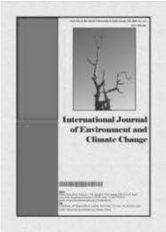

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Mapping, Inventory and Change Detection of Wetlands of Thavanur Grama Panchayath using Multispectral Satellite Imagery

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Wetlands are the submerged or waters saturated lands, both natural and man-made, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed 6 meters. Effective wetlands management and protection are critical. Accurate and comprehensive wetland classification maps as well as spatiotemporal change information are essential for ecological protection and local government decisions. Wetland mapping and classification help to preserve and improve wetland quality.

A study was conducted on wetland mapping, inventory and change detection wetlands of Thavanur Grama Panchayath in Malappuram district of Kerala using multispectral satellite imageries of high resolution (2.4x2.4m) during the year 2020-2021. The image processing was carried out by Visual Interpretation Technique. The accuracy of mapping was assessed by kappa coefficient.

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The various wetland classes found in Thavanur Grama Panchayath were Aquaculture, Marshy land, River and other ponds and small waterbodies. The major wetlands identified in the Panchayath were Ayankalam kayal, Maravanchery kaayal, Varo kaayal, Thavanur kaayal (marshy type wetlands), Bharathapuzha River, Ayankalam aquaculture, Mathur aquaculture and several other ponds. The change detection analysis showed that the percentage change in wetland during the decade was found maximum for pond and well (-33.18%). The major land use changes during the period 2008 and 2018 were that coconut plantation increased by 70.79 ha, paddy land decreased by 61.62 ha and marshy land decreased by 7.04 ha. The kappa coefficient of mapping was obtained as 0.93 which indicted good accuracy.

Keywords: Wetland mapping; visual interpretation technique; change detection analysis and kappa coefficient.

1. INTRODUCTION

A wetland is a distinct ecosystem that is flooded by water, either permanently or seasonally [1]. They are eco-tones or transitional zones that occupy an intermediate position between dry land and open water. Wetlands are vital for human survival that modifies the human history as well as the culture. The primary factor that distinguishes wetlands from terrestrial land forms or water bodies is the characteristic aquatic vegetation [2]. It performs a variety of useful functions, such as recycle nutrients, purify water, prevent floods, maintain stream flow, recharge groundwater, and also serve in providing drinking water, fish, fodder, fuel, wildlife habitat, buffer shorelines against erosion and recreation to the society. They also play a critical role in climate change, biodiversity, hydrology, and human well-being. Sources of hydrological flows into wetlands are predominantly precipitation, surface water, and groundwater. Hydrodynamics affects hydro-periods (temporal fluctuations in water levels) by controlling the water balance and water storage within a wetland [3].

Kerala is one of the green states of India and is well known for its wetlands. Wetlands play an important role in the economy of Kerala [4]. Kerala is also well known for its wetland’s cultivation. Cultivation in these wetlands has received global attention now.

Wetlands are in danger all across the world right now. In order to make space for development, wetlands are contaminated, drained, or filled up. The rate of wetland destruction has accelerated in recent years. Infrastructure development disrupted the wetlands' connectivity and obliterated large swaths of coastal vegetation [5,6]. Due to intensive anthropogenic activities, climate change and decreasing biodiversity, the ecological functions of wetlands are retrogressing and triggering numerous environmental and social problems [7,8]. Therefore, an accurate and comprehensive wetland classification maps and spatio-temporal change information are very important for ecological protection and local government decisions. Wetland inventories especially on their spatial extent are a prerequisite for management and conservation of any wetland.

The basis of wetland ecological conservation is to know the wetland’s location, distribution, size and type. However, traditional measurements of wetlands, that is, field investigations or the manual visual interpretation of aerial photographs, have limited spatial or temporal coverage, consume a large number of human resources and are difficult to undertake [9,5]. Visual interpretation technique use satellite imageries of large spatial and temporal coverage and it generally involves in viewing images, making measurements on images, performing image interpretation tasks, and transferring interpreted information to base maps (Lillesand *et al.,* 2014). Hence visual interpretation technique can be used efficiently to classify the complex and heterogeneous landscapes with image pattern characteristics which deliver better spatial details in enhanced quality from medium-resolution satellite data [10].

Thavanur Grama Panchayath is a land rich in water resources and wetlands. The cultivation and livelihoods of the Panchayath mainly depend on these water sources. Therefore, their variations and changes affect the agriculture and other related activities of the Panchayat. There is no proper documentation on wetland mapping, its inventory and its change detection over the last decade for the Panchayath. Hence this study was conducted with objective of mapping, inventorying and change detection of wetlands of the Panchayath.

2. MATERIALS AND METHODS

2.1 Study Area

A study was conducted in Thavanur Gramapanchayath situated in Malappuram district of Kerala during the year 2020-2021. The total area of Thavanur Grama Panchayat constitutes 2530.459 ha. The study area lies between 10°51'5" N Latitude and 75°51'5" E longitude at an altitude of 8.54 m above mean sea level. Thavanur has a tropical humid climate with an oppressive summer and plenty of seasonal rainfall. The average annual rainfall is 2952mm. The minimum and maximum temperature prevails between 20°C and 39℃ while average annual relative humidity is about 85%. The area receives rainfall during South-West and North-East monsoon.

2.2 Data and Software Used

2.2.1 Data acquisition

The remote sensing data required for the study was downloaded using the facility of Google Earth Image Downloader version 6.381 of the Kerala State Remote Sensing and Environment Centre (KSREC), Thiruvananthapuram from Google Earth Pro. The cloud-free combined images of Cartosat-1 and Quick bird-1 satellite data set for the years 2008 and 2018 were acquired. The satellite image of Thavanur Grama Panchayath is shown in Fig. 2.

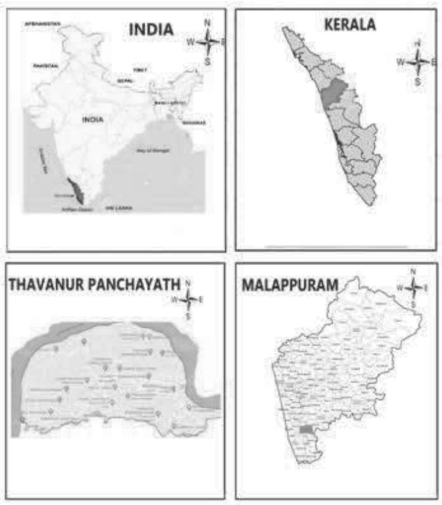

Fig. 1. Location map of study area

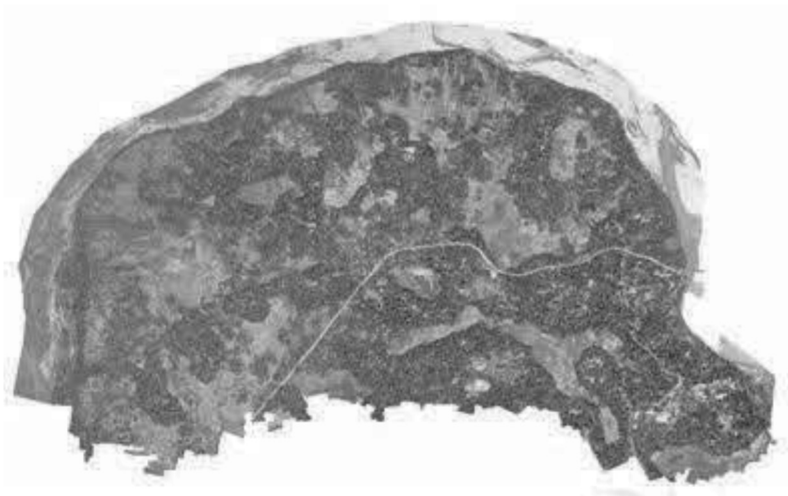

Fig. 2. Satellite image of study area

2.2.2 Software used

The ArcGIS and Google earth pro image downloader were used for data creation, data analysis and output generation of this study. Google Earth Image Downloader version 6.381 and ArcGIS 10.8 of the Kerala State Remote Sensing and Environment Centre (KSREC) were used in this study.

2.3 Spatial Data Processing for LULC Mapping, Wetland Mapping and its Classification

ArcGIS 10.8 software was used for LULC mapping and its classification. Visual Interpretation Technique (VIT) was adopted for spatial data processing. Visual image interpretation is a process of identifying what we see on the images and communicates the information obtained from these images to others for evaluating its significance. LULC map of study area was prepared by drawing polygon in the shape of each object seen in the satellite image using the cut polygon tool in ArcGIS and then specifically mention what each object's land use class with its assigned colour. National Remote Sensing Centre (NRSC) LULC classification system was adopted for land use classification. The LULC maps prepared were used for identification and delineation of wetlands. Besides the satellite data, ground truth data and collateral data were also used for delineation of wetland types / category. Ground truth data collection was done using Etrex 30 GPS device. The National Remote Sensing Centre (NRSC) wetland classification system was adopted for wetland mapping. The wetland maps of 2008 and 2018 were thus prepared by visual interpretation technique. The details of National Remote Sensing Centre, NRSC – ISRO LULC classification system and NRSC wetland classification system adopted in this study are shown in Table 1 and Table 2.

According to the NRSC-ISRO land use classification, wetlands like waterlogged land and Marshy / Swampy lands are grouped under wasteland class, whereas rivers / streams, canals and lakes / reservoirs / tanks are grouped under water bodies.

Table 1. NRSC land use Land Cover classification system

S. No	Level-I	Level-II
1	Built up Land	1.1 Towns/ Cities
		1.2 Villages
2	Agricultural Land	2.1 Fallow
		2.2 Plantation
3	Forest	3.1 Evergreen/ Semi-evergreen
		3.2 Deciduous (Moist & Dry)
		3.3 Scrub Forest
		3.4 Forest Blank
		3.6 Mangrove
4	Wasteland	4.1 Salt Affected Land
		4.2 Waterlogged Land
		4.3 Marshy / Swampy Land
		4.4 Gullied / Ravenous Land
		4.5 Land with scrub
		4.6 Land without scrub
		4.7 Sandy area (Coastal and desertic)
		4.8 Mining / industrial wasteland
		4.9 Barren Rocky / Stony waste / sheet rock area
5	Water Bodies	5.1 River / Stream
		5.2 Canals
		5.3 lake / Reservoirs / Tank
6	others	6.1 Shifting Cultivation
		6.1 Grass land / Grazing land
		6.3 salt pans
		6.4 Snow covered / Glacial Area

Table 2. NRSC wetland classification system

Sl. No	Level 1	Level 2
1	Inland wetlands	Oxbow lakes, cut-off meanders, playas, marsh
2	Coastal wetlands	Estuaries, lagoons, creek, backwater, bay, tidal / mud flat, sand / beach, rocky coast, mangrove, salt/marsh hydrophytic vegetation and saltpans
3	River / Stream / Canal	
4	Water bodies	Pond, lake, tank and reservoirs

2.4 Accuracy Assessment of Mapping

Accuracy assessment is used for comparing the land cover classification results to actual geospatial data that are assumed to be true. A stratified random sampling method was used to collect a total of 100 reference data to ensure that all the LULC classes were adequately represented depending on the proportional area of each class. Google earth pro images were used to extract reference data. Confusion matrix (error matrix) was prepared for accuracy assessment. The accuracy was assessed in terms of Kappa coefficient, overall accuracy, producer's and user's accuracy derived from the confusion matrix [11]. The Kappa coefficient reports the relationship between the classified map and reference data [12].

Kappa coefficient is a measure of how the classification results compared to values assigned by chance. It can take values from 0 to 1. Classification is not complete until its accuracy is assessed using the known Kappa statistics agreement between the predictive model and a set of field surveyed sample points [13]. The Kappa coefficient was computed using equation proposed by Jensen and Cowen [14] and is shown as

$$K = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \text{ x } x_{+1})}{N^2 - \sum_{i=1}^{r}(x_{i+} \text{ x } x_{+1})}$$

Where: K = Kappa coefficient of agreement

N = Total number of observations (sample points)
Xi = Observation in the line *i* and column *I*
Xi+ = Total marginal of the line *I*
X+1 = Total marginal of the column *i*

The Kappa coefficient agreement values are shown in Table 3.

Table 3. Kappa coefficient agreement

Sl. No.	Kappa Coefficient	Rating
1.	Less than 0.4	Poor
2.	0.4 < KC < 0.5	Fair
3.	0.55 < KC < 0.7	Good
4.	0.7 < KC < 0.85	Very Good
5.	KC > 0.85	Excellent

The various equations used for the accuracy assessment were as follows.

$$\text{User's accuracy } = \frac{\text{Number of currently classified pixels in each category}}{\text{Total number of classified pixels in that category (Row total)}} \text{X } 100$$

$$\text{Producer's accuracy } = \frac{\text{Number of currently classified pixels in each category}}{\text{Total number of Reference Pixels in that Category (The column Total)}} \text{X } 100$$

$$\text{Overall accuracy } = \frac{\text{Total number of correctly classified pixels (TCS (Diagonal)}}{\text{Total number of reference pixel (TS)}} \text{X } 100$$

$$\text{Kappa coefficient (T) } = \frac{\text{(TS x TCS)} - \sum\text{(column Total x Row Total)}}{\text{T S2 } - \sum \text{ (column Total x Row Total)}} \text{X } 100$$

Table 4. General LULC change transition matrix

Time T2		Time T1						
		LULC 1	**LULC 2**	**LULC 3**	**LULC 4**	**LULC 5**	**Total T1**	**Loss**
	LULC 1	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{1+}	A_{1+}- A_{11}
	LULC 2	A_{21}	A_{22}	A_{23}	A_{24}	A_{25}	A_{2+}	A_{2+}- A_{22}
	LULC 3	A_{31}	A_{32}	A_{33}	A_{34}	A_{35}	A_{3+}	A_{3+}- A_{33}
	LULC 4	A_{41}	A_{42}	A_{43}	A_{44}	A_{45}	A_{4+}	A_{4+}- A_{44}
	LULC 5	A_{51}	A_{52}	A_{53}	A_{54}	A_{55}	A_{5+}	A_{5+}- A_{55}
	Total T2	A_{+1}	A_{+2}	A_{+3}	A_{+4}	A_{+5}	1	
	Gain	A_{+1}-A_{11}	A_{+2}-A_{22}	A_{+3}-A_{33}	A_{+4}-A_{44}	A_{+5}-A_{55}		

[17]

Where:

Aij = The land area that experiences transition from LULC, from category i to LULC category j
Aii = The diagonal elements indicating the land area that shows persistence of LULC category i while the entries off the diagonal indicate a transition from LULC, from category i to a different category j
Ai+ (total column) = The land area of LULC category i in T1 which is the sum of all j of Aij
A+j (total rows) = Land area of LULC category j in time 2 which is the sum of over all of i of Aij
Losses (Ai+ – Aii) = Proportion of landscape that experiences gross loss of LULC category I, between T1 and T2
Gains (A+i – Aii) = Proportion of landscape that experiences gross gain of LULC category j, between T1 and T2

2.5 Change Detection Analysis

The changes brought about in the land use of wetlands during the years 2008 and 2018 were assessed. Change detection quantifies the changes that are associated with LULC changes in the landscape using geo-referenced multi-temporal remote sensing images acquired on the same geographical area between the considered acquisition dates [15]. This study employed post-classification comparison (PCC) change detection method [16] to detect the LULC changes of two independently classified maps that occurred between two different dates of the study period. The use of the PCC technique resulted in a cross-tabulation matrix (LULC change transition matrix) which highlight the land use classes where the change has occurred. The general LULC change transition matrix table is shown in Table 4.

2.6 Annual Rate of Change

The annual rate of change of LULC at two different years (2008 and 2018) was calculated using following equation as suggested by Puyravad (2003), Teferi et al. [18] and Batar et al. [19].

r= (1/ (t2-t1)) x ln (A2/A1)

where: r is the annual rate of change for each class.

$A2$ and $A1$ are the class areas (ha) at time 2 and time 1 respectively and t is time (in years) interval between the two periods.

2.7 Gains and Losses of LULC (Net Change)

The difference between the gain and loss is the net change [18]. The gains and losses in LULC between 2008 and 2018 were calculated using the cross-tabulation matrix.

3 RESULTS AND DISCUSSION

3.1 Land Use/Land Cover mapping and its classification using Visual Interpretation Technique (VIT)

The Land use Land Cover (LULC) map of Thavanur Grama Panchayath for the years 2008 and 2018 are shown in Fig. 3 and Fig. 4. The areas of LULC classes in 2008 and 2018 and its changes mapped by visual interpretation technique are shown in Table 5.

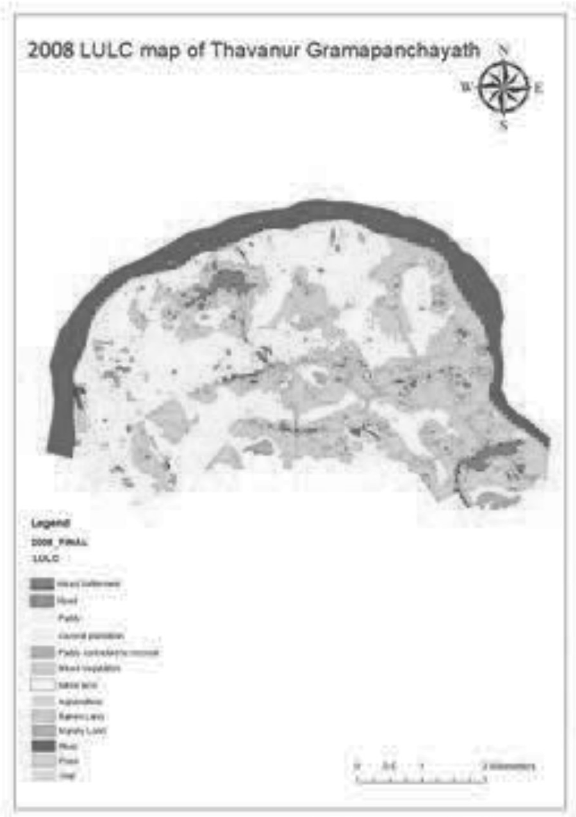

Fig. 3. LULC Map of Thavanur Grama Panchayath-2008

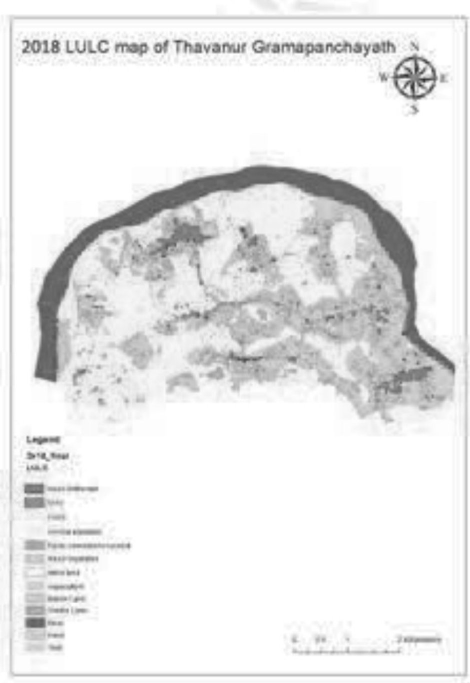

Fig. 4. LULC Map of Thavanur Grama Panchayath-2018

Table 5. LULC of Thavanur in 2008 and 2018 and its changes obtained by VIT

LULC-Ist level	LULC-II nd level	Area in 2008 (ha)	% Area in 2008	Area in 2018 (ha)	% Area in 2018	Rate of change (By applying Growth Variation Rate, GVR)
Built up Land	Settlements (mixed)	128.82	5.09	177.59	7.02	37.86
	Road	28.97	1.14	28.97	1.14	0
Agricultural Land	Paddy	568.25	22.45	506.63	20.02	-10.84
	coconut	472.20	18.66	542.99	21.46	14.99
	Paddy converted to coconut	22.18	0.88	16.29	0.64	-26.56
	Mixed Vegetation	854.65	33.77	829.14	32.76	-2.98
	Fallow Land	3.25	0.13	6.78	0.27	108.62
	Aquaculture	0	0	2.18	0.09	-
Wasteland	Barren Land / wasteland	46.96	1.86	36.32	1.44	-22.66
	Marshy Land	36.58	1.45	29.54	1.17	-19.25
Water Bodies	River	372.98	14.74	374.34	14.79	0.36
	Pond	4.57	0.18	3.46	0.14	-24.29
	Well	0.013	0.00	0.015	0.00	15.38
	Total	2530.893		2530.893		0

Nb: Applying the Growth variation rate we can obtain positive values for growth and negative values for decrease

The total area of the Panchayath was estimated as 2530.89 hectares in which, the area of built-up land, agricultural land, wasteland and water body were 157.79ha, 1921.33 ha, 83.54 ha, 377.563 ha in 2008 respectively, and the same in 2018 were 206.51 ha, 1904.01 ha, 65.86 ha, 377.815 ha respectively. The built-up land (mixed settlements) occupied an area of 128.82 ha (5%) in 2008 and the same was 177.59 ha in 2018. The main settlements were found in the Northern and Southern region with well-developed road networks. The road networks occupied an area of 28.97 ha (1%) both in 2008 and 2018.

Under agriculture land use, the mixed vegetation occupied the largest area coverage of 854.64 ha which represented 34% of the total area in 2008 and the same was 829.14 ha in 2018. Paddy fields spread over 568.25 ha (22%) in 2008 and 506.63 ha in 2018, whereas coconut plantation occupied 472.20 ha (18%) in 2008 and 542.99 ha in 2018. They are concentrated mainly at the Northern & Western parts and small patches in southern parts of the Panchayath. Fallow lands were found below 1% as small patches here and there (3.25 ha in 2008 and 6.78 ha in 2018). It was observed that there was no Aquaculture in the Panchayath during the year 2008 but an aquaculture area of 2.18 ha was found in 2018.

Barren land / waste land occupied an area of 46.96 ha (1.86%) in 2008 and 36.32 ha in 2018, whereas Marshy land occupied an area of 36.58 ha (1.45%) in 2008 and 29.54 ha in 2018. Water body (river) occupied an area of 372.98 ha (14.74%) in 2008 and 374.34 ha (14.79%) ha in 2018 were on the western and northern boundary of the Panchayath. Ponds and wells demarcated with an area of 4.57 ha and 0.013 ha respectively in 2008 and 3.46 ha and 0.015 ha respectively in 2018.

3.2 Wetland Mapping and Inventorying

Field survey and satellite imagery interpretation was carried out to document and make inventories of the wetlands of Thavanur Grama Panchayath. The different wetland classes identified in 2008 were marshy lands (swamps), river and other small waterbodies including ponds and wells. The total area of wetlands in 2008 was 414.16 ha whereas the total area of wetland in 2018 was 409.52 ha which included aquaculture, marshy land (swamps), river and other small waterbodies. The wetland map of Thavanur Grama Panchayath in 2008 and 2018 are shown in Fig. 5 and Fig.6.

Fig. 5. Wetland map of Thavanur Grama Panchayath-2008

Fig. 6. Wetland map of Thavanur Grama Panchayath-2018

It is clear from the wetland maps that Thavanur Grama Panchayath is dominated by marshy type wetlands. An aquaculture area of 2.18 ha was found in the study area during 2018. This was a source of income for the wetland farmer in the area. The marshy land area decreased by 7.04 ha during the last ten years. However, the area of Bharathapuzha has increased by 1.36 ha from 2008 to 2018. The areas of other waterbodies decreased from 4.60 ha to 3.46 ha. Hence it is evident that the increase was only for riverine and aquaculture areas and may be due to the devastating flood during 2018. The areas of all other wetlands decreased significantly during the ten-year period. The Area of each wetland type in Thavanur Grama Panchayath during 2008 and 2018 is shown in Table 6.

Table 6. Distribution of different types of wetlands in Thavanur during 2008 and 2018

Sl. No	Wetland Type	Area - 2008 (ha)	Area - 2018 (ha)
1	Aquaculture	0.000	2.180
2	Marshy Land	36.580	29.540
3	River	372.980	374.340
4	Others	4.608	3.460
Total		414.168	409.520

3.3 Identification of Major Wetlands of Thavanur Grama Panchayath

The major wetlands of Thavanur Grama Panchayath identified were Thavanur Kayal, Ayankalam Kayal, Ayankalam Fish farm, Mathur Fish farm, Varo Kayal and Bharathapuzha River and is shown in Fig. 7 and Fig. 8 and their details are shown in the Table 7.

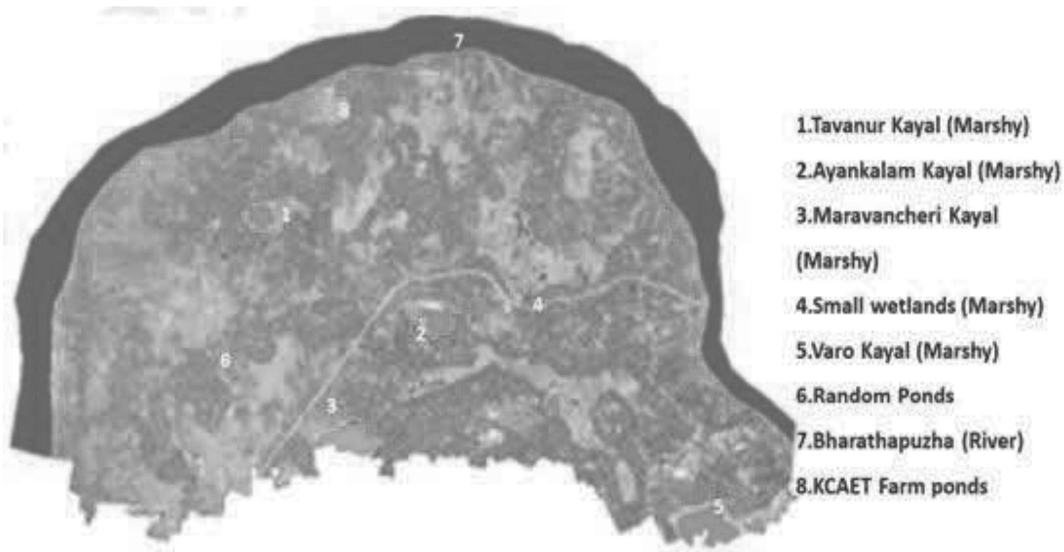

Fig. 7. Name and location of wetlands – 2008

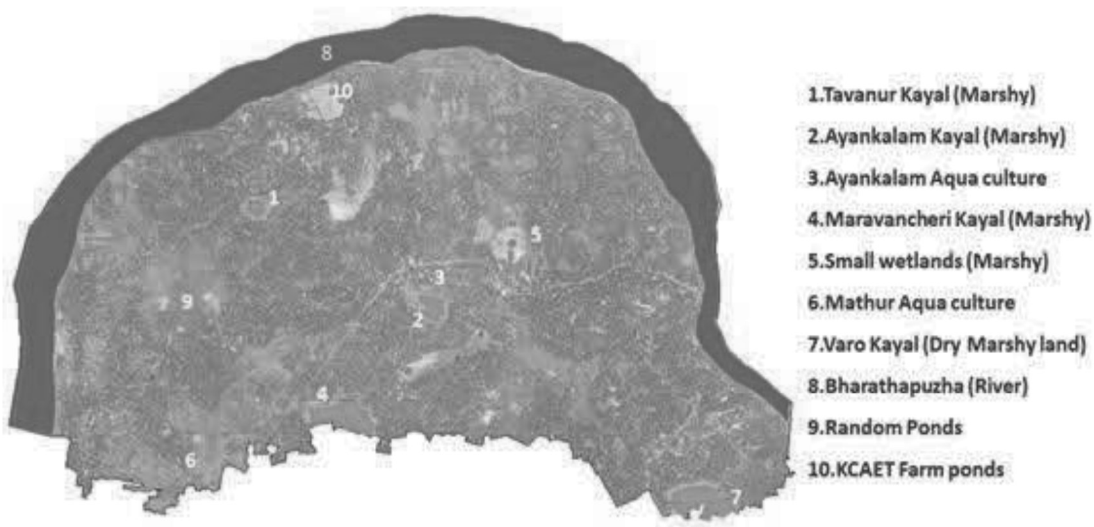

Fig. 8. Name and location of wetlands – 2018

Table 7. Details of Major wetlands of Thavanur Grama Panchayath

Sl.No	Name, type and location of wetlands	Wetlands -2008	Area in 2008	Wetlands -2018	Area in 2018	Particulars and purpose
1	Tavanur Kayal Marshy Land 10°50'50.7"N 75°58'55.8"E		4.11 ha		2.93 ha	• Irrigation purpose • Domestic purpose other than drinking
2	Ayankalam Kayal Marshy Land 10°50'20.7"N 75°59'53.7"E		4.3 ha		2.6 ha	• Irrigation purpose
3	Ayankalam Fish farm Aquaculture 10°50'25.6"N 75°59'54.4"E	Nil			1.82 ha	• Silopia, bedfish, rohu, anabis, katla, banded snake's head and pangusis are major fish varieties
4	**Maravanchery Kayal Marshy Land** **10°49'48.1"N** **75°59'27.6"E**		**3.11 ha**		**2.56 ha**	• **Water Lilly and lotus are regularly cultivated**
5	**Small wetlands Marshy land** **10°50'41.3"N** **76°00'19.3"E**		**13.16ha**		**12.07 ha**	• **Agriculture uses**
6	**Mathur Fish farm Aqua culture** **10°49'38.2"N** **75°58'37.6"E**	Nil	0		**0.28 ha**	• **Silopia, bedfish, rohu, anabis, katla, banded snake's head and pangusis are the major fish varieties**

7	**Varo Kayal Marshy land** **10°49'22.0"N 76°01'18.3"E**		**11.9 ha**		**9.38 ha**	• **Agriculture purpose** • **Almost dried**
8	**Bharatha Puzha** **10°51'41.9"N 75°59'08.5"E**		**372.98ha**		**374.34 ha**	• **Agriculture and livelihood of Tavanur and cheruthirunnavaya Panchayats are mainly depended on Bharathapuzha.** • **Irrigation purpose** • **Domestic purpose other than drinking**
9	**Random Ponds and wells**		**5.15ha**		**3.88 ha**	**Agriculture Purpose**
10	**KCAET Farm ponds**		**0.5 ha**		**0.6 ha**	**Agriculture Purpose**

Table 8. Confusion Matrix of Visual interpretation

	Settlements (mixed)	Road	Paddy	Coconut plantation	Paddy converted to coconut	Mixed Vegetation	Fallow Land	Aquaculture	Barren Land / wasteland	Marshy Land	River	Pond	Well	Row total	User's accuracy (%)
Settlements (mixed)	8								1					9	88.88
Road		8												8	100
Paddy			8			1								9	88.88
coconut				6		1								7	85.71
Paddy converted to coconut					8	1								9	88.88
Mixed Vegetation						9								9	100
Fallow Land					1		5							6	83.33
Aquaculture								6						6	100
Barren Land / wasteland							1		8					9	88.88
Marshy Land										9				9	100
River											8			8	100
Pond												7		7	100
Well													4	4	100
Column Total	8	8	8	6	9	12	6	6	9	9	8	7	4	100	
Producers Accuracy	100	100	100	100	88.88	75	83.33	100	88.88	100	100	100	100		
Overall Accuracy = 94%															
Kappa Coefficient = 0.93															

Table 9. LULC change trend and annual rate of change in Thavanur

LULC	Area in 2008 ha	Area in 2018 ha	Rate of change (By applying Growth Variation Rate, GVR)	Annual rate r (%) [c]
Settlements (mixed)	128.82	177.59	37.86	0.0321
Road	28.97	28.97	0	0.0000
Paddy	568.25	506.63	-10.84	-0.0115
coconut	472.20	542.99	14.99	0.0140
Paddy converted to coconut	22.18	16.29	-26.56	-0.0309
Mixed Vegetation	854.65	829.14	-2.98	-0.0030
Fallow Land	3.25	6.78	108.62	0.0735
Aquaculture	0	2.18	-	-
Barren Land / wasteland	46.96	36.32	-22.66	-0.0257
Marshy Land	36.58	29.54	-19.25	-0.0214
River	372.98	374.34	0.36	0.0004
Pond	4.57	3.46	-24.29	-0.0278
Well	0.013	0.015	15.38	0.0143
Total	2530.893	2530.893	0	

Table 10. The transition matrix of LULC from 2008 to 2018

		LULC 2018													
		Aquaculture	**Barren land**	**Coconut plantation**	**Fallow land**	**Marshy land**	**Mixed settlement**	**Mixed vegetation**	**Paddy**	**Paddy converted to coconut**	**Pond**	**River**	**Road**	**Well**	**2008 total**
LULC 2018	Aquaculture														0
	Barren land		18.309	4.093	0.509		2.088	22.831	0.127						46.96
	Coconut Plantation		0.714	436.845			12.851	20.429	1.363						472.202
	Fallow land			1.495	1.331		0.032		0.391						3.249
	Marshy land	0.0004				15.667		21.585							36.58
	Mixed settlement		2.853	2.895			108.895	14.011	0.156				0.011		128.823
	Mixed vegetation		1.029	60.149	0.016		47.623	744.230	0.214		0.044	1.351	5.3E-06		854.659
	Paddy	1.966	7.726	32.021	4.918	14.740	5.848	27.508	481.106	2.381			0.015	0.015	568.25
	Paddy converted to coconut		1.690	5.387			0.242	0.034	0.921	13.904					22.179
	Pond	0.213		0.110		0.022		0.089	0.744		3.421				4.599
	River							2.5E-07				372.982			372.983
	Road						0.011		0.015			2.6E-07	28.951		28.977
	Well						0.002	0.004	0.005	0.002				0.002	0.014
	2008 total	2.180	36.32	542.999	6.775	29.5	177.593	829.138	506.68	16.286	3.464	374.333	28.977	0.015	2530.949

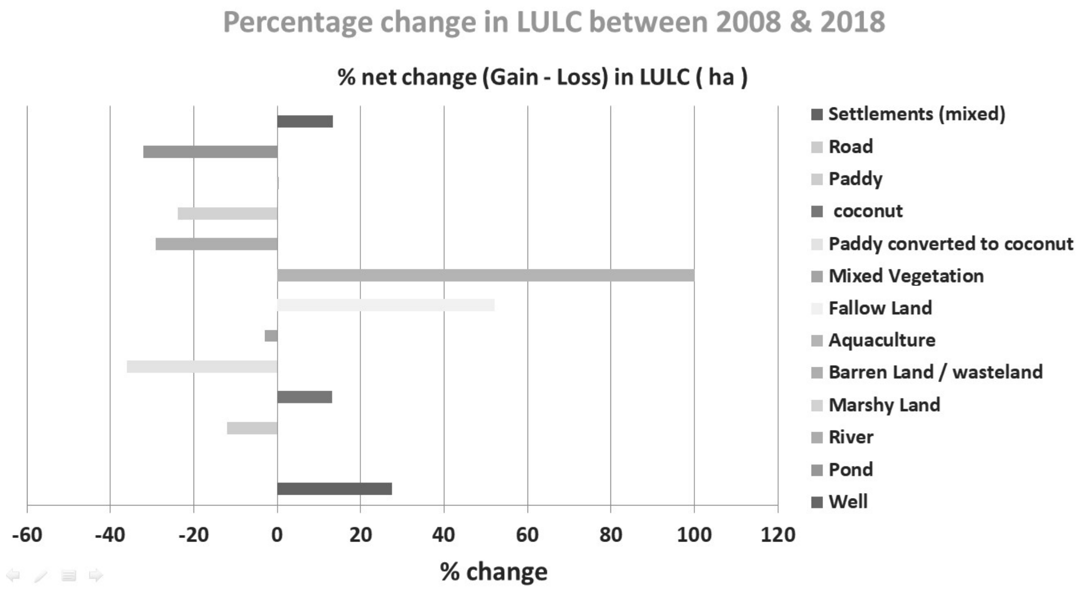

Fig. 9. LULC change trend and annual rate of change in Thavanur

3.4 Accuracy Assessment

The accuracy assessment for the different classes and the corresponding confusion matrix is shown in Table 8. The overall accuracy of visual interpretation was found 94%. The Kappa value was found 0.93. The range of value showed that the classification accuracy is excellent.

3.5 Change Detection Analysis

3.5.1 Land use and land cover change dynamics

Both in 2008 and 2018, Paddy land and mixed vegetation were the predominant LULC classes. The negative sign in the change dynamics indicated the losses in LULC and positive sign indicated the gain in LULC between 2008 and 2018.

The annual rate of change revealed a varied changing progression for each LULC category throughout the study period from 2008 to 2018. There was an annual increase in settlement (0.0321 %), coconut (0.014 %), fallow land (0.0735 %), river (0.0877 %) and well (0.014%). The coconut plantation and aquaculture farming increased to a larger extend from 2008 (472.20 ha) to 2018 (542.99 ha). Table 9 and Fig. 9 shows the LULC change trend and the annual rate of change.

3.5.2 Land use and land cover change (transition) matrix

The LULC change (transition) matrix for the period from 2008 to 2018 were shown in Table 10. The distribution of main transitions in the thirteen LULC categories showed that there were major changes and transition in all the thirteen LULC classes. Between 2008 and 2018, the land use “paddy” experienced the major transition that 32.02 ha converted into coconut plantation. In the case of coconut plantation, the majority of it being converted into mixed vegetation (20.42 ha). The barren land experienced transition to paddy land (0.12 ha) and mixed settlement (2.08 ha). Majority of fallow land converted into coconut plantation (1.49 ha). In the case of marshy land, 21.58 ha converted into mixed vegetation. But in the case of paddy land, 14.74 ha converted to marshy land. About 47.62 ha of mixed vegetation converted to mixed settlement. There was not much transition found in the case of river, pond, road and well.

4. CONCLUTIONS

The study was carried out based on remote sensing and GIS analysis. GIS techniques was found very useful for mapping and inventorying of wetlands. LULC mapping was done by visual interpretation technique. Accuracy of mapping was checked by confusion matrix (error matrix) and change detection analysis was carried out by PCC method.

Visual interpretation technique was found more accurate than supervised classification for mapping wetlands of Thavanur Panchayat, in this study. The study found that there were conspicuous changes in the land use pattern of Thavanur Panchayat during the last decade and the wetlands were also found slowly disappearing in Thavanur. Hence there an urgent need to make aware of the importance and preservation of these wetlands to prevent further degradation. This will be highly useful for the Panchayath for the further planning in protection and management of these valuable wetlands.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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