ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 7, Issue 1, pp: (250-257), Month: January - March 2019, Available at: www.researchpublish.com

Land degradation and water quality assessment of a part of Thrissur Kole wetland, Kerala, India –Ramsar site

Sinta K .B[1], Sreekumar.S[2], Diljo Jose .T[3], Harilal C.C[4]

Department of Geology and Environmental science, Christ College, Irinjalakuda. University of Calicut.Kerala
Division of Environmental science, University of Calicut, Malappuram .Kerala

Abstract: **The Kole wetlands already been declared as complex Ramsar sites in Kerala, India. The study involves to assess the degradation of Vembanad kol wetland (Ramsar site), Kerala, India using Remote Sensing (RS) and Geographical Information Technology (GIS) and to monitoring the monthly water quality with special reference to salinity in surrounding areas of kole wetland system. By analyzing the data such as Survey of India toposheet (1969), LANDSAT image (2001) and IRS P-6 satellite image (2008) showed a significant degradation of Kole wetland from 61% to 28% during the period 1969-2008 respectively. It is inferred that Kole land area shrinked by 10 percent within a period of 32 years (1969-2001).Seven ground water samples were collected during the period of September 2007 to July 2008 and the quality of groundwater has been made through the analysis of physical and chemical parameters. The conductivity value ranged between 50µmhoscm^{-1} (Well-7) to 400 µ mhoscm^{-1} (Well-1) and showed the variation in peak season.(April, June and November). This is due to the saline water inflow in to inlet of Chettuva estuary during peak summer season. All parameters within the drinking water permissible limit prescribed by BIS except pH and Turbidity. The study confirm that the extent of salinity is confined in an area of inlet of chettuva estuary.**

Keywords: **Kole wetland, Vembanad Kole, Water quality, Salinity.**

1. INTRODUCTION

Wetlands are ecotones or transitional zones that occupy an intermediate position between dry land and open water. It is highly productive areas with rich biodiversity; they serve as a spawning and nursery ground for fishes, reptiles, birds, mammals etc. and hence can be used as an excellent area for conservation of rare and endangered species (Gopal, 1992). Wetlands are of great economic, cultural, scientific, and recreational value to human life. The wetlands are currently subjected to acute pressure owing to rapid developmental activities and indiscriminate utilization of land and water. During past Status and Trends studies the types of land use activities that most influence wetland conversions have been documented. These include Conversion of wetland in to agriculture, urban development rural development, forest plantation and other upland use (Dahl, 1993). Remote sensing and Geographical information Technology (GIS) have been used extensively by Status and Trends to monitor wetland acreage changes (Dahl, 1991). India has a wealth of wetland ecosystems distributed in different geographical regions. Twenty five wetlands in India are designated as Ramsar sites (WWF, 2006). State like Kerala is well known for its wetlands and these wetlands provide livelihood to the residents in the area in the forms of agriculture produce fish, fuel ,fiber ,fodder ,and a host of other day-to-day necessities .As much as one fifth of the State's total land mass is wetlands which include a vast network of backwaters, lagoons ,mangrove ecosystem, natural lakes, ponds, tanks, rivers and canals, manmade reservoirs, ponds et From Kerala, three wetlands were included in the list of Ramsar sites(2002)-Vembanad Kole wetlands, Ashtamudi lake, Sasthamkotta lake (WWF,2006).The Kole wetlands already been declared as complex Ramsar sites. The name "Kole" refers to the peculiar type of cultivation carried out from December to May and this Malayalam (mother tongue of state Kerala, India) word indicates bumper yield of high returns in case floods do not damage the crops (Johnkutty and Venugopal, 1993).The

ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 7, Issue 1, pp: (250-257), Month: January - March 2019, Available at: www.researchpublish.com

usually flooded areas of the Thrissur Kole wetland also suffered from salinity intrusion through the inlets at Chetwai and Kottappuram. Enammakkal barrage was constructed about five decades ago, to prevent salinity intrusion into the Kole lands from Chetwai. Regulator at Enammakkal and the minor one at Kottenkottuvalavu in the lower reach of the Karuvannur river act both as spillway for the flood waters from the Kole land and as a regulator of salt water entry (CED, 2007).The Kole wetlands with an extend of 13632 ha are spread over Thrissur and Malappuram districts in Kerala state (Johnkutty and Venugopal, 1993). It extends from the Northern bank of Chalakkudy River in Southern banks of Bharathapuzha River in North. Eastern side of the Kole wetlands is Thrissur town and Western side extend up to Arabian Sea.

2. STUDY AREA

The present study area covers the northern part of kole land which includes the boundaries of Panchayat Manaloor, Venkitangu, Mullassery, Elavally, Tholur, Adat and a part of Thrissur Corporation. The study area falls within the Latitude76^0 3'0"E to 76^0 15' 0"E and Longitude10^0 30' 0" N to 10^0 39'0" N (Fig.1). The study area covers an area of about 153.6sq.km. The Kole wetlands are low lying tracts located 0.5 to 1 meter below MSL and it remains submerged for about six months in year.

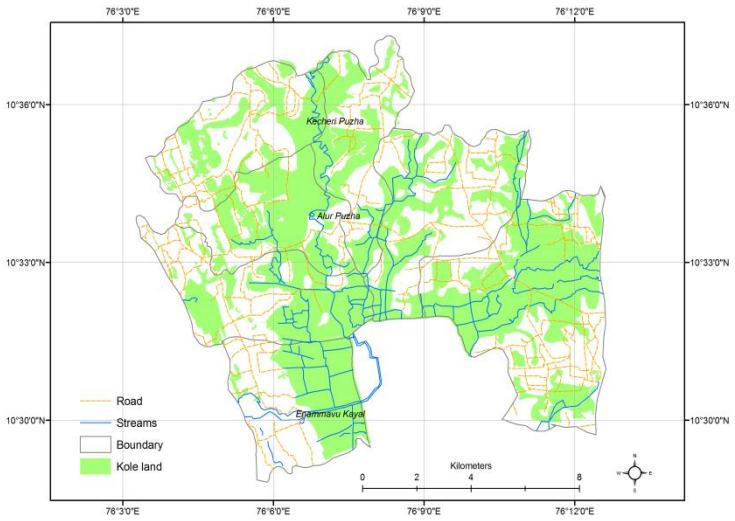

Fig 1: Study area

These lands were formerly shallow lagoons which gradually were silted up. Keecheri and Karuvannur rivers being the flood water into the wetlands which finally empty into Arabian Sea. These rivers in spate discharge the flood waters into the low lying Kole wetlands and raise the water depth to more 550cm.The Kole wetlands function as the flood basin for both the rivers. The climate is moderate and 4 different seasons-dry weather from December to February, hot weather from March to May, South-West monsoon from June to September and retreating or North East monsoon from October and November. About 60 percent of rainfall is obtained during South-West monsoon, 30 percent during North East monsoon and remaining 10 percent in summer. The average rainfall is 3200mm (James 1993) and there is temporal distribution of rainfall. At present the region appears as a saucer shaped basin flanked by laterite hills in the Western and Eastern margins. The valley fill material formed of gravel and sand of laterite composition mainly brought down laterite hills. Large quantity of nutrient rich alluvial soil gets deposited during the process of inundation making the wetlands highly fertile for paddy cultivation. One hundred and nine Padasekharams (section of paddy fields) exist in Kole wetlands. The present study aimed to assess the degradation of Vembanad Kole wetland (Ramsar site) using Remote Sensing (RS) and Geographical Information Technology (GIS) and to monitoring the seasonal water quality with special reference to salinity in surrounding areas of Kole wetland system.

3. MATERIALS AND METHODS

The spatial and temporal changes Kole-wetland are mapped using Survey of India-topographical maps and remote sensing data. This study done by using the GIS soft ware ArcGIS 9.2, Mapinfo9.2 and ERDAS IMAGINE 9.2.From the topographic sheet (1969), the boundary of Kole land with communication arteries and drainage network has been

delineated (Fig.1). The study of topographic forms or geomorphologic units or land forms is the Science of Geomorphology. On screen visual interpretation of Land sat TM data has been carried out to identify various landforms taking into consideration the various images and terrain elements. A popular GIS package was used to mark the polygons of various landforms .The landforms, which are very important in wetland ecosystems are digitized and their distribution has been delineated from the remotely sensed data using standard image interpretation elements and characters. Reconnaissance and validation survey has been carried out for the present study. During reconnaissance survey GPS reading has been collected randomly from different places of the study area. These GPS readings were used to locate the places in the imager to get an overall idea about these places and this was helpful for the preparation of thematic maps. Three data such as Survey of India toposheet (1969), LANDSAT, IRS P-6 were used for assessing the change in kol wetland during the period 1969-2008. Details of data used in GIS as shown in the Table 1.

Table 1: Materials used for the study

Types Of Data	Details of the data	Source of the data
Survey of India(SOI)Toposheet	58B2,58B3 (1969)	Survey of India(SOI) Dheradhun
IRS P-6	1:50000,January,2008 Resolution-0.5m	NRSC Hyderabad
LANDSAT TM FCC	Resolution23.5 2001	NRSC Hyderabad

Seven ground water samples were randomly selected using statistical randomisation techniques (Levin, 1998) from different parts of study area. The more priority given to the areas where salinity intrusion facing the fringes of wetland. The sample collection done during the period of September 2007 to July 2008. The samples were collected in pre cleaned polythene bottles and were analysed according to methods prescribed by APHA (2005). The samples were treated on site and preserved by appropriate Method (APHA, 2005). pH analysed at the spot and other water quality parameters were analysed in the Environmental Laboratory, Christ College Irinjalakuda. The physico chemical and biological parameters analysed includes pH, conductivity, turbidity, total dissolved solids, total hardness and salinity etc. Table-2 showing the Locations of sampling site.

4. RESULT AND DISCUSSION

After analyzing different land use maps, the area of kol land was determined. The data obtained from the survey of India toposheet (1969) shows that there was an area of about 80.26 sq.km during that time (Table-2, Fig.2). The analysis of data from the LANDSAT TM image 2001, the kole land area drastically decreased in a faster rate. The analysis showed that during that period there was only 59.96 sq km kole land in the study area (Fig.3). The kole lands are mainly used for building purposes and road construction. The human settlements were traditionally concentrated around the wetland systems and the reasons are obvious.

Table 2: Locations of water sampling sites

SL no.	Sample	Location
1	Well -1 (W-1)	Manalur
2	Well -2 (W-2)	Mullassery
3	Well -3 (W-3)	Venkidangu
4	Well -4 (W-4)	Tholur
5	Well -5 (W-5)	Adat
6	Well -6 (W-6)	Thrissur
7	Well -7 (W-7)	Elavally

According to the census data (2001), the population of State Kerala doubled over five times in the last century (6 million in 1901 to 32 million in 2001) whereas India's population could grow slightly more than three times (238 million in 1901 to 1027 million in 2001).However, the trend has changed now and the population growth range in Kerala during the last decade works out to be 9.42 percent (for the whole India it is 21.34 percent), the lowest after the formation of Kerala State. According to the census data, the number of households in Kerala has increased from 55 lakhs in 1991 to 67 lakhs in 2001.The rapid urbanization and consequent development of infrastructure have taken a heavy toll to the wetlands.

ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 7, Issue 1, pp: (250-257), Month: January - March 2019, Available at: www.researchpublish.com

The increase in the population and households and urban expansion thus becomes major driving forces for most of the wetland issues identified. The urban expansion requires more wetland areas to be converted resulting to ecosystem changes and biodiversity loss. The recent studies from IRS P- 6 showed that there was a rapid decline in Kole lands during 8 years, the area reduced to 54.39 sq.km. (Fig.4). In Adatt panchayat, a number of commercial and residential building works are done .A leading company Sobha developers reclaimed 55acres of Kole land for their building projects. Reclamation for various developmental activities is still going on in these areas. The change in the distribution of Kole land area from 1969 to 2009 is illustrated in Fig.5 &Table 2. From the analysis it is inferred that Kole land area shrinked by 10 percent within a period of 32 years (1969-2001).However the decline is much faster in the last 7 years (2001-2008) (Fig.5) than the previous three decades. The study conducted by U.S. Fish and Wildlife Service (USFWS) describes the process with the objective of using GIS to identify geographically discrete areas where significant wetland changes are taking place and data indicate that this usually occurs in areas where rapid land use changes are ongoing, either because of population changes, agricultural or silvicultural practices, or changes in land values. (Richard D.Young et.al, 1994).

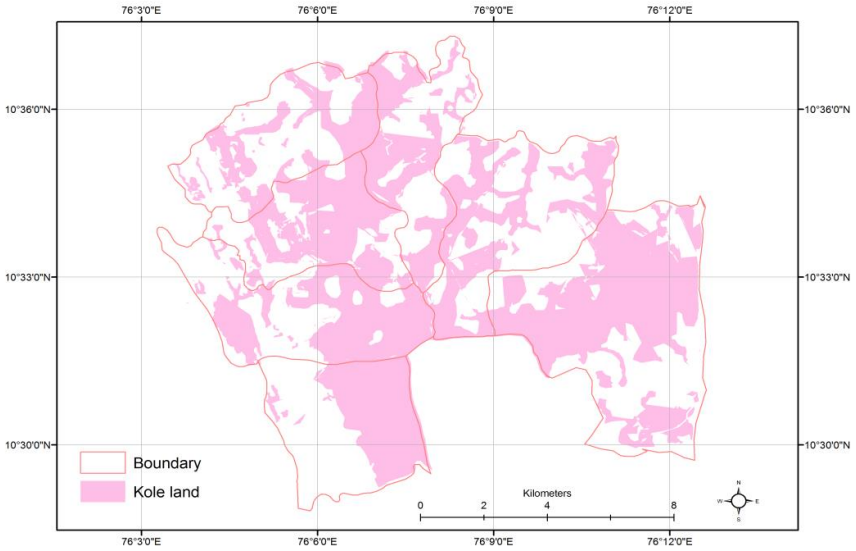

Fig 2: Kole land distribution in 1969

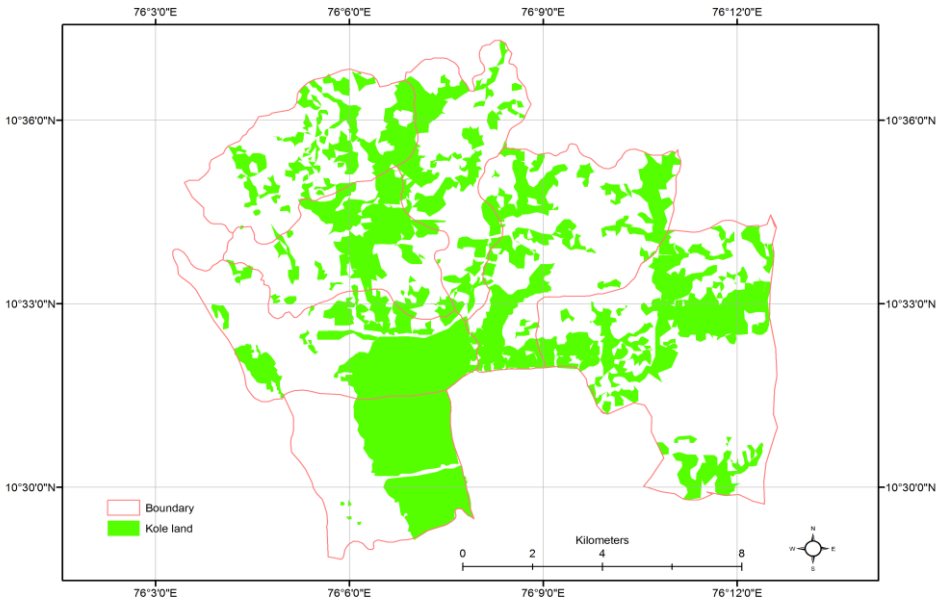

Fig 3: Kol land distribution in 2001

ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 7, Issue 1, pp: (250-257), Month: January - March 2019, Available at: www.researchpublish.com

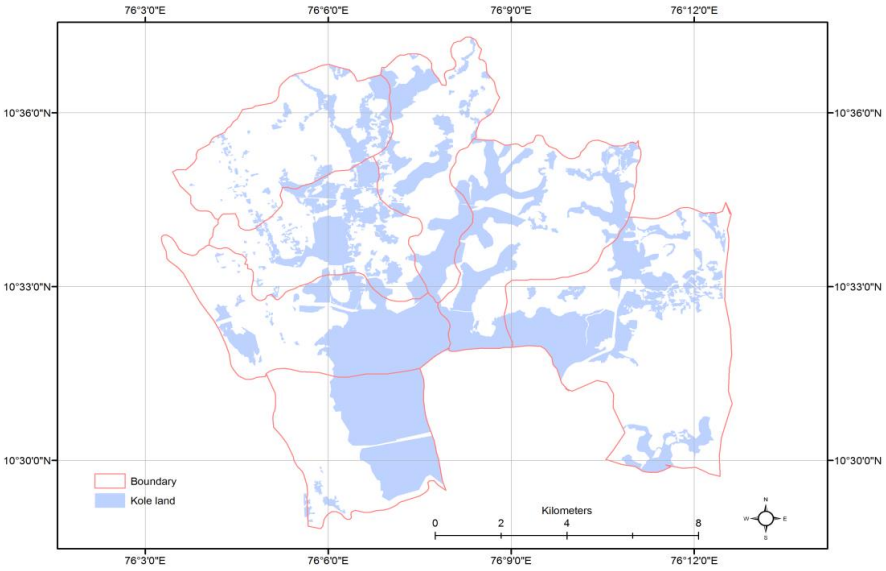

Fig 4: Latest distribution of Kole land as revealed from IRS P-6 2008

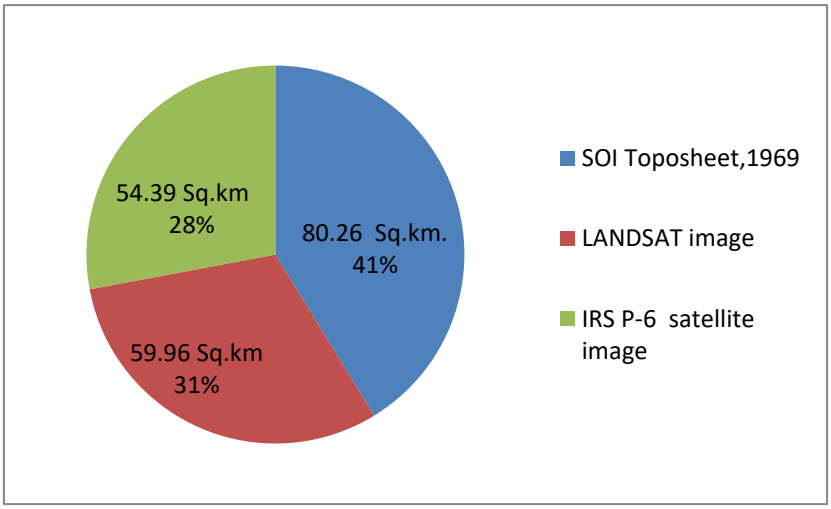

Fig 5: Change in Kole land area in different periods

Water quality characteristics with special reference to salinity:

The range and average values of various physicochemical parameters of the seven ground water samples as shown in Table 3&4. The physical and chemical water quality during the months of June 2008, April 2008 and November 2007 as shown in Table 5 and 6. From the analysis it was shown that pH of the water sample ranges from 6.20 (Well-5) to 7.8 (Well-1). According to BIS the desirable pH in drinking water is about 6.5-8.5. Average pH value of Well-5 is below the minimum value prescribed by BIS for drinking water. Samples showed both alkaline (Well-1, 2 and3) and acidic in nature (Well-4, 5, 6&7). pH showing slight decrease in July (monsoons) to April (pre monsoon).

Turbidity ranges from 0.34 (Well-7) to 10.66 (Well-1). According to BIS (1991) the desirable limits of turbidity is 5 NTU.Turbidity in Well-1 higher than limit prescribed by BIS. This well is located nearby site of the Enamavu Kayal in the north part of kole land area. Influence of Enamavu kayal affect the quality of wells which is the inlet of Chettuva Estuary.

Electrical conductivity value ranges from 50µmhoscm^{-1} (W-7) to 400 µ mhoscm^{-1} (W-1) .It has been suggested that the irrigation of water having conductivity lower than 250 µ mhos/cm does not contain enough salt to cause trouble. (Singh,1995). Conductivity more than 500 µ mhos/cm is not suitable for drinking purpose (Sharma B.K, 2007).The presence of salts and contamination with waste waters increase the conductivity of water (Trivedi and Goel, 1982). The well samples 1, 2 and 3 showing the high levels of conductivity value. The usually flooded areas of the Thrissur Kole

ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 7, Issue 1, pp: (250-257), Month: January - March 2019, Available at: www.researchpublish.com

suffered from salinity intrusion through the inlets at Chetwai and Kottappuram. (CED, 2007). These well sites are located on the inlets of chettuva estuary. Conductivity was maximum showed in the premonsoon period of April and minimum values showed in monsoon periods. From the present study it showed that conductivity value increased from monsoon to pre monsoon season. The inlets from chettuva estuary cause salinity intrusion in Thrissur Kole land are prone in pre monsoon season (Ahammed Ali K.*et al*, 1987). TDS content is usually the main factor, which limits or determines the use of groundwater for any purpose (Nordstrom, 1987). Since EC is directly related to TDS, the locations showing high contents of EC support higher TDS (N. Kannan, and Sabu Joseph, 2009).The TDS values ranges between 35 mgl^{-1}(Well-7) to 280 mgl^{-1}(Well-1).Average values of well waters shows within the permissible limit prescribed by BIS (500 mgl^{-1}).Salinity of the sample ranges from 0.05 (Well-4) to 0.2(Well-1). Salinity increases from monsoon (July) to premonsoon season (April). This is due to the saline water inflow in to inlet of chettuva estuary during peak summer season.When the dry summer month's advance, salt swings back to the surface soil again by capillary rise. The trapped salts will vertically oscillate between the perched ground water lens and the soil horizons for many years before being completely removed (Alex P M, 2005).

The hardness values of water samples ranges from 24.7 mgl^{-1} to 159 mgl^{-1} which is below the permissible limit prescribed by BIS (1992). According to BIS the permissible limit of hardness in the drinking water is 300 mgl^{-1}. High concentration of total hardness in water may cause kidney stone heart disease in human (Jain, 1996). The chlorides varied widely from 24.5 (Well-4) to 119.8 mgl^{-1} (Well-1) with a minimum average value of 25.9 mgl^{-1} and maximum average value of 78.67 were found below the acceptable limit of BIS. Naturally, chloride occurs in all types of waters. The contribution of chloride in the groundwater is due to minerals like apatite, mica, and hornblende and also from the liquid inclusions of igneous rocks (Das and Malik, 1988). The chloride values showed significant seasonal variation (well1, 2&3) and in the month of April showed higher values possibly due to leaching of salts adsorbed to the sand grains. Conductivity is related to chloride all months in well sample. Chloride values are comparatively low in well- 4, 5, 6&7. Significant variations are not showing in these samples. There is less possibility of high chloride value (W-1, 2&3) due to mineralogical origin. Salinity intrusion is the main factor of significant seasonal variation in well-1, 2&3.

Table 3: The range and average values of physico-chemical parameters of four well waters samples

Parameters	Well-1		Well-2		Well-3		Well-4	
	Range	Average	Range	Average	Range	Average	Range	Average
pH	7.70-7.80	7.74	7.21-7.67	7.48	7.20-7.37	7.29	6.45-6.95	6.64
Turbidity (NTU)	1.75-10.66	4.76	1.41-2.34	1.88	1.21-5.33	2.52	1.99-6.10	3.82
Conductivity ($\mu mhoscm^{-1}$)	134-400	241.9	66-155	112.2	97-210	147.3	42-59	52.3
TDS (mgl^{-1})	93.8-280	169.3	46.2-108.5	78.54	67.9-147	103.11	29.4-41.3	36.61
TH (mgl^{-1})	84.5-159	107.08	45.3-90.7	59.71	45.3-90.9	60.1	31.6-34.5	33.01
Chloride (mgl^{-1})	64.9-119.8	78.67	53.4-60.1	56.72	54-87.9	63.82	24.5-27.1	25.9
Salinity (ppt)	0.11-0.20	0.13	0.09-0.10	0.09	0.09-0.15	0.11	0.04-0.05	0.04

TH-Total Hardness TDS-Total Dissolved Solids

Table 4: The range and average values of Physico-chemical parameters of three well waters samples

Parameters	Well-5		Well-6		Well-7	
	Range	Average	Range	Average	Range	Average
pH	6.20-6.50	6.33	6.51-6.80	6.7	6.69-6.81	6.75
Turbidity (NTU)	1.50-2.10	1.84	1.10-1.64	1.31	0.34-1.67	1.01
Conductivity ($\mu mhoscm^{-1}$)	53-81	65.3	64-69	67.7	50-60	57.2
TDS (mgl^{-1})	37.1-56.7	45.71	44.8-48.3	47.36	35-42	40.04
Total Hardness (mgl^{-1})	25.5-29.2	27.09	24.7-27.4	26.81	34.5-36.9	35.59
Chloride (mgl^{-1})	42.4-45	43.68	33.3-35	34.14	31.2-36.9	33.88
Salinity (ppt)	0.07-0.074	0.072	0.05-0.058	0.056	0.05-0.06	0.056

ISSN 2348-1218 (print)
International Journal of Interdisciplinary Research and Innovations ISSN 2348-1226 (online)
Vol. 7, Issue 1, pp: (250-257), Month: January - March 2019, Available at: www.researchpublish.com

Table 5: Showing the physical and chemical water quality during peak monsoon, post monsoon and pre monsoon seasons (July, November, April)

Sample	Water quality Parameters											
	pH			Turbidity (NTU)			Conductivity (μ mhos cm^{-1})			Total Dissolved Solids (mgl^{-1})		
	July	November	April	July	November	April	July	November	April	July	November	April
W -1	7.8	7.72	7.7	1.8	3.44	10.66	134	154	400	93.8	107.8	280
W -2	7.7	7.63	7.25	1.5	1.77	2.34	88	90	155	61.6	63	108.5
W -3	7.3	7.31	7.2	1.5	1.65	5.33	97	122	210	67.9	85.4	147
W -4	7	6.7	6.51	2	2.95	5.99	45	51	59	31.5	35.7	41.3
W -5	6.5	6.36	6.2	1.5	1.82	1.99	55	66	81	38.5	46.2	56.7
W -6	6.8	6.8	6.6	1.1	1.25	1.57	65	64	68	45.5	44.8	47.6
W -7	6.8	6.71	6.69	0.6	1.23	1.56	50	59	59	35	41.3	41.3

Table 6: Showing the chemical water quality during peak monsoon, post monsoon and pre monsoon seasons (July, November, Apr

Sample	Water quality Parameters								
	Total hardness (mgl^{-1})			Chloride (mgl^{-1})			Salinity (ppt)		
	July	November	April	July	November	April	July	November	April
W -1	85	87.7	159	65	67.8	119.8	0.11	0.11	0.2
W -2	46	47.9	90.7	56	56.4	59.9	0.09	0.09	0.1
W -3	45	46.1	90.9	55	59.8	87.9	0.09	0.1	0.15
W -4	32	32.3	34.2	25	26.5	27.1	0.04	0.04	0.05
W -5	26	26.9	29.2	42	43.9	45	0.07	0.07	0.07
W -6	25	27.2	27.4	33	34.1	35	0.06	0.06	0.06
W -7	35	35.7	36.9	31	32.4	36.9	0.05	0.05	0.06

5. CONCLUSION

The Kole land area drastically decreased in a faster rate. The study carried out reveal that Kole land area shrinked from 41% to 28% during the period 1969-2008. Population pressure and urbanization have disturbed the desirable land use system of the area. The indiscriminate reclamation of wetlands, especially paddy fields, and their conversion for non-agricultural purposes, reduced the food crop production and degraded the ecosystem balance. In order to overcome the deteriorating scenario, agricultural intervention has to be planned considering the resource potential, its sustainability and environmental aspects, especially the aspects of land capability and suitability. Most of the government sponsored projects especially in urban areas are finding space for which large scale reclamation is going on. The unscientific land use and agricultural practices along with the forest clearing in uplands and in wetland areas exerts major pressure on wetlands leading to soil erosion. This causes siltation leading to vertical shrinkage and related problems like salinity intrusion, ecosystem change and biodiversity loss. The paramount consideration however, is the methodology described relies on the availability of timely, nationally-based GIS information to provide a cost effective approach to assessing areas of rapid wetland change The present study gives us sufficient data to confirm that the extent of salinity is confined in an area of inlet of Chettuva estuary. The wells in this zone become prone to saline on the pre monsoon period of April. Three well sample (W-1, W-2&W-3) showing significant seasonal variation in the water quality. Well water in all other areas remains within the permissible limits of drinking water standards. Immediate measures needed for the protection of Kole wetland to maintain the ecological balance.

REFERENCES

[1] Ahmmed Ali K, E.J. James and K.D.Nambudripad.: Salinity intrusion into the Chettuva-Kottappuram sound of Trichur Kole Lands, Proceedings, *National Seminar on Estuarine Management*, Trivandrum. (1987).

[2] APHA: *Standard methods for the examination of water and wastewater.* 21stEdn. APHA, AWWA, WPCF, Washington DC, USA. (2005).

[3] Centre for Environment and Development (CED): State of Environment Report- Land Environment, Wetlands of Kerala and Environmental Health, Vol.1. (2007).

[4] Das, P.K. and S.D. Malik: Groundwater of Khatra region of Bankura district, West Bengal: Some chemical aspects in reference to its utilization. *J. Indian Water Res. Soc*., 8(3), 31-41 (1988).

[5] Dahl, T.E. and C.E. Johnson: Status and trends of wetlands in the conterminous United States, mid-1970's to mid-1980. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 28 pp. (1991).

[6] Dahl, T.E.: Monitoring wetland changes - the U.S. Wetlands Status and Trends Study, In (Eds. M. Moser, R.C. Prentice and J.VanVessem).IWRB Special Publication No. 26., P.170-174. (1993).

[7] Gopal, B.: Tropical wetlands and degradation and needs for rehabilitation in Ecosystem Rehabilitation (Ed. M.K. Wali) .The Hague: Academic Publishing, pp. 277-296. (1992).

[8] Jain, P.K.: Hydrogeochemistry and ground water quality of Singhari river basin, district Chatarpur (M.P). *Poll. Res*., **15**, 407-409 (1996).

[9] James E J, M.D.Nandeshwar, A.B.Anitha: Management of wetlands, Proceedings *4th National Convention*, June 1993.

[10] Johnkutty, I. and Venugopal V.K.: Kol lands of Kerala, Kerala Agricultural University, Thrissur. (1993).

[11] Kannan, N. and J. Sabu.: Quality of groundwater in the shallow aquifers of a paddy dominated agricultural river basin, Kerala, India. *World Academy of Science, Engineering and Technology*., **52**, 475-493. (2009).

[12] Levin, R. I. and Rubin, D. S.: Statistics for Management, 7th ed., Prentice Hall. (1998).

[13] Nair, G.A., J.A. Bohjuari, M.A. Al Mariami, F.A. Attia and F.F. El Toumi: Groundwater quality of north-east Libya. J. Environ. Biol., **27**,695-700. (2006).

[14] Nordstrom, P.L.: Groundwater resource of the antlers and Travis peak formations in the outcrop area of North Central Texas. Texas Water Development Board, Report p. 298, 280. (1987).

[15] Prasad, S.N. and C. Pattaniak: Role of Geoinformatics and free and open source ICT tools in wetland research, inventory and management for the sustainable development in India. Nat. conf. on wetlands, science and society-An assessment of their Integration, DUBS, Delhi. (2007)

[16] Richard D. Young and T. E. Dahl.: Use of GIS in assessing areas of rapid wetland change. *GIS/LIS*, p .851-859. (1994)

[17] Singh, V. P.: Watershed Modelling: Computer models of watershed hydrology. Water Resources Publications, Highlands Ranch., Colorado. 1-22. (1995).

[18] Sharma, B. K.: Environmental Chemistry. Goel Publishing House, Meerut. (2007).

[19] Trivedi, R.K. and P.K.Goel.: Chemical and biological methods for water pollution studies. Environmental publications, Karad.p.6. (1986).

[20] WWF-India: "India highlights new Ramsar sites on World Wetlands Day". (2 February 2006).