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RESEARCH ARTICLE

Correlation of stagnant wetland depths and their ecological status in the Central Tamil Nadu District, Tamil Nadu

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Abstract
The wetland stagnation is the premise of the wetland depth (WD) but is lacking in detail. The research looks into the correlation of stagnant wetland's depth and their ecological status in the Central Tamil Nadu District (CTND) because of few studies. Seventy-five chosen stagnant wetlands are hydrologically isolated; depths were categorized into less than 5 ft., 6 to 10 and above 10 ft., surveyed by the range of methods from districts such as Karur (KD), Namakkal (ND) and Tiruchirappalli (TD). The human disturbance score (HDS) is categorized as least impacted (0–33), moderately impacted (33–67) and highly impacted (67–100). The impacts of land use and land cover (LULC) changes over 9 years (2010–2019) through the maximum likelihood method. Overall, 54% of wetland depths (WD) were less than 5 ft.; 25.6% were 6–10 ft. and 20.2% were 100 ft. District-wise, wetland degradation was the utmost in the TD, followed by ND and KD. Except in KD, the remaining district wetlands were of MI category with diverse HDS. The correlation test revealed a positive relationship between WD against the alteration of the buffer zone, habitat, hydrology and HDS. However, it is a negative relationship between landscape alteration and wetland pollution. The impacts of land use and land cover (LULC) changes confirm that severe decline in wetlands habitat and water bodies' area is due to built-up area, cultivated land expansion and increasing population. Our study provided evidence that the WD is connected to wetland conditions that have a quantitative influence, and the ramifications of the findings were examined in the context of local development planning. Additional research will be needed due to limited surveyed wetlands with similar geographical locations.

Keywords Hydrological data · Central Tamil Nadu District (CTND) · Stagnant wetlands · Water depth · Ramsar · Human disturbance score · District · Anthropogenic

Introduction

Wetlands are seen everywhere and range from open water to covered with forest ecosystems or just from near the surface stable lakes to short-term ponds. Wetland ecosystems perform numerous essential features or provide a diverse set of services, such as storing water, flood prevention, agriculture, climate regulation and soil depletion regulation (Zhang et al. 2014; Chatterjee et al. 2015; Beuel et al. 2016). In spite of ecological processes and human homes and lives, between 30 and 90% of the globe's wetlands were drastically altered or destroyed (Junk et al. 2013; Reis et al. 2017), but most still exist challenged and spoiled as a result of high population explosion and urbanization (Central Pollution Control Board 2008; Bassi et al. 2014). The depth, length, probability and period of flash floods (which include water logging) are the most crucial hydrological factors that have an impact on all physiological, chemical and biological attributes of different wetlands (Gopal and Sah 1995). Wetlands entail 12.1 million km^2 and account for 40.6% of biosphere amenities (Costanza et al. 2014). To sum up, 1052 spots in Europe, 359 in Africa, 289 throughout Asia, 211 in North America, 175 in South America and 79 in Oceania were denoted as spots or wetlands of worldwide importance (Ramsar

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2018). Due to the population, anthropogenic growth soon started, and onshore wetlands in aquatic habitats were easily destroyed, and interconnection among wetlands has reduced (Davidson 2014; Gibbs 2000; Mori et al 2018a, b). Water is observed to be highly rare as population expands, and the amount of water rises, and global warming affects the hydrological processes (World Water Assessment Programme 2012). Despite wetlands being hydrologically concerned ecosystems, an abiotic component (hydrology, water depth, climate and chemistry) is extensively considered being the most vital controller of wetland biota (Mitsch and Gosselink 2000). The architecture of a wetland's river flows, in conjunction with its physiographic context, determines almost all of its ecosystem attributes, together with soil conditions, water quality and the form of biota that lives there (van der Valk 2012). Evaporation and monsoon too are important factors in wetland water levels (Van der Kamp and Hayashi 2009; Ackerman et al. 2015). Hydrological variation connected to climatic alteration, such as rainfall variability, is probably to trigger further ecological alteration. Wetland water stagnation is based on individual wetland characteristics over their stagnation and is influenced by seasonal changes. Nearly 50% of wetlands have gone global, and plenty of the wetlands stand deteriorated because of hydrologic modification (Zedler and Kercher 2005). Wetland deterioration resulting due to aquifer outflow, river desiccation and monsoon decline has turned into a gradually urgent predicament (Pattern et al. 2008; Zhang et al. 2008; Johansen et al. 2011). In wetlands, average depth influences the shield and configuration of macrophytes as well as growth of microorganisms on plant communities' substrates (Tournebize et al. 2017; Maine et al. 2017, 2007) and also affects the hydraulic performance and vegetation abundance (Guo et al. 2017; Alley et al. 2013; Chen 2011; Liu et al. 2014). Land use and land cover (LULC) alteration by humans since the last few periods is one of the key issues responsible for wetland ruin. Because of overpopulation and associated human induced growth, inland wetlands in aquatic habitats have been easily destroyed, and interconnection among wetland habitats has decreased (Davidson 2014; Gibbs 2000; Mori et al 2018a, b). Understanding and mapping wetland distribution for broadscale valuations is hence a key initial stage concerning crucial and ranking exact conservation requests (Nel et al. 2007; Vörösmarty et al. 2010). In the last few decades, land use land cover changes caused by humans assumed responsibility for wetland deterioration. However, water bodies' dynamics observation is essential for ecosystem valuation (Ahamad et al. 2020) and long-term biodiversity sustainable management (Li et al. 2019). The information acquired about land use land cover enables a tested awareness of land usage and its perception against farming methods, neighbouring territories, forest lands, fallow land and ground water bodies through thorough and achievement goals (Suneela and Mamatha 2016; Sreenivasulu et al. 2010). Rainy season in India exceeds 130 cm, and the country's varied geography and climatological regulatory framework model help and make distinct wetland eco systems (Prasad et al. 2002). Rapid urbanization, intensive farming, contamination, high water drawdown, salinization, forest destruction, exotic species and fish farming all cause degradation of Indian wetlands (Prasad et al. 2002; MoEF 2009; Vikas et al. 2012). In Tamil Nadu, 32 river systems, 11 reservoirs, 2679 canals, 38,863 tanks, and 31 aquatic habitats cover the ground of 58,068 has and 20,030 man-made wetlands with an area of 2,01,132 has (SACON 2006). Wetlands are called in Tamil Nadu State by many vernacular names such as small ponds mostly called storage water (Ilanzi), drinking water tank (Oorani), irrigation tank (Eri), reservoir (Kammai), small pond (Kuttai), large pond (Kuttam), small pool (Kundai), pool (Kundu) and bathing tank (Kulam). Wetlands cover 18.05% of the land area in Ramanathapuram District and as little as 1.08% in Coimbatore. In Kancheepuram District, the highest wetland area is 80,445 ha (8.91%), and Chennai has the least (917 ha, 0.10%). Almost all districts' lakes, ponds and tank are the dominant wetland types in Tamil Nadu. In Central Tamil Nadu, in the Namakkal District, the wetland area is 7687 ha with a percentage of 2.29% of wetlands. Karur District contains 16,383 ha of a wetland area with 5.66% wetlands, and in the Tiruchirappalli District, the wetland area of 18,626 ha which comprises 4.23% are wetlands (TNSWA 2020). In CTND; some of the 510 wetlands were available in diverse sizes, but few studies have investigated the wetland depth influence of the key ecological states. Also, the local people's perception of wetland management remains poorly studied. Various studies on the wetlands' ecological status and ecosystem services and correlation of the wetland depth are in a few papers. The association of the stagnant wetland's depth versus the ecological condition (EC) and their land use, land cover (LULC) changes in the Central Tamil Nadu District (CTND), Tamil Nadu (Fig. 1). The land use and land cover change analysis is a useful technique to monitor wetlands, urban, environmental and ecological quality with various spatiotemporal scales. The specific objectives are to examine the ecological state of wetlands in relation to human impact, to identify the wetland degradation factors by using human disturbance score (HDS) from the three districts of CTND, to explore the link between wetland depth and wetland ecological ailment and to evaluate the LULC types and changes over the periods in the CTN.

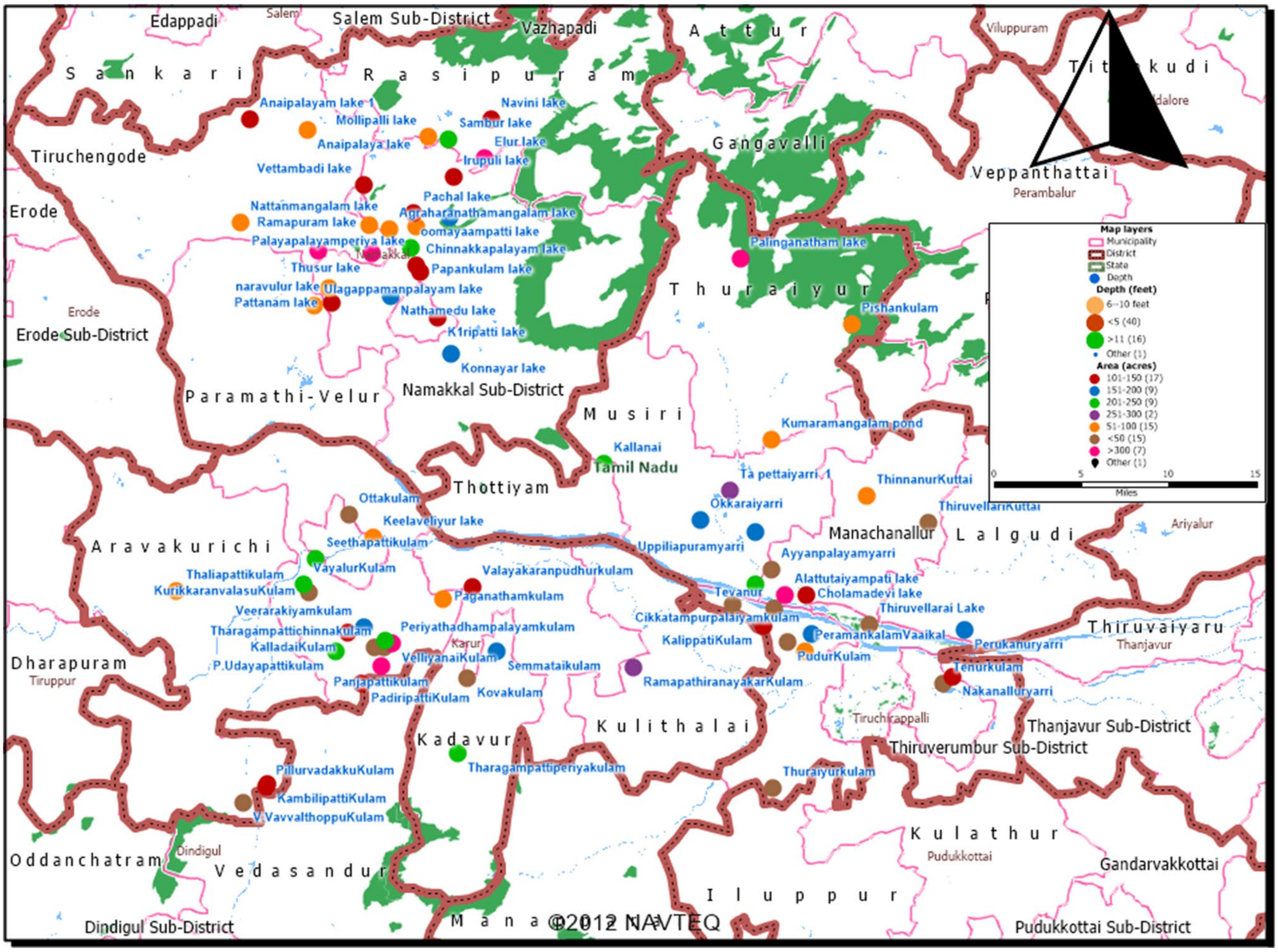


Fig. 1 GPS coordinates used to find surveyed stagnant wetlands in the Central Tamil Nadu District (CTND)

Materials and methods

Study area

Namakkal District Namakkal District is called Transport city or Egg city in (N; 11.36, 78.30 East) the state of Tamil Nadu, India (Fig. 1) and is separated from the Salem District with Namakkal town from 01–1997 onwards and functions independently. The district has two Revenue Divisions, Namakkal and Tiruchengode, and has 7 Taluks viz. Namakkal, Tiruchengode, Kumarapalayam, Rasipuram, ParamathiVelur, Kolli Hills and Sendamangalam. The Namakkal District is bounded on the north by Salem; Karur, in the south; Tiruchirappalli, Perambalur District and Salem, in the east and in the west by the Erode District. This district is under the north-western agro-climatic zone. The Namakkal District has 1298.47 areas (sq. mi) in the total area with a population of 14.96 lakhs. The Namakkal District comprises a good forest area with moderate precipitation. The climate conditions such as hot during summer start from March to May, and winter is cold and misty (November to February). The annual precipitation is approximately 900 mm, and the mean temperature is from 18 to 40 °C.

Trichy District Trichy District at latitude N; 11.20, 78.10 East in the central region of Tamil Nadu is bounded to the north by Perambalur District; Pudukkottai District; in the south; in the west, Karur and Dindigul Districts and in the east by the Thanjavur District. Trichy District comprises eight Taluks viz. Thuraiyur, Lalgudi, Musri, Trichy, Thottiyam M. nallur, Srirangam and Manapparai. The Cauvery Delta begins 16 km west of the city and is among the river systems that run across Tamil Nadu. Cool months are from December to February, followed by hot months from March to May; windy months from June to August and rainy months from September to November. The winter months have a maximum temperature of 37.7 °C and a minimum of 18.9 °C. Rainfall varied from 778 to 821 mm. The critical amount of rain earned during northeast monsoons lasts from

October to December. Southwest monsoon started in June and was an over-dominant force till the end of August. The utmost population was in the Trichy Taluk which comprises 45% of the total population. The total geographical area is 1700.329 (sq. mi). Nearly 6% of the lands were under forest coverage.

Karur District Karur Taluk merged with the Trichy or Tiruchirappalli District in 1910. The Karur District is between (N; 11.12, 77.46 East) the banks of the Amaravati River. The Karur District is 23.889 sq. mi of the total forest area. About 25% of the population is present in the town areas. Precipitation is received from the southwest and utmost during the northeast monsoons. The southwest monsoon rains are erratic, and summer rains are insignificant. In the Karur District, the temperature ranges from 17 to 39 °C, and the average temperature is 28.7 °C. The southwest monsoon onset from June and the southwest monsoon onset and lasting till August bring scant precipitation, since Karur is a rain shadow region. The majority of the rainfall is received during summertime (late April and May), with the northeast monsoon arriving in October, November and December. The average annual rainfall is 590–600 mm. Major Cauvery River is flowing on northern and eastern boundaries.

Maptitude software

Maptitude is a mapping program developed by the Caliper Company that enables users to examine, modify and combine maps. The program and generation are made to make it easier to visualize and analyse information from either inside the system or outside sources, geographically. Utilizing the India Vavteq2012 for their image, the Mapitute Version 2020 tool was utilized to evaluate the clarity and quality of the satellite imageries generated on December 22, 2020. The map-based relationship is 1:1,313,972 (Fig. 1a).

Method

From June 2019 to April 2020, wetland surveys and questionnaire inquiries were in the community within 1-km radius of each water body.

Wetland selection

We consider that the stagnant wetlands have water holding capacity throughout the year, but there is a little fluctuation of the water level during summer (discovered by field visit and with the questionnaire survey) in an area above 8 ha. Wetlands are defined and classified differently in different countries, owing to their diverse variety of forms, sizes and dispersion but followed Ramsar classification. There are many definitions of wetlands like water presence at the ground's edge or in the root zone during the rainy season or distinct (hydric) soil circumstances distinct from non-wetland areas next to wetland areas and plants suited to continually or intermittently wet seasons (Mitsch and Gosselink 2007). Twenty-five wetlands were chosen from the three districts, including Namakkal, Karur and Tiruchirapalli. The wetland size, altitude and GPS location were noted in supplementary file 1. The selected wetlands were chosen based on their impact, availability and access, as well as their land, uses and human disturbance score (HDS), which was calculated using the Gernes and Helgen's technique (2002).

Water quality analysis

Collected water samples from all wetlands and stored in polythene bottles are then analysed in the laboratory by using APHA method (APHA 1985).

Human disturbance score

A number of methodologies (interviews, ecosystem services (ES), human disturbance (HD) and physical parameters) were used to calculate the wetland's ecological and biological states. Wetlands are further classified as having low, medium or high impact on human disturbance. Water quality is concerned with the physical characteristics of water and the ecological state of wetlands. The human disturbance score (HDS) protocol approach was used to assess the level of human disturbance to the wetlands (Gernes and Helgen 2002). Using relevant information with the first cluster interview sessions, benefits produced in each wetland or the ecological services (ES) were secured and tested.

A field survey was carried out to investigate the ground impact of wetlands, ecosystem services and the physical state of the wetlands. The collected data included several quantitative criteria to calculate the human perturbation element.

- Factor 1: Buffer zone disturbance within 50 m of the wetlands' edge — 0–18 points
- Factor 2: Landscape disturbance within 500 m of the wetlands' margin — 0–18 points
- Factor 3: Habitat alteration disturbance within 50 m of the wetlands' edge — 0–18 points
- Factor 4: Hydrological change disturbance within 50 m of the margin of wetlands — 0–21 points
- Factor 5: Pollution of chemical disruption within 50 m of the margin of wetlands — 0–21 points
- Factor 6: The presence or absence of fish yields a score of 0–4 points.

The standard enumeration method was used to collect information on wetland types, hydrological conditions, land use patterns, ecological state and habitat evaluation. Finally, each component was rated and classified (ranked) into one of four categories ranging from best to worst, as previously indicated. Each study of wetland's human disturbance gradient score (HDS) was calculated by adding all scored values from each element to a total of 100%. According to Gernes and Helgen (2002), if the category range of a specific wetland's HDS falls within 0–33, 33–67 and 67–100, it can be categorised as least impacted, somewhat influenced, and most or strongly impacted. Respondents were asked to assign a value to the ES stated for each wetland based on relative relevance, namely socioeconomic variables, wetland importance and management elements.

Wetland ecological status

Household survey

Ecological status of wetlands' data was gotten from the native peoples by using questionnaire survey methods and field survey observations. From each wetland, a minimum of five household surveys (HHS) were randomly selected from the nearby area. Three hundred two individuals took part in this study. A questionnaire comprising twenty questions was structured into four sections: (1) The socioeconomic factors were family size, questioner age, appellant scale of formal qualifications and sex. (2) The questionnaire comprises a factor-wise wetland degradation. The interview had been pre-tested before being managed in person to 302 respondents. Initial and rapid assessment of the wetland survey was carried out in 2 villages that were not part of the selected sample. The interviewers were allowed to do pre-testing to gain expertise with the questionnaire and provided an opportunity to apply and review the method. The focus was on considering how respondents assumed our questions and recognizing any problems met in providing solutions. Changes were proposed, reviewed and incorporated into our final questionnaire. Try to cover all the questions raised by the researcher and in the survey conducted, first, the most senior accessible user was asked. In order to understand the gender context of the project site, an age and sex factor survey for the Central Tamil Nadu District (CTN) wetland sites was done. This survey is seen as a crucial first step in the process of integrating gender into the whole design, implementation and evaluation process of the CTN wetlands. The gender analysis for the CTN project site focuses on analysing how gender roles and conventions differ for men and women, as well as how these variations affect their needs, opportunities and lives. The assessment's main goal is to make sure that gender standards are upheld and that, whenever possible, the program makes up for gender-based inequities.

Sampling and data collection A pilot survey was conducted in each village, with 5 families randomly selected from the nearby area householders. As a result, 302 homeowners were taken into account and chosen at random for the survey (103 in the Karur District, 93 in the Namakkal District and 105 in the Tiruchirapalli District). They were locals who lived in these houses. Table 1 displays some demographic information about the analysed samples. Each householder received a unique questionnaire, which was created (Supplementary file 1). The participants' homes were where the questionnaire was administered, and the location's coordinates were noted. Each participant received an explanation of the ES concept before the survey began. This survey took into account the five elements of the Ecological Status of Wetlands Degradation. These included the fact that any disruption to the buffer zone occurs within 50 m of the edge of the wetlands. (The main criteria points are wetland protection, sewage mixing, infrastructure development, tree cutting, dumbing debris, cattle grazing and wildlife habitat). The landscape disturbance occurs within 500 m of the wetlands' margin (protection of wetlands; sewage mixing; infrastructure development; tree removal; dumbing of debris; cattle grazing and wildlife habitat); the habitat alteration disturbance is within 50 m of the wetlands and habitat (residential development, roads, offices, schools and colleges, company, tourism, boating, livestock pasture, soil erosion and algae debris); hydrological change disturbance is within 50 m of the margin of wetlands; hydrological alteration (roads, draining and dewatering, water withdrawal, drain discharge, sewage, channelization, landslides, drought, flooding and municipal waste); pollution through chemical disruption (industrial dumbing, sewage outflow,

Table 1 Characteristics of studied householders' details in Central Tamil Nadu District (CTND)

	Karur wetlands $N=102$	Namakkal wetlands $N=95$	Trichy wetland $N=105$
Total families	60	57	67
Average family size	4.17	3.97	4.52
Mean male age	31.47	43.58	47.49
Mean female age	35.05	41.08	42.40
Male respondent	60	52	59
Female respondent	43	41	46
Occupation			
Farming	61.3%	67.8%	65.7%
Poultry	4.9%	6.8%	3.0%
Others	33.83%	25.4%	31.3%
Total occupation	100%	100%	100%

fish hatching, water colour, odour, agricultural application, municipal waste, household dumping, demolition debris and dead animals) 50 m of wetland margin and the presence or absence of fish yields and other disturbances. The demographic and socioeconomic information, such as gender, age and employment, of the respondents was the first thing that the questionnaire was intended to record. Each responder was offered a list of instances of wetland degradation and asked to rank them in order of priority. For data analysis, to assess the relative significance given to each ecological condition of wetlands, we used a frequency rank analysis to ascertain whether (and how) variables affect wetland degradation. We divided the participants into three categories based on their (1) ages (2) gender (women, men) and (3) employment status (farming, poultry and others). Wetland threats appeared to be the ones most frequently utilized in the communities under study, according to the factors the poll mentioned above. Based on the relative frequency of citation, which is calculated by dividing the total number of referrals for a given component of wetland hazard by the total number of respondents for that ecological status, the most common wetland threats were identified.

Focus group discussion During the focus group talks, the list of ES collected results of the household survey was verified. During the survey period, five public focus group discussions (FGD) were hosted in the villages with 5–10 individuals on median at every cluster. Members of the focus groups were chosen depending on their means of subsistence and reliance on the wetland. To prevent some of the recognized issues with focus debate clusters, we restricted group sizes to 5–10 persons and rated the listed ES throughout group conversations.

Key informant interviews Before the survey, representatives from government agencies, non-governmental organizations, research institutes and researchers were contacted for a list of the wetland's ecological services. During the interviews, the major questions concentrated on income-generating tactics and the causes of alteration in the wetland ecosystem. During the study, 15 delegates from various organizations were engaged as key informants to assist us to comprehend the arrays of variations and the causes for them. The crucial informants were chosen based on their understanding of wetland resources as well as their reliance on and engagement in wetland management.

Data analysis The statistical data were assessed using regularity table and the Statistical Set (SPSS 25th Edition) for Social Sciences computer software tool to assess the dependency of a local population and the consequences of anthropogenic issues and influences on the wetland environment. Based on the study topics, the qualitative information from interviews was first classified and grouped into topics; related coded themes were then grouped. The rating of ecological services was carried by utilizing participative tools. Participants in focus group talks requested that essential ecosystems available from wetlands be identified. Following the listing of key ecosystem services, a scale of 1 to 10, participants rated the designated ecosystem services (1 is the least preferred and 10 is the most preferred). The overall ranking was calculated by dividing the total points for each ecological service by the digit of responders. Equally, the reasons of qualitative approach were used to expose ecosystem transition (focus group talks) as well as household surveys.

LULC utilization The LULC of the study area (Namakkal District) were analysed using Landsat pictures (TM, ETM + and OLIS/TIRS) obtained from the US Geological Survey (USGS, https://www.usgs.gov/). All images were cloud free and acquired in 2010 and 2019. ArcGIS used to analyse variants in land use land and cover classes in the Namakkal District. Landsat 5 thematic mapper (TM) images containing six bands for 2001 with the pixel resolution of 30–120 m, Landsat 7-improved thematic mapper (TM) for 2010 with a resolution of 30 and 60 m and Landsat 8 in OLI operation land image with 9 spectral bands under resolving 114 × 112 mm were gained from the United States Geological Survey (UGGS). All of the photos were taken between 2010 and 2019 and were cloud-free. The level 1 brands were previously estimated geographically at UTM zone 37N WGS84. The photos were aggregated and eliminated in ArcGIS 10.4 to use the study region boundary shapefile. Subsequent image advancements (typical falsified layout and standard deviation extend) yielded enough instructional polygons to define LULC kinds using ArcGIS 10.4's training design manager (Lillesand et al. 2015). Using the Variational Forest image classification method, the five pictures were grouped into five land-use subgroups (water bodies, rice cultivation, vegetative cover, built-up area and forest areas). Breiman (2001) predicted unintended forestry, which was progressively adopted by specialists. This is due to the fact that it is more powerful than outdated image grouping algorithms and provides high classification accuracy when using demented and compact training data. The proportion variability (PC, Eq. (1)), and transition probability designs were used to assess the level of different land use land and cover variation (Fenta et al. 2017; Berihun et al. 2019) (Gashaw et al. 2017; Berihun et al. 2019).

$$PC = \frac{Ub - Ua}{Ua} \times 100 \tag{1}$$

where $PC = LULC$ rate of changes; Ua = area of start date LULC type and Ub = area of end-date LULC type.

Table 2 Frequency results showing the list of factors influencing the wetland degradation in the CTND

	Buffer zone disturbance	Landscape disturbance	Habitat alteration	Hydrological alteration	Pollution	Total
Karur District	52.5	9.8	13.1	16.4	6.6	100%
Namakkal District	59.3	11.9	13.6	10.2	5.1	100%
Tiruchirapalli District	58.2	10.4	11.9	14.9	4.5	100%

A land-use transition matrix was used to show how the position and region of various land use land and cover types shift over time. This was accomplished by utilizing cross-tabulation and coincide passage in ArcGIS 10.4 application. The criterion tables obtained from these assessments were extracted from Microsoft Excel in calculating outer covering and rate of change over the years. The execution classification performance analysis (kappa coefficient and overall accuracy) using ground GPS coordinates, aerial photographs, team debate, key informant meetings and source images revealed the performance map precision (Congalton 1991). The land use land and cover categories of the Namakkal District and their descriptions such as agricultural land (including crops, vegetables, fruits and irrigated land), barren land (all barren lands), built-up area (including all residential and commercial roads.), cultivated land (including all kinds of cultivation) and water body (including all water bodies (river, lakes, stream, canals and reservoirs). In 2019, data from the interviews, fieldwork and Google Earth were used in sequential manner and permit the photograph. Approximately 50 to 60 test dataset points and Google Earth-Pro images were acquired in the ground by each land use land and cover type (Lillesand et al. 2015). Ultimately, there are the categorized pictures of the five land use land and cover classes, namely water bodies, cultivated land, agricultural areas, barren land and built-up areas with the help of Arcmap application software. All images covered the area of the Namakkal District. The range of study areas was separated by raster images by the spatial analytical tool in the ArcGIS mask extraction method. Three LULC maps and the distribution area information are presented in Fig. 5a, b and c).

LULC accuracy assessment The categorized results are compared to the reference sets of data that are believed to be accurate in identifying a classification, for accuracy assessment. Numerous practices are used to assess the accuracy of remote-sensed data and the user (Aronica and Lanza 2005). The change accuracy of LULC is influenced by issues such as sensor aspect issues and data pre-processing practices to use with standard situations during image capture (Morisette and Khorram 2000). In an error matrix, 3 distinct measurements are used in the accuracy processing and analysis on the error of commission or omission, accuracy of the user, producer and overall accuracy (Coppin and Bauer 1996; Carlotto 2009). The kappa coefficient that can be used to calculate the accuracy rate required for all fundamentals is an extra unit of measure in the illustration classification procedure (Foody 2010). In the latest research, 40 samples were selected for evaluation from 2010 to 2019. We used a stratified sampling method, collecting at least ten ground truth data points from the ground with each LULC class using GIS ArcMap application. Overall accuracy, producer's accuracy, user's accuracy and kappa statistics are generally reported, and these terms have been explained in detail in many studies (Smits et al. 1999; Congalton 1991; Jensen 2005; Liu et al. 2007; Lunetta et al. 1991).

Table 3 Average mean water quality parameters of wetlands in CTND

District	Tiruchirapalli	Namakkal	Karur
Temperature (°C)	26.13 ± 1.71	28.49 ± 0.913	29.27 ± 1.81
Turbidity (NTU)	7.59 ± 2.71	9.79 ± 0.307	65.88 ± 63.47
Ph (Ph metre)	6.9 ± 0.57	7.36 ± 0.324	8.5 ± 12.07
Electrical conductivity (µS/cm)	268.20 ± 18.14	261.20 ± 17.03	213.40 ± 10.06
Total solids (mg/l)	1798.66 ± 73.97	2211.93 ± 47.40	186.06 ± 54.97
BOD ((mg/l)	23.41 ± 13.32	6.53 ± 1.68	2.15 ± 0.94
DO (mg/l)	4.63 ± 0.163	6.53 ± 1.125	4.38 ± 0.20
Average area (acres)	14.3 ± 27.3	21.8 ± 15.2	17.1 ± 72.2
Average depth (ft.)	3.3 ± 1.0	2.8 ± 0.4	2.8 ± 0.0.3
Altitude (metre)	35.7 ± 0.5	11.3 ± 0.3	88.9 ± 0.3

$$User's\ accuracy = \frac{number\ of\ correctly\ classified\ pixels\ in\ each\ category}{total\ number\ of\ reference\ pixels\ in\ that\ category\ (the\ row\ total)} \times 100$$

$$Producer\ accuracy = \frac{number\ of\ correctly\ classified\ pixels\ in\ each\ category}{total\ number\ of\ reference\ pixels\ in\ that\ category\ (the\ column\ total)} \times 100$$

$$Total\ (overall)\ accuracy = \frac{number\ of\ correctly\ classified\ pixels\ in\ each\ category \times 100}{total\ number\ of\ reference\ pixels}$$

$$Kappa\ coefficient\ (T) = \frac{(TS \times TCS) - \sum (column\ total \times row\ total)}{TS2 - \sum (column\ total - row\ total)}$$

Results

Three hundred two people/respondents completed the questionnaire survey. The mean respondent's age in males and females in all the 3 districts is mentioned in Table 1. The respondent's occupations in farming in all the districts were about 60%; poultry farming was the maximum in the Namakkal District (6.8%) and others category was 33.83% in the Karur District. The average mean age, a cumulative sample of people and jobs were documented (Table 1).

In CTND, rural communities living in and around the wetland depend heavily on wetland resources on a daily basis for their livelihoods, nutrition/food security and general wellbeing. In the study sites, approximately about 10 villages (with a combined population of about 10,000) may be found, and they are the ones most closely involved in managing the wetland resources. With a population of about 5000, an additional of 65 village communities rely on wetland resources and ecosystem services, however, to a lower extent and with less direct involvement.

According to local residents' perceptions, the primary criteria for wetland degradation in all the three districts is a buffer zone modification of more than 52%, followed by hydrological amplification, habitat amplification, landscape disturbance and pollution (Table 2). In CTND, in each district, 25 wetlands were selected for this study, and the GPS location, size, depth and individual HDS were mentioned in Supplementary file 1. These wetlands were selected based on easy accessibility and availability. The majority of the wetlands within the districts have elevations of up to 237.74 m. The HDS value of each district's wetlands is mentioned in Table 2. The overall size of stagnant wetlands from 0.0314 to a maximum of 1.0390 sq. mi in size was observed in the CTND during this study period.

Physical characteristics of wetlands in the CTND

The wetlands are analysed by physical characteristics into seven parameters for a better understanding of wetlands in the CTN districts; the temperature range is from 23 to 33 °C. In the CTND physically, differences among the wetland structures were noted. Overall $n = 65$ (86.7%) wetlands were colourless, and $n = 10$ (13.3%) were green. According to the Ramsar category, the wetlands in the CTND had divided into five major types: marine, estuarine, lacustrine, palustrine and riverine. Besides, many artificial wetlands have seeds for culturing species (shrimp/fish/prawn farms). There were varied sizes of wetlands in the three districts, and the largest size of wetlands occupied all in the 3 districts. In the Karur District, three wetlands were more than 350 ac in size as follows: Periyathadhampalayamkulam (350), VelliyanaiKulam (400) and Panjapattikulam (665). In the Namakkal District, three wetlands were above 300 ac like Elur Lake (370), Thusur Lake (319) and Paruthipalli Lake (310). In the Trichy District, three wetlands were above 290 ac like Alattutaiyampati Lake (390), Palinganatham Lake (350) and Ta Pettaiyarri (290) and were observed in our study, and the average mean values of size and depth of each district wetland are mentioned in Table 3. In the CTND, we have selected the almost lacustrine wetlands, but stagnant water may vary. According to the wetland area size, it is classified into three types. The chief origins of the water to the wetlands were rainfall, river water and drain or the canal system.

Water quality of wetlands in CTND

There was less difference in temperature, and pH between the different wetlands was recorded. The respective district average values of the wetlands are mentioned in Table 2. The turbidity of water was more or less the same, but in the

Table 4 Overall average means, standard deviation and standard error of human disturbance scores in the Central Tamil Nadu Districts

	Karur			Namakkal			Trichy		
	Average mean (AM)	Standard error (SE)	Standard deviation (SD)	Average mean (AM)	Standard error (SE)	Standard deviation (SD)	Average mean (AM)	Standard error (SE)	Standard deviation (SD)
Factor 1 Buffer zone alteration	6.5	0.33	1.67	12.00	0.00	0.00	12.00	0.00	0.00
Factor 2 Landscape alteration	12.0	0.00	0.00	10.56	0.52	2.62	12.50	0.35	1.69
Factor 3 Habitat alteration	2.6	0.61	3.04	10.80	0.85	4.24	7.00	0.47	2.28
Factor 4 Hydrology alteration	7.0	0.00	0.00	9.68	0.75	3.73	7.29	0.29	1.43
Factor 5 Pollution	7.0	0.00	0.00	7.28	0.28	1.40	8.46	0.59	2.91
HDS	28.9	0.70	3.51	50.32	1.37	6.84	47.25	0.88	4.31

Karur District, the values were slightly higher. The electrical conductivity (EC) in the Karur District was much lesser but within the permissible limit. Total solids (TS) had shown different parameters in each district wetland. The biological oxygen demand (BOD) and dissolved oxygen (DO) in the wetlands are within the control limits of the World Health Organization (WHO) or the American Public Health Association (APHA) standard level. The total solids were the highest in the Namakkal District, followed by Tiruchirapalli and least in the Karur District (Table 3).

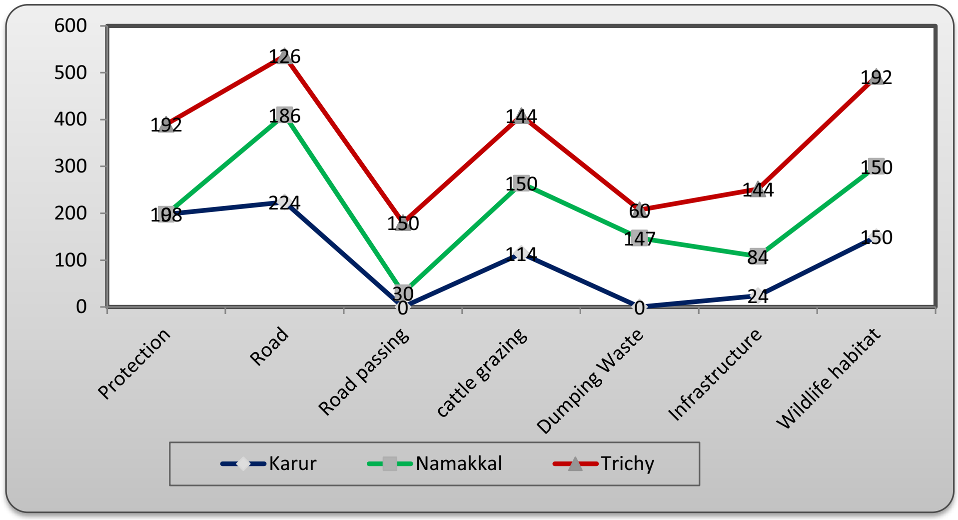
In our study, wetlands' disturbance is due to 5 factors in the CTND. According to the stagnant wetland in a different district, the degradation was utmost in the TD wetlands, followed by ND and Karur Districts. Overall, factor-wise, wetland degradation is utmost due to landscape disturbance, buffer zone alteration, pollution, hydrological and habitat alteration. The wetland's average mean, standard deviation and standard error are mentioned in Table 4.

Overall, the wetland buffer zone disturbance is due to lack of protection, road construction and the road passing through the middle of wetlands, cattle grazing, dumping waste, infrastructure development and damage to wildlife habitat, which were primary issues. In all the three districts, the buffer zone disturbance is the utmost as construction of roads and lack of wetland protection as follows: in KD, road construction (AM: 8.9, SD: 0.66, SE: 3.3) and lack of wetland protection (AM: 7.9, SD: 0.5, SE: 2.8); in ND, construction of roads (AM: 7.4, SD: 0.71, SE: 3.5) and lack of wetland protection (AM: 6.72, SD: 0.239, SE: 1.9) and in TD, construction of roads (AM: 8.0, SD: 0.93, SE: 4.5) and lack of wetland protection (AM: 6.25, SD: 0.25, SE: 1.2) (Fig. 2).

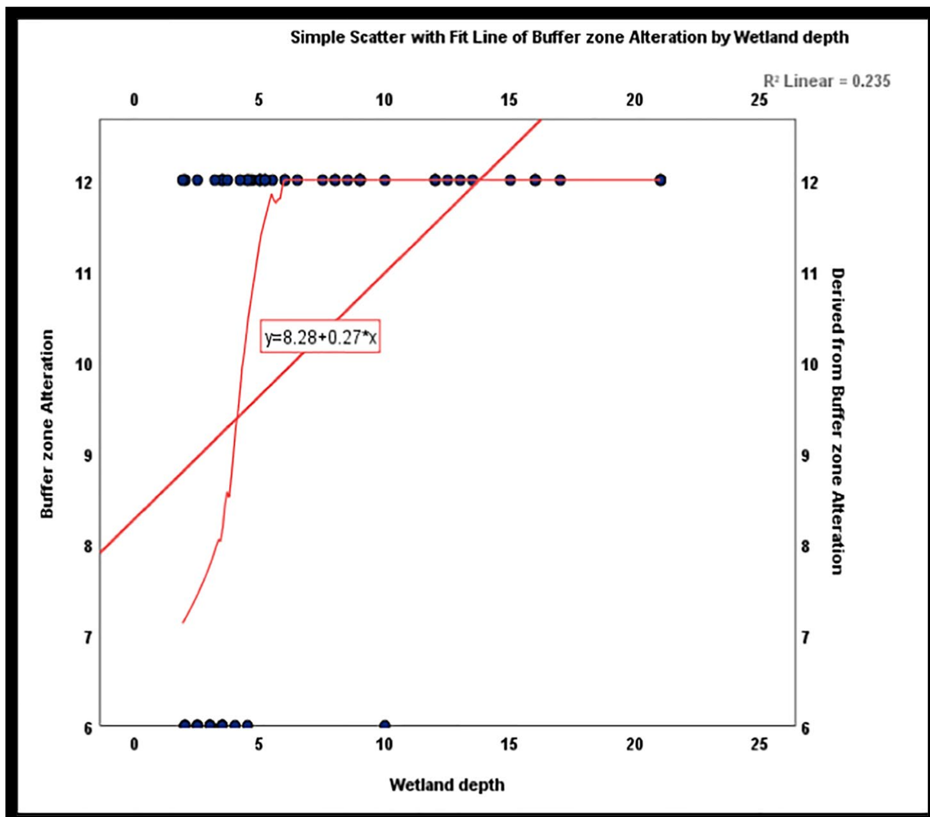
The factor-wise wetland degradation correlation with the wetland depth is mentioned in Table 1 Supplementary file. The results of Spearman's correlation test show that there is a strong potential correlation between the wetland depth and the buffer zone alteration ($r = 72$, 0.484, $P < 000$), explaining the wetland depth at 23% variation in the buffer zone alteration (Graph 1). In the Karur District, landscape destruction, like infrastructure development (AM: 9.1, SD: 0.61, SE: 3.0) and lack of protection and cattle grazing were major concerns. In the Namakkal landscape destruction, also the same as the buffer zone disturbance, cattle grazing and garbage dumping (AM: 5.04, SD: 0.44, SE: 2.2) and increasing hunting around wetland habitats were the primary concerns. In the Trichy District landscape destruction, lack of protection (AM: 6.50, SD: 0.50, SE: 2.4 and infrastructure development and hunting (AM: 5.50, SD: 1.24, SE: 6.1) are mentioned in Fig. 3. The correlation results show that there is no significant negative relationship between the wetland depth and the landscape alteration ($r = 72, -0.344$, $P < 003$) with the wetland depth (Graph 2).

In KD, the habitat alterations like residential buildings (AM: 1.6, SD: 0.55, SE: 2.7 and dumping of municipal waste (AM: 0.96, SD: 044, SE: 2.2); in ND, commercial buildings (AM: 8.16, SD: 0.58, SE: 2.9, and dumping of municipal waste (AM: 5.8, SD: 0.52, SE: 2.6) and the Trichy District, cattle grazing and disposal of waste (AM: 3.75, SD: 0.60, SE: 2.9) which are vital concerns of wetland degradation are observed and mentioned in Fig. 3. The results of the correlation test by Spearman indicated a strong correlation for both the wetland depth and the habitat alteration of wetlands ($r = 72$, 0.571, $P < 000$). The results explained that the wetland depth at 32% of the variations in the alteration of wetland habitat was noted (Graph 3). Pollution is quite less in the KD, but in ND, pollution is burning waste (AM: 6.4, SD: 0.38, SE: 1.9) and disposable wastes. The results of Spearman's correlation revealed a non-significant, inverse correlation of the wetland depth, and the wetland pollution ($r = 52, -0.142$, $P < 0.317$) is mentioned in Graph 4.

Fig. 2 The Central Tamil Nadu District is experiencing problems due to the degradation of the wetlands in the buffer zone habitat



Graph 1 The disturbance factors in the wetland buffer zone versus wetland depth



In all the three districts, the hydrological alterations caused by size shrinkage, destination and drought are vital for wetland degradation (Fig. 4). The results of Spearman's correlation test show that there is a strong positive correlation among the wetland depth and the hydrology alteration ($r = 72$, 0.475, $P < 000$), explaining the wetland depth of 22% variation in the hydrology alterations (Graph 5). In KD, habitat-wise, the wetland disturbance is caused by a buffer zone and landscape disturbance. The level of disturbance level was more or less similar in all areas. However, the landscape disturbance, pollution and hydrological alteration were at the same level in all the three habitats. The overall wetland size above 0.2171 sq. mi was recorded (Fig. 2). In TD, habitat-wise, the wetland disturbance is caused by landscape disturbance, and buffer zone disturbance is more or less the same in rural and semi-urban

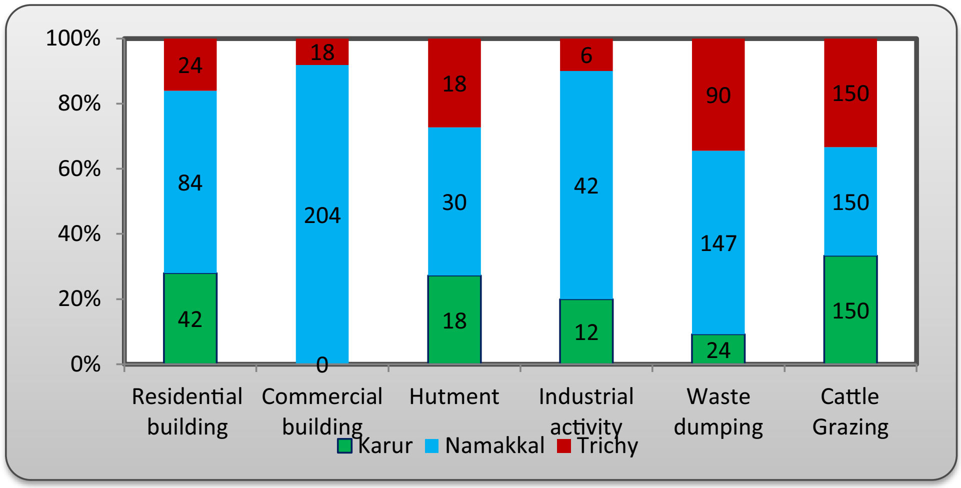
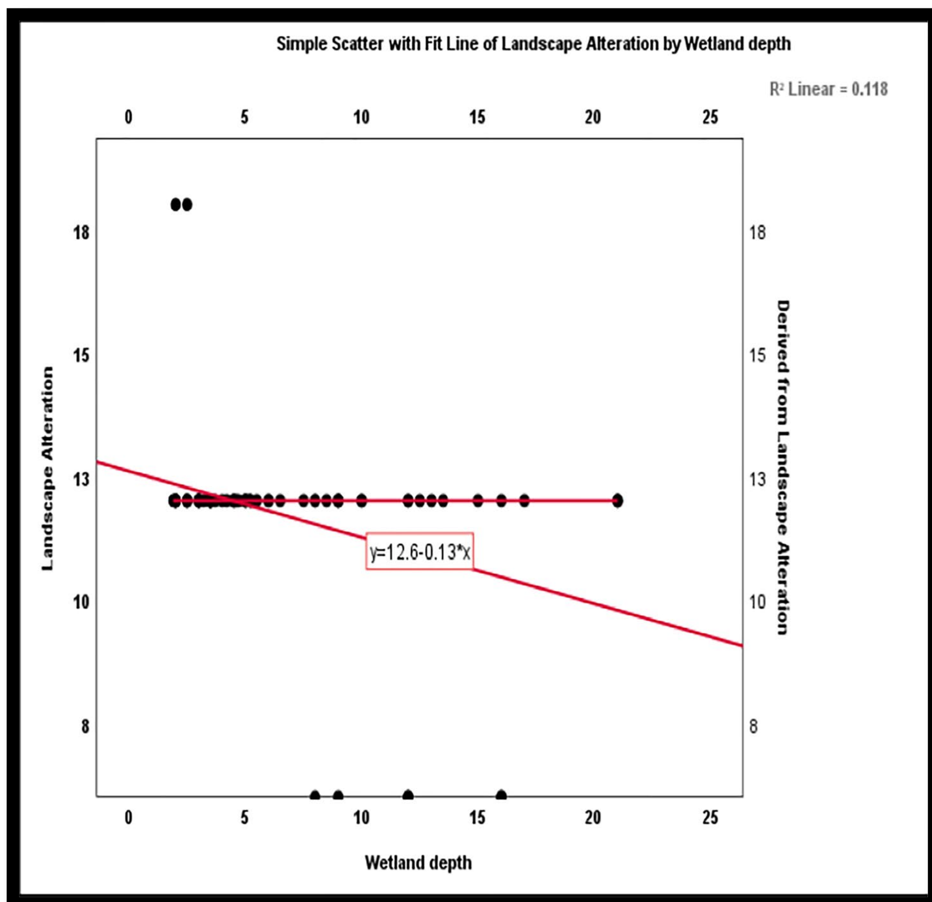
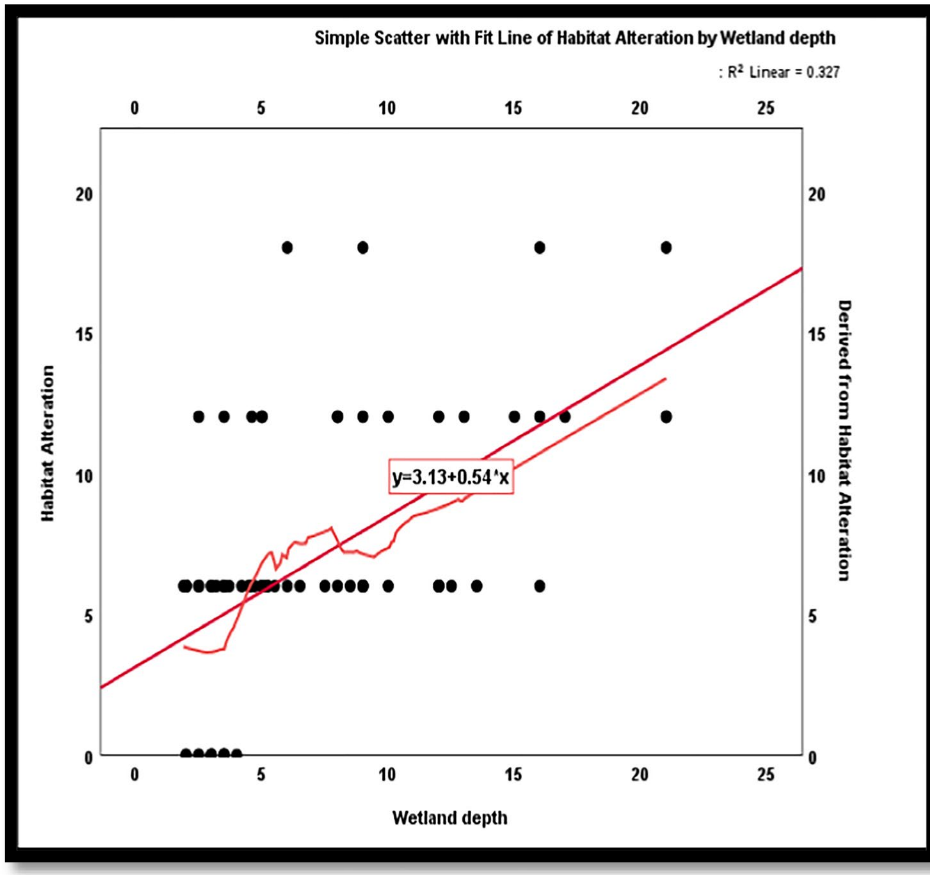


Fig. 3 The overall degradation of wetlands in the Central Tamil Nadu District is due to habitat alteration factors



Graph 2 The wetland landscape alteration factors versus the depth of the wetland

areas. The hydrological alteration was the same in all the three habitats, but with very less pollution damage to the wetlands. The overall wetland size above 0.09375 sq. mi was recorded in the Trichy District (Fig. 2). The HDS were categorized into three types. The scores were computed with the overall scores of a combination of five parameters of the individual wetlands (detailed in the "Method" section) and were mentioned in Supplementary file 1. Overall, the wetlands on the rural side were the dominant form, which contains above 84% of the wetland category. In the



Graph 3 The wetland habitat alteration factors versus the depth of the wetland

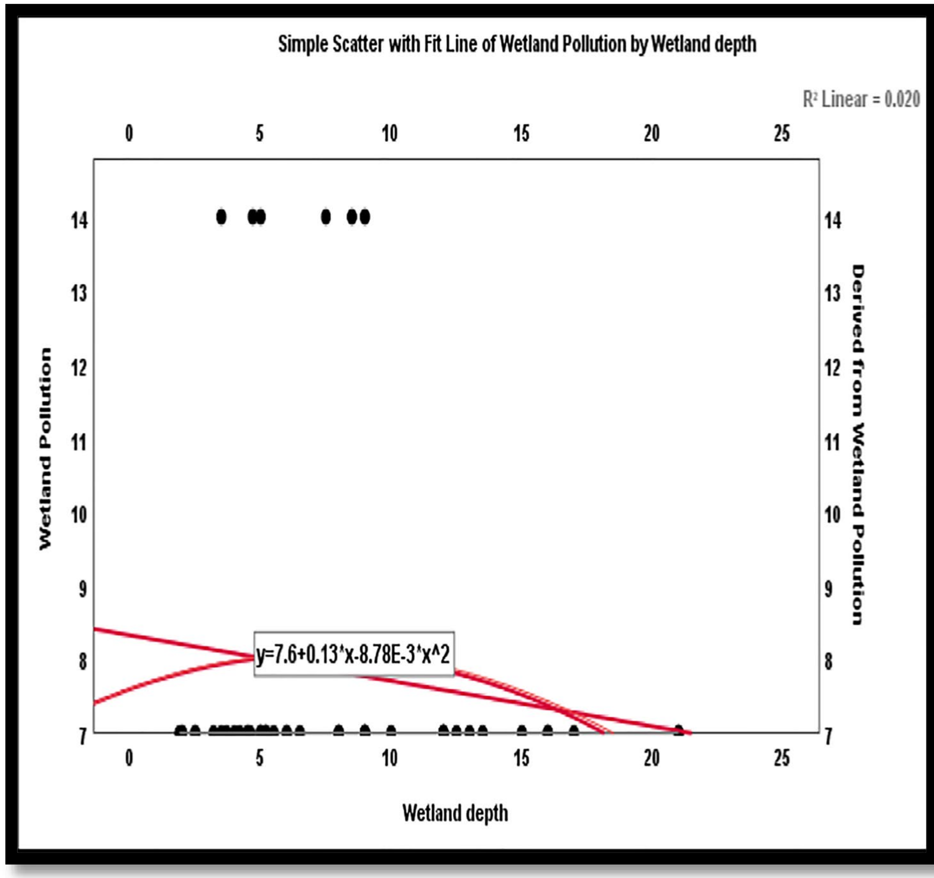
KD, there is one urban wetland and two semi-urban, and the remaining 22 wetlands were rural side wetlands. The HDS range from 25 to a maximum of 32 points, and 24 (96%) wetlands were of the LI categories and 1 (4%) was of the MI category. In the Trichy District, there were three urban and two suburban wetlands and the remaining 20 wetlands were rural side wetlands. The HDS range from 44 to a maximum of 58 points, and all are of the Mid Impacted categories. In ND, two were urban wetlands; two were suburban wetlands and the remaining 21 wetlands were rural side wetlands. The HDS range from 44 to a maximum of 63 points. The 25 (100%) wetlands of MI categories were noted. The results of Spearman's correlation test show that the wetland depth and HDS performances have a significant positive relationship ($r=72$, 0.560, $P<000$), explaining the wetland depth of 31% variation in the HDS, as mentioned in Graph 6 and Table 5.

District-wise, we observed that 37 wetlands were less than 5 ft. in depth; the average mean (AM) is 3.3; standard deviation (SD) is 0.96 and the HDS is AM: 36.6; SD: 10.9; 19 wetlands were 5–10 ft. in depth with the AM: 7.61; SD: 1.68 and the HDS (AM: 47.1; SD: 7.15); and 15 wetlands were above 10 ft. in depth (AM: 15.3; SD: 3.4), and the HDS (AM: 49.87; SD: 6.56) were observed.

A comparison of stagnant wetlands in the three districts of the CTND was assessed by survey respondents. The quantitative tests used to test variations among locations were generalized linear model statistical methods, and the results were given as F value (degrees of freedom), significance value and effect size n2. NS indicates that no statistically significant differences were discovered. Table 6 shows the result of ANOVA tests.

The planned execution and monitoring of programs at the local, regional and national levels heavily rely on LULC maps. On the one hand, this type of information aids in a deeper comprehension of land utilization issues, and on the other hand, it is crucial in the establishment of the policies and programs needed for development planning. Monitoring the ongoing pattern of land use/land cover through time is essential to ensuring sustainable development. The LULC maps of the CTND were produced for two reference years (2010 and 2019). The areas are classified into classes as water bodies, agricultural land, barren land, cultivated land and built-up areas. Three land cover maps, distribution area and class percentage information are presented in Fig. 5 a, b and c.

The district-wise wetland distribution area details are mentioned in Table 5. In all the three districts, agricultural



Graph 4 The wetland pollution factors versus the depth of the wetland

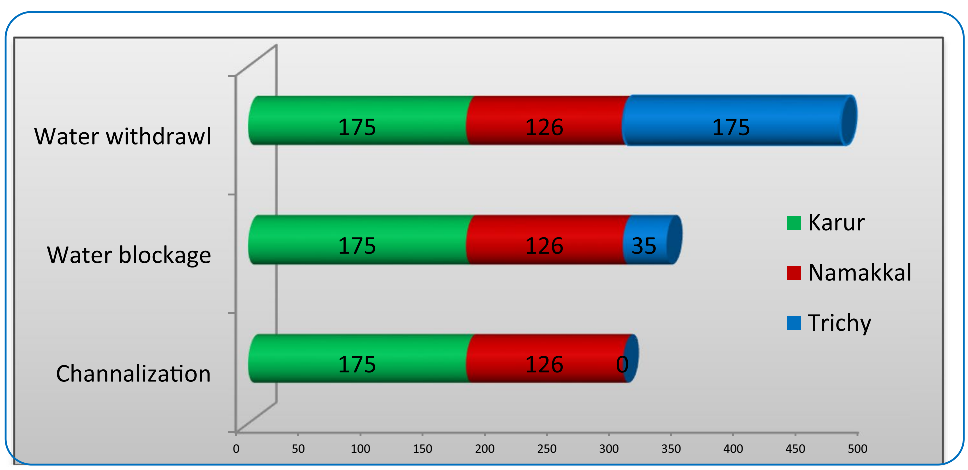
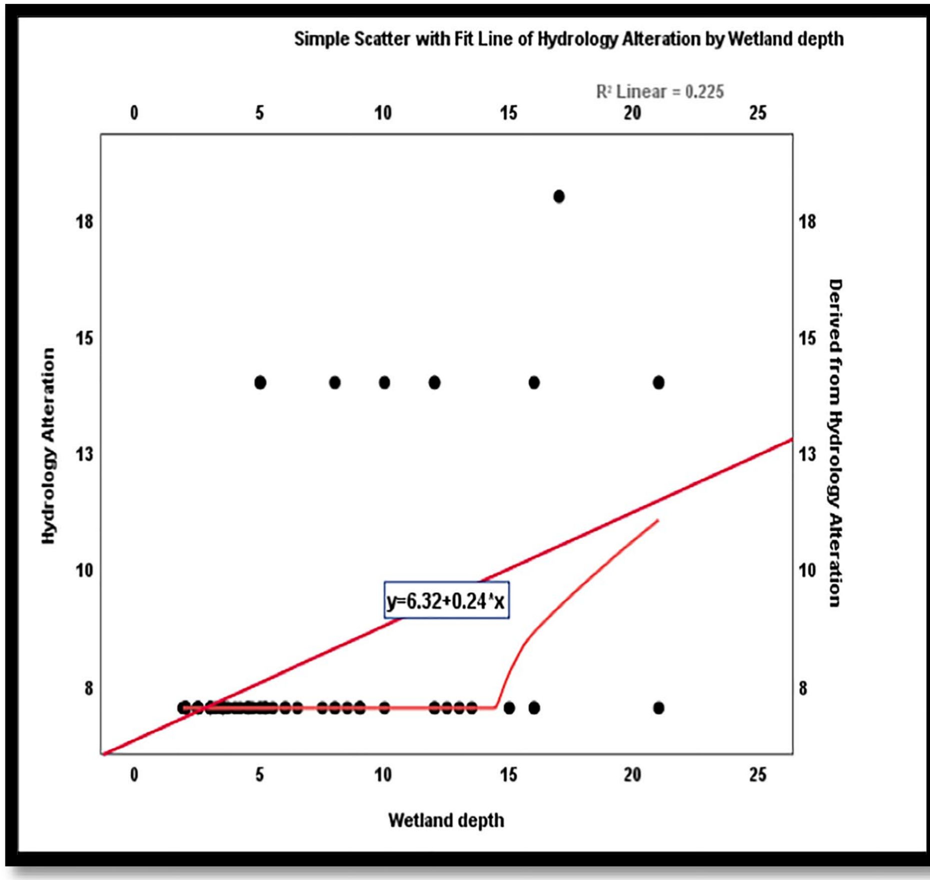


Fig. 4 The overall degradation of wetlands in the Central Tamil Nadu District is due to hydrology changes

land areas were dominant in 2010, but a gradual reduction of area size in 2019, except TD, is followed by an increase of built-up lands and a decline in water bodies' size nowadays.

The landscape type 2010 was considered a basic map in all the three districts. The two periods of wetland landscape raster maps were overlapped, and intersect map properties were separated using ArcGIS software 10.7.1. The land use land and cover map initial state of the transition matrix and the area type of classification are calculated from the period 2010 to 2019 and are mentioned in Tables 7, 8 and 9. The initial transition matrix was calculated for mapping and calculation using maximum livelihood type.

The transition data depicts the transition of land use land and cover in one form to another. All classes in ND experienced a progressive percentage of change. The transition matrix showed decreasing agriculture land, cultivation land,



Graph 5 The wetland hydrology alteration factors versus the depth of the wetland

water bodies including rivers, barren land and increasing built-up areas all over the district. Percentage-wise, changes in all the three districts and overall details are mentioned in Table 5 and Fig. 5 b. The accuracy level of the land use land and cover map, including overall accuracy, and producer's and user's accuracy are also recorded in all the three districts. Also, the kappa accuracy is calculated by using the formula. Producers' accuracy and users' accuracy were 100%, except for built-up land which is 72.7%. The overall accuracies showed that in 2011 and 2019, 95% and 87% were noted, respectively. The kappa accuracies in 2010 and 2019 were recorded at 0.937 and 0.69, respectively.

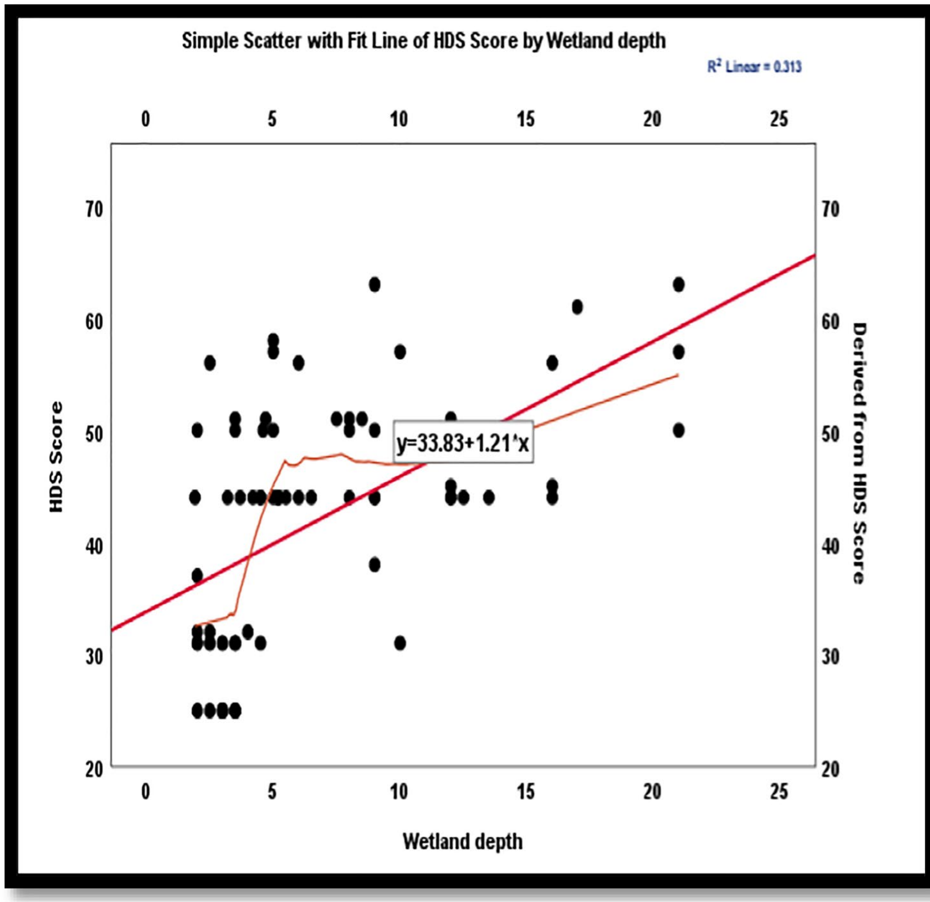
The gradual proportion of transition occurred among all classes in the Karur District from 2010 to 2019. The results revealed decreasing land for agriculture, cultivation land, water bodies including rivers, barren land and increasing buildings all over the district. The producer's and users' accuracy was 100%, except for built-up land which is 97.7%, and the overall map accuracies showed in 2010 at 95% and in 2019 at 87%. The kappa accuracies in 2010 at 0.809 and in 2019 at 0.74 were observed.

The change matrix analysis shows the transition had occurred among all the classes in TD. The transition matrix showed decreasing land for agriculture, cultivation land, water bodies including rivers, barren land and increasing built-up areas all over the district. In producers and users, accuracy was 100%, except for built-up land which is 87.2%. The overall accuracies of the map showed in 2011 at 96% and in 2019 at 87%, and the kappa accuracies in 2010 at 0.913 and in 2019 at 0.89 were recorded (Table 10).

Discussion

The physical characteristics of the stagnant wetlands had categorized into seven parameters for a better understanding of wetlands. In the CTND, physically, there are differences among the wetland structures. The temperature ranges from 23 to 29 °C according to season, and water temperature is highest in the summer because of the hot climatic season and open nature of the wetland site. Overall, 87% of the wetlands were colourless, leftover wetlands are indeed green due to abundant phytoplankton and harmful algal blooms; concentration of pollutants and corrosion is typically green. The chemical parameters were not done on all individual wetlands, but the selected wetlands are used for drinking and agricultural purposes. There is a correlation between wetland depth and the buffer zone alteration,

Graph 6 The wetland HDS versus the depth of the wetland



as reported. In our study, in all the three regions, the buffer zone disturbance is utmost, as construction of roads and lack of wetland protection lead to a lack of nutrient accumulation. It evolves in wetland morphology convolution and coalescence, as human nuisance levels increase (Liu and Cameron 2001 and Li et al. 2010). Our study also suggested that all the three wetlands were being destroyed by landscape destruction, like infrastructure, development and lack of protection; cattle grazing and huntment were vital concerns. Our study also supported that livestock drinking and grazing were abundant in wetland habitats in CTND and also provided a negative impact, if overused. The negative correlation of wetland depth and the landscape alteration was reported, and landscape alterations of human modernization of natural environment within adjoined terrain has had a huge impact within 500 m from the buffer zone in most of the wetlands in CTND, due to lack of fencing. Human impacts have completely affected surroundings in human-populated areas, and this landform shift has become a significant driver of ecological systems globally (Loffman and Kouki 2001; Naveh 2007). Our study also supported that the landscape alteration of all the three districts was

Table 5 A correlation table of factors affecting wetland degradation against the wetland depth in the CTND

	Wetland depth	Buffer zone alteration	Landscape alteration	Habitat alteration	Hydrology alteration	Pollution	HDS	Mean	Std. deviation
Wetland depth	1							6.87	5.009
Buffer zone alteration	0.484**	1						10.14	2.796
Landscape alteration	−0.344**	−0.0.112	1					11.68	1.959
Habitat alteration	0.571**	0.605**	−0.0.078	1				6.81	4.692
Hydrology alteration	0.475**	0.262*	−0.0.162	0.244*	1			8.00	2.586
Pollution	−0.0.142	0.089	0.072	−0.0.036	−0.0.031	1		7.81	2.258
HDS	0.560**	0.852**	0.056	0.809**	0.463**	0.332*	1	42.11	10.782

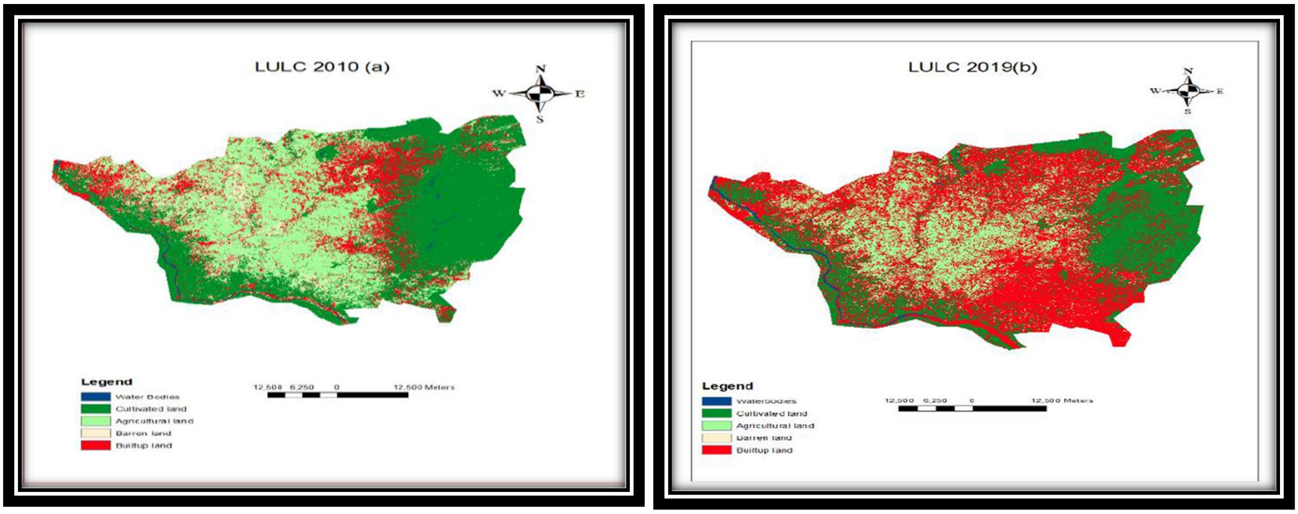
Table 6 Results of ANOVA tests in the stagnant wetlands at three districts in the CTND

	Karur	Trichy	Namakkal
Buffer zone disturbance	*df* (22.2) = 0.244; *P* < 0.001:0.969	NS	NS
Landscape disturbance	NS	NS	*df* (20.4) = 0.582; *P* < 0.001:0.815
Habitat alteration	*df* (22.2) = 0.1.029; *P* < 0.001:0.606	*df* (18,5) = 0.278; *P* < 0.001:0.980	*df* (20.4) = 1.857; *P* < 0.001:0.291
Pollution	NS	NS	NS
Hydrology alteration	NS	NS	*df* (20.4) = 1.841; *P* < 0.001:0.294

because of anthropogenic activities in the CTND. A positive correlation between wetland depth and the habitat alteration was reported. However, alteration had been caused by several factors. Habitat alterations such as residential buildings and dumping of municipal waste are vital issues in the Karur District, which affect the quality and overall health of the ecosystem. Also, the impact was much lower because of the lack of water availability most of the year. In ND, habitat alterations like commercial buildings and dumping of municipal debris are important issues observed. In the Trichy District, habitat alterations such as cattle grazing and disposal of waste are vital concerns. Pollution-wise, a negative correlation with the wetland depth had been reported. District-wise, the pollution level is less in the Karur District; whereas, in the Namakkal and Trichy Districts, burning waste and disposable dumping were general around the wetland habitat. Hydrology alteration had been caused by several factors, but a positive correlation between wetland depth and the hydrology alteration had been reported. Wetland hydrology measurement also enables the identification of local climatic changes (Schuyt and Brander 2004). In the CTND, stagnant wetlands had various depths during the flooding period and summer season. The wetlands' depth had been based on wetland types, locations and hydrology. Our study has supported the depth and duration of water flowing in different wetlands that can be extremely variable (Rahman Ahidur 2016). In the CTND, the Trichy area receives rainfall during the southwest and northeast rainfall, rivers and dams. In the Namakkal and Karur areas, the water source is mainly from the annual precipitation itself. Stagnant wetlands in the different districts had various sizes observed. Our study revealed those wetland conservation projects had based on size and water holding capacity during summer. In the Indian subcontinent, the precipitation concentration over a short period of June–September, followed by a hot season over the large variability of total rainfall ranging from 20 to 100% has a significant impact on the wetlands. The water level of river systems, lakes and waterways varies greatly seasonally and year over year. Maintenance of the buffer strips is a critical factor governing their longer-term nutrient retention effectiveness (Hille et al. 2019).

The positive correlation between wetland depth and the HDS was reported, and wetland alteration is caused by several factors. In all the three districts, hydrological alteration, caused by size shrinkage, destination and drought, is a vital source for the degradation of wetlands. Our study supported that even with a slight change in hydrologic condition, transformation in biota richness, species diversity and ecosystem efficiency may result (Prasad et al. 2002). Overall, the rural side wetlands were the dominant (84%) of the wetland category. HDS were higher in urban side wetlands because of anthropogenic activities. Urbanization has become a critical cause for losing wetland areas in developing countries because of commercial buildings, road infrastructure and residential development. Our study supported that wetland ruination in rapid urbanization weakens wetland careers in long-term urban wetlands (Booth Derek 1991; Knutson et al. 1999; Lehtinen et al. 1999; Azous and Horner 2000). Wetlands are evolving due to changes in hydrology, increased nutritional and pollution runoff, overexposure to introduced species and increased breakdown because of impacts of urbanization. In the Karur District, out of 25 stagnant wetlands, 22 wetlands were rural side wetlands under the status of 96% LI category because of non-usage and less anthropogenic activities. However, in the TD and ND, over 20 wetlands were present in the rural side under the MI categories.

Our study revealed little information on stagnant wetland distribution, mapping and correlation of wetland depth with the ecological status in the Central Tamil Nadu District. Our land use land and cover evidenced the drastic drop of wetland areas, together with water bodies, in the study area over the last 10 years (2010–2019). Many studies have reported that wetland regions are being lost due to urban growth, which our survey endorsed (Belayneh et al. 2020; Hailu et al. 2020). The emergence of built-up areas in the CTND was the significant driver for their evolution by discharging, infilling and vastly increased wetland habitat, as assisted by many other publishers (Mao et al. 2018; Huang et al. 2019). The transition matrix of the CTND from 2010 to 2019 had been created by the maximum likelihood method. The results showed that gradual changes in land use land and cover in all the classes and all the districts had been observed. The transition matrix revealed decreasing land for agriculture,



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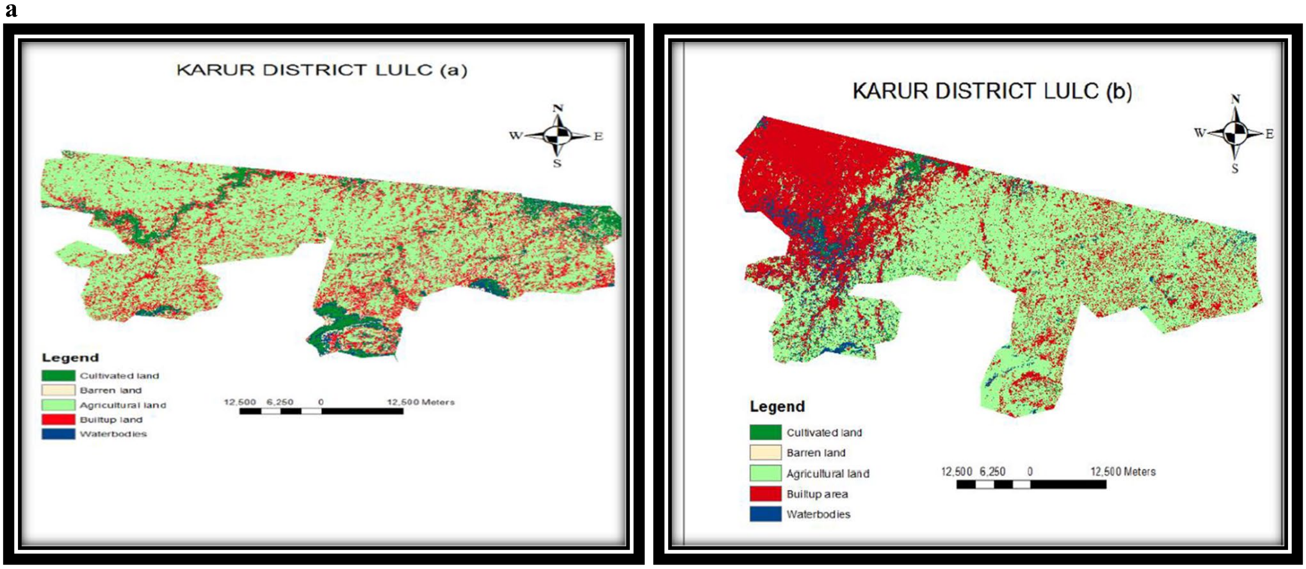

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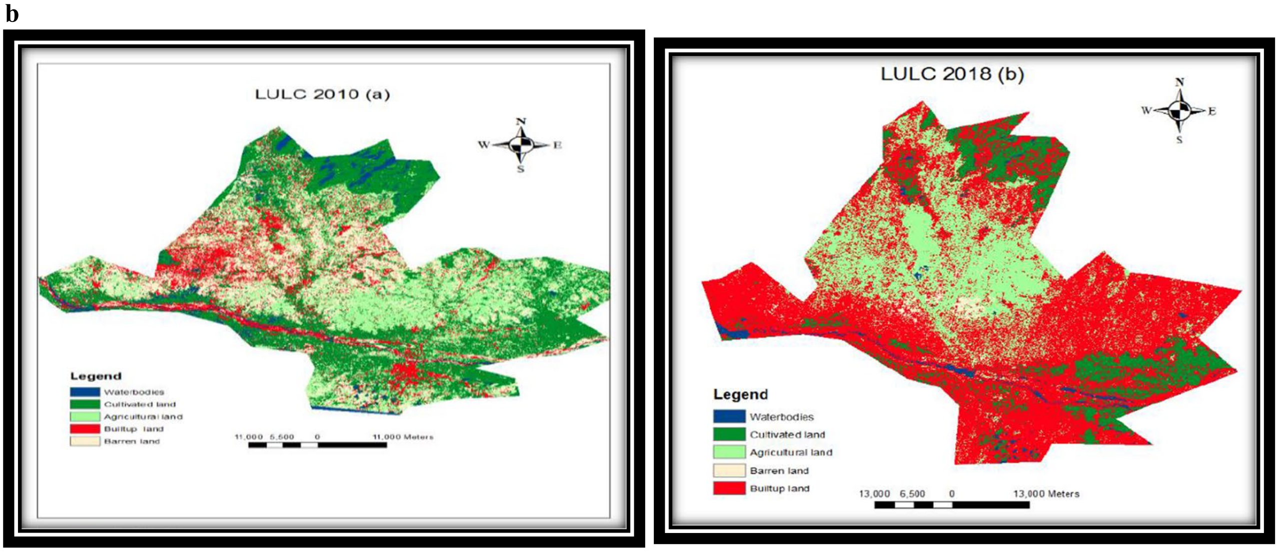

c

Fig. 5 **a**. Land use/land cover classification in the Namakkal District in 2010 (a) and 2019 (b). **b**. Land use/land cover classification in the Karur District in 2010 (a) and 2019 (b). **c**. Land use/land cover classification in the Tiruchirappalli District in 2010 (a) and 2019 (b)

Table 7 Wetland distribution area in the Districts of Namakkal, Karur and Tiruchirappalli (unit: sq. mi)

Class	Namakkal District (ND)				Karur District (KD)				Tiruchirappalli District (TD)			
	2010		2019		2010		2019		2010		2019	
	Sum of area sq. mi	Total %	Sum of area sq. mi	Total %	Sum of area sq. mi	Total %	Sum of area sq. mi	Total %	Sum of area sq. mi	Total %	Sum of area sq. mi	Total %
Agricultural land	574.661	43.74	260.003	19.76	604.140	63.145	418.126	37.84	311.021	25.33	652.923	44.07
Barren land	40.598	3.09	3.778	0.28	55.832	5.836	42.422	3.83	238.337	19.41	1.109	0.075
Built-up land	225.829	17.18	645.512	49.06	190.303	19.89	428.348	38.77	170.239	13.87	162.995	11.01
Cultivated land	465.848	35.45	397.655	30.22	76.777	8.025	216.082	19.55	465.365	37.90	285.536	19.27
Waterbodies	6.871	0.52	8.609	0.65	29.659	3.10	0.081	0.007	42.861	3.49	379.067	25.58
Grand total	**1313.807**	**100**	**1315.558**	**100**	**956.712**	**100**	**1105.058**	**100**	**1227.822**	**100**	**1481.630**	**100**

Overall values were mentioned in the bold form

rivers and pond and an increase in water bodies and few differences in built-up areas. Overall (7%), size reductions were noted from the period 2010 to 2019. The built-up area has been expanded every year because of urbanization. The increase in building is inversely related to increase in population, which disrupts the sensitive ecological integrity by over-using natural resources and exacerbating waste problem. Our research found that newly built infrastructure projects, as well as various market facilities among residences, have attributed to the shrinking of wetlands, water bodies, cultivated land, vegetative cover and rangeland. Human systems are not complex machines; they frequently have a direct impact on ecosystems, such as expanded particulate pollution, water and land, as well as biodiversity loss. The built-up area expansion had been caused by rapid population growth. In our study area, as per the 2011 census of India, District KD has 1,064,493; Trichy, 2,722,290 and Namakkal, 1,726,601; and in 2021, 1,124,822, 2,876,573 and 1,824,454, respectively (estimates as per aadhar uidai.gov.in Dec 2020 data). The built-up regions in each of the three districts have an impact on the population status growth throughout time. Additionally, more than 47% of the district's population resides in urban areas, per the 2011 Census. In all the three districts, the built-up area is growing, notably following a significant increase in 2011. As the population continues to grow, a better understanding of previous LULC shift scenarios and their impacts on society and the environment can aid in reducing the environmental harm caused by people. The southern region of the state would have a significant expansion in constructed land and socioeconomic development, as a result of monitoring the implementation. Rivers and ponds gradually shrink from the time frame until 2019. However, from 2011 through 2022, the impact will be lessened. Except for built-up land, both producer and user accuracies were 100%. The overall accuracies showed 96.6% in 2010 and 87.5% in 2021. In CTND, the drastic changes in increasing built-up area due to the development of nuclear families and emerging urbanization trends accelerated the pace of housing unit growth, compared to 2017. Also, a significant rise in remote population movements to urban locations is because of job orientation. Furthermore, LULC recognition establishes clear legislators for the efficient oversight of the land use region.

Conclusion

The first time, we had surveyed 25 wetlands in each district to determine the wetland depth associated with their ecological status in the CTND. Studies revealed that wetland degradation was because of the factors such as landscape disturbance, buffer zone alteration, pollution, hydrological alteration and habitat alteration. Also, WD has a positive relationship with alteration of the buffer zone, habitat, hydrology and HDS, but it has a negative relation with

Table 8 Wetland type area transition matrix from 2010 to 2019 in the Namakkal District (sq. mi)

Land class 2010		Land class 2019 (sq. mi)					
Row labels	Sum of area	Agricultural land	Barren land	Built-up land	Cultivated land	Waterbodies	Grand total
Agricultural land	1.1570	41,157.332	1.4084	2,324,381.327	13,748.158	124.529	2,379,412.467
Barren land	654.989	195,903.602	1.3804	1,744,089.088	4556.829	4.5559	1,944,553.328
Built-up land	495,029.299	201,879.691	1.731	4,826,585.864	93,460.275	141.495	5,122,069.845
Cultivated land	17,350,311.309	61,536.189	3.047	3,759,654.325	116,465.013	55.935	3,937,701.474
Waterbodies	241.894	0.340	0.010	55,543.112	64,008.402	93.049	119,644.951
Grand total	29,415,733.492	500,477.201	7.577	12,710,251.398	292,238.793	419.562	13,503,382.452

Table 9 Wetland type area transition matrix from 2010 to 2019 in the Karur District (sq. mi)

Land class 2001		Land class 2019 (sq. mi)					
Row labels	Sum of area	Agricultural land	Barren land	Built-up land	Cultivated land	Waterbodies	Grand total
Agricultural land	1.669	5.722	118.240	2.031	23,086.125	0.029	7.986
Barren land	678.538	1.861	582.761	5.471	5.202	0.039	2.460
Built-up land	19,345.375	2.431	222.474	7.289	22,312.585	0.055	3.183
Cultivated land	4.2852	3.7176	1063.475	1.036	17,111.192	0.023	4.935
Waterbodies	800.076	5.066	2256.569	9.031	32,156.525	0.019	6.312
Grand total	1.676	5.745	4243.518	1.673	1.467	0.165	7.566

Table 10 Wetland type area transition matrix from 2010 to 2019 in the Tiruchirappalli District (sq. mi)

Land class 2001		Land class 2019 (sq. mi)					
Row labels	Sum of area	Agricultural land	Barren land	Built-up land	Cultivated land	Waterbodies	Grand total
Agricultural land	8.361	5.179	0.399	6278.339	9.210	1.494	5.427
Barren land	36,376.295	5.285	1.231	1979.355	4.222	9.610	4.426
Built-up land	28,590.441	4.757	0.706	2673.856	5.120	1.124	4.924
Cultivated land	3.706	3.067	1.123	4245.999	28,601.389	7.560	3.176
Waterbodies	3305.755	1.923	0.612	409.632	13,722.350	4.977	2.561
Grand total	4.610	1.848	4.071	15,587.181	2.279	4.832	1.921

landscape alteration and wetland pollution. The wetland degradation was the utmost in the District of Tiruchirappalli, followed by Namakkal and Karur Districts. Except in KDW, the remaining district wetlands were of the MI category. Varied HDS had been observed among the regions. Studies supported that WD had based on water availability throughout the year, but SW were facing water shortages because of a hydrological alteration and lack of management activities. District-wise wetland depth showed that 54% (less than 5 ft.), 25.6% (5–10 ft.) and 20.2% (100%) categories and the rural side wetlands were the dominant form in all the districts. Overall, the ES of wetlands against the water depth showed a strong correlation between them. The impacts of LULC changes over 9 years confirm a severe decline in wetland habitat and water bodies' size because of established territory, arable land advancement, increasing urban population and demand to feed the population. For wetland management, the data such as individual wetlands, land use land and cover and human disturbance scores are needed. Also, expanding the research on other parts of the districts will be useful for the documentation of regional wetlands. Our study suggested that the depth of wetlands leads to some quantified amount of impact on wetlands, and more research will be required to evaluate the influence on wetlands. With the use of LULC maps, we can monitor changes in our ecology and surroundings at CTND. If we have inch-by-inch information on the land use and land cover of the research, we might develop legislation and launch programs to protect our environment.

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Author contribution Dr. Varunprasath Krishnaraj: supervision, original draft writing, conceptualization, writing review, final analysis, and editing. Subha Mathesh: data collection, investigation, visualization, and formal analysis.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethical approval Not applicable.

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