technology. 2013; 2(4): 679-670.

16) Sreekumari VM, John SE, Rajan RT, Kesavan M, Kurian S, Damodaran P. Human interventions and consequent environmental degradation of a protected freshwater lake in Kerala, SW India. Geosciences Journal, 2016; 20(3): 391-402.

17) Divya RS, Kani KM. Water quality assessment of Sasthamcotta lake, Kollam, Kerala. International Journal of Engineering and Advanced Technology. 2018; 7(3): 119-129.

18) Dharmapalan B. Conserving the Vellayani Lake. Science Reporter. 2014; 22-24

19) Geethu G, Babu NS, Nair TV. Water quality assessment of Polachira wetland in Kerala. Journal of Advances in Biological Science. 2015; 2 (1&2): 41-44

20) Lakshmi TG, Tessy PP. Impact of poultry and aquaculture pollution on the water quality of Vallivattom wetland, Thrissur district, Kerala.Meridian. 2016; 5 (1):19 – 21.

21) Thomas TT, Sony CD, Kuruvila EC. Rapid environmental impact assessment of eco-tourism in Pookote Lake, Wayanad. International Research Journal of Engineering and Technology. 2017; 4(4): 3149-3154.

22) Kallarackal J. Impact of Converting Natural Vegetation into Plantations on the Watershed Hydrology of the Western Ghats of Kerala. Proc. Workshop on Watershed Development in Western Ghats Region, February. 2000;102-107

23) Chattopadhyay S, Rani L A, Sangeetha PV. Water quality variations as linked to land use pattern: a case study in Chalakudy river basin, Kerala. Current Science. 2005; 89(12): 2163-2169. Assessed 21 April 2022
Available https://www.jstor.org/stable/24111081

24) Muraleedharan PK, Kallarackal J, Menon ARR, Balagopalan M, Sasidharan N, Rugmini P. Land use change and its impact on selected biophysical and socioeconomic aspects of Karuvannur river basin in Thrissur district of Kerala. Kerala Forest Research Institute Research Report No 298. 2007.

25) Jennerjahn T C, Soman K, Ittekkot V, Nordhaus I, Sooraj S, Priya R S, et al. Effect of land use on the biogeochemistry of dissolved nutrients and suspended and sedimentary organic matter in the tropical Kallada River and Ashtamudi estuary, Kerala, India. Biogeochemistry. 2008; 90(1): 29-47. DOI 10.1007/s 10533-008-9228-1

UNDER PEER REVIEW

Assessed 23March 2018. Available: http://www.jstor.org/stable/40343615

26) Arun Raj N, Vasudeo AD. Salinity Intrusion of Valapattanam river, Kerala. International journal of Engineering Research and Technology. 2015; 4(11):710-713.

27) Rajan DS, Keerthitha T. Seasonal Variations of certain physico-chemical parameters in the Valapattanam River of Kannur district, Kerala. Journal of Indian Association for Environmental Management. 2021; 41(2): 29-35.

28) Harikumar S. Wetlands of Kerala: Degradation, Restoration and Future Management-A Case Study of Kavvayi wetlands- a coastal wetland in the northern Kerala. Proceedings of Lake: 2016: Conference on conservation and sustainable management of ecologically sensitive regions in Western Ghats. 2016; 250-253. Assessed 21 March 2018. Available http://ces.iisc.ernet.in/energy

29) Khalid NK, Devadasan D, Aravind UK, Aravindakumar CT. Screening and quantification of emerging contaminants in Periyar River, Kerala (India) by using high-resolution mass spectrometry (LC-Q-ToF-MS). Environmental monitoring and assessment, 2018; 190(6): 1-12. Assessed 19 April 2022. Available: https://doi.org/10.1007/s10661-018-6745-9

30)) Mohan U, Krishnakumar A. Geochemical aspects and contamination evaluation of major and trace elements in the sediments of Kallada river, southern Western Ghats, India. Journal of Environmental Science and Health. Part A, 2022. DOI:10.1080/10934529.2022.2053450. Assessed 17 April 2022. Available: https://www.tandfonline.com/loi/lesa20

31) Sonu TS, Mohammed FC, Bhagyanathan A. The impact of upstream land use land cover change on downstream flooding: A case of Kuttanad and Meenachil River Basin, Kerala, India. Urban Climate, 2022; 41: 1-24. Assessed 19 April 2022
Available: https://doi.org/10.1016/j.uclim.2022.101089

32) Saha A, Paul TT, Sudheesan D, Sharma SK, Suresh VR, Das BK, et al. Assessment of spatial and temporal changes in water quality of a tropical river in southern Western Ghats, Kerala, India, using physicochemical quality indices and multivariate analysis. Natural Resources Research. 2022; 1-27. Assessed 17 April 2022. Available: https://doi.org/10.1007/s11053-022-10040-z

33) Nair NB, Azis PA. Ecology of the Ashtamudi Estuary, southwest coast of India. Journal of the Marine Biological Association of India. Cochin.1987; 29(1): 177-194.

34) Ambika Devi M. Ecological studies on coconut husk retting areas in the Cochin backwaters and its relation to fish seed availability. Dissertation submitted to Cochin University of Science and Technology. 1988

35) Bijoy N S. Retting of coconut husk - a unique case of water pollution on the south west coast of India. International Journal of Environmental Studies. 1997; 52:1-4: 335-355, DOI: 10.1080/00207239708711110

UNDER PEER REVIEW

36) Kumary KA, Azis PA, Natarajan P. Water quality of the Adimalathura Estuary, southwest coast of India. Journal of Marine Biological Association of India. 2007; 49 (1): 1-6.

37) Jayachandran PR, Bijoy NS, Sreedevi OK. Water quality variation and nutrient characteristics of Kodungallur-Azhikode Estuary, Kerala, India. Indian Journal of Geo-Marine Sciences. 2012; 41 (2): 180-187

38) John SE, Rajimol TR, Mohan SV, Maya K, Padmalal D. Environmental degradation of a tropical estuary due to human interferences—a case study from southern Kerala, SW India. Arabian Journal of Geosciences, 2017; 10(16): 1-15.

39) Premodh N, Srinivasan C. Impact of Houseboat Tourism–A Study on Alappuzha Region, Kerala. Annals of the Romanian Society for Cell Biology, 2021; 25(6): 7475-7489.

40) Khaleel KM, Jaleel CA. Environmental challenges to the mangrove wetlands of north Malabar (Kerala), India: their sustainable development and influence on local people. Knowledge and Management of Aquatic Ecosystems. 2009; 392, 03: 1-8. DOI: 10.1051/kmae/2009009

41) Sheela FK. Identification of mangroves and mangrove associates of Thrissur district, Kerala, their adaptive biology, germination study and nutritive value. [Minor research project]. UGC; 2013.

42) Vidyasagaran K, Madhusoodanan VK. (2014). Distribution and plant diversity of mangroves in the west coast of Kerala, India. Journal of Biodiversity and Environmental Sciences. 2014; 4:38-45.

43) Sreelekshmi S, Preethy CM, Varghese R, Joseph P, Asha CV, Nandan S B et al. Diversity, stand structure, and zonation pattern of mangroves in southwest coast of India. Journal of Asia-Pacific Biodiversity. 2018; 11(4): 573-582.

44) Surya S, Hari N. Diversity analysis and present status of Mangroves from Kerala, West coast of India. International Journal of Advanced and Innovative Research. 2018; 7 (6): 1-15

45) Chandran S, Prakash L, Geetha P, Raj A. (2014). Estimation of mangrove vegetation density in Ernakulum district of Kerala. 15th Esri India User Conference.2014. Available www.esri.in

46) Vaheeda KK, Simon T K. Aquatic and semi aquatic macrophytic flora of brackish waters of Kodungallur, Thrissur District, Kerala. Annals of Plant Sciences. 2014; 3(06): 748-751.

47) Sneha T G. Mapping and monitoring of Nettoor mangroves. [Project report]. Dept. Of Environmental Science, Sacred Heart College, Centre for Environmental Studies; 2020.

48) Hamno A, Petterson A. Impact of Major Waterway Systems on Groundwater Quality. [Master's Thesis] TRITA-LWR, Stockholm; 2005.

49) John J, Rosamma CN, Thampi SG. Assessment and Prediction of Soil Erosion and its Impact on the Storage Capacity of Reservoirs in the Bharathapuzha River Basin, India. Environmental Modeling & Assessment. 2022; 27(1):77-103.

50) Kokkal K, Harinarayanan P, Sahu KK.Wetlands of Kerala. In Proceeding of Taal 2007: The 12th World Lake Conference. 2008; 1889-1893

UNDER PEER REVIEW

51) Jayadev SK. The status of wetlands in Kollam district. [PhD Thesis]. University of Kerala; 2012

52) Dipson PT. Spatio-temporal changes in the wetland ecosystem of Cochin city using remote sensing and GIS. [PhD Thesis]. Cochin University of Science and Technology; 2012. Assessed 24 July 2018

Available: http://dyuthi.cusat.ac.in/purl/3750

53) Suraj R, Neelakantan R. Detection of land use pattern changes and management priorities for Thrissur district, Kerala, India. International Journal of Remote Sensing & Geoscience. 2013; 2(1): 22-29.

54) Prasanth KM, Thomas T P. Soil and water quality as influenced by land use in Koratty, Kerala. [PhD Thesis]. Cochin University of Technology; 2016

55) Bindu CA, Mohamed AR. Water bodies as a catalyst to growth and development- the case study of Kodungallur town, Kerala. Procedia Technology. 2016; 24:1790-1800.

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