

Case study

Mapping, Inventory and Change Detection of wetlands of Thavanur Grama Panchayath using multispectral satellite imagery

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. The cultivation and livelihoods of an area depends mainly on the wetlands of the area. Wetland mapping and classification help to preserve and improve wetland quality.

A study was conducted in Thavanur Grama Panchayath in Malappuram district of Kerala using high resolution (5x5m) multispectral satellite imageries during the year 2020-2021. Thavanur Grama Panchayath is a land rich in water resources and wetlands. Wetlands were identified and classified by Visual Interpretation Technique and accuracy was assessed by kappa coefficient. The various wetland classes found in Thavanur Grama Panchayath were Aquaculture (2.18 ha), Marshy land (29.54 ha), River (374.340 ha) and other ponds and small waterbodies (3.460 ha). The major wetlands identified in the Panchayath were Ayankalam kayal, Maravanchery kaayal, Varo kaayal, Thavanur kaayal (all these four were of 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%) followed by marshy land (-23.83%). 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. Paddy land experienced the highest transition among the different LULC classes. The kappa coefficient was found 0.93.

KEY WORDS: _____

Comment [FC1]: Please specify 3-4 key words (ex: Land Use, Land Cover, Mapping, satellite data....)

1 INTRODUCTION

A wetland is a distinct ecosystem that is flooded by water, either permanently or seasonally (Keddy, 2010). 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 culture. The primary factor that distinguishes wetlands from terrestrial land forms or water bodies is the characteristic aquatic vegetation (Ramsar convention, 2010). 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. Water flows out of wetlands by evapotranspiration, surface runoff, and subsurface water outflow. Hydrodynamics affects hydro-periods (temporal fluctuations in water levels) by controlling the water balance and water storage within a wetland (Richardson *et al.*, 2001). 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. 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. Due to intensive anthropogenic activities, climate change and decreasing biodiversity, the ecological functions of wetlands are retrogressing and triggering numerous environmental and social problems (Gong *et al.*, 2010; Han *et al.*, 2015). 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 advancement in geospatial techniques has offered a wide range of methodological applications to prepare maps & inventories of wetlands.

The basis of wetland ecological conservation is to first identify a 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. 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 (Ghorbani and Pakravan, 2013).

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. So far, no proper documentation is available on wetland mapping, its inventory and its change detection over the last decade for the Panchayath. Hence the study was conducted for Mapping and inventorying of wetlands of the Panchayath.

2. MATERIALS AND METHOD

2.1 Study area

A research study was conducted in Thavanur Gramapanchayath situated in Malappuram district of Kerala during the year 2020-2021. The total area of Thavanur Grama Panchayat is 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 normal rainfall is 2952mm. The minimum and maximum temperature prevails between 20°C and 39°C while average annual relative humidity is about 85%. The area receives rainfall during South-West and North-East monsoon.

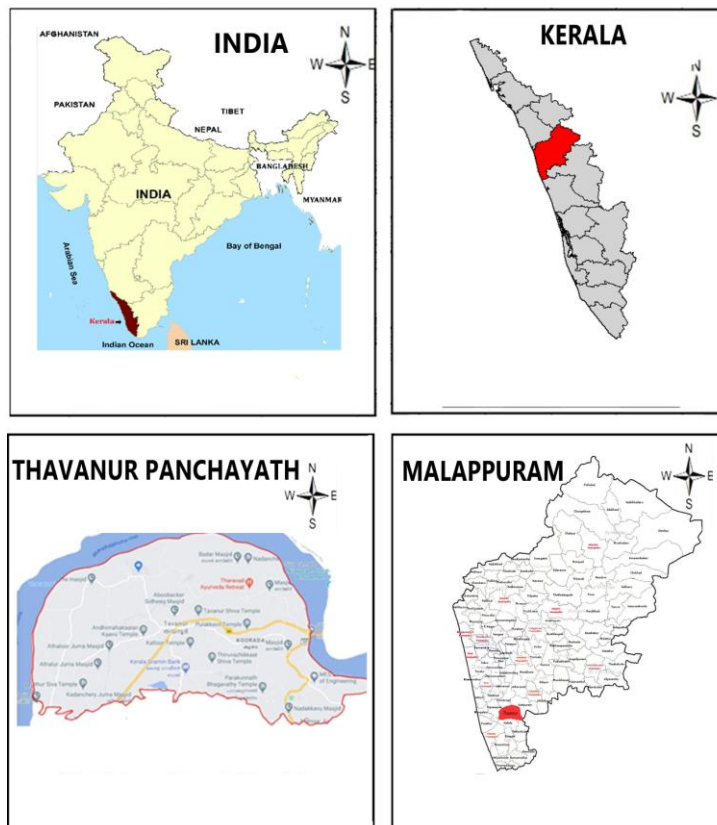


Fig. 1 Location map of study area

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. 2 Satellite image of study area

2.2.2 Software used

The soft-wares 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.

Comment [FC2]: softwares

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 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. For this NRSC LULC classification system was adopted. 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 NRSC wetland classification system was adopted for wetland mapping. Thus, wetland maps of 2008 and 2018 were prepared by visual interpretation technique. The details of NRSC –

Comment [FC3]: Decode NRSC

ISRO LULC classification system and NRSC wetland classification system adopted in this study are shown in Table 1 and 2.

Comment [FC4]: Decode NRSC

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 |

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 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 (Liu *et al.*, 2007). The Kappa coefficient reports the relationship between the classified map and reference data (Lillesand and Keifer, 2000).

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 (Forkuor and Cofie, 2011). The Kappa coefficient was computed using equation proposed by Jensen and Cowen (1999) and is shown as

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

Where: K = Kappa coefficient of agreement

N = Total number of observations (sample points)

X_i = Observation in the line i and column I

X_{i+} = 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.

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

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

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

$$\text{Kappa coefficient (T)} = \frac{(\text{TS} \times \text{TCS}) - \sum(\text{column Total} \times \text{Row Total})}{\text{TS}^2 - \sum(\text{column Total} \times \text{Row Total})} \times 100$$

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 (Ramachandra and Kumar, 2004). This study employed post-classification comparison (PCC)

change detection method (Jensen, 2005) 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.

Table 4 General LULC change transition matrix

| | | Time T1 | | | | | | |
|---------|----------|-------------------|-------------------|-------------------|-------------------|-------------------|----------|-------------------|
| Time T2 | | 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 | $A_{+1} - A_{11}$ | $A_{+2} - A_{22}$ | $A_{+3} - A_{33}$ | $A_{+4} - A_{44}$ | $A_{+5} - A_{55}$ | | |

(Maggie *et al.*, 2019)

Where:

A_{ij} = The land area that experiences transition from LULC, from category i to LULC category j

A_{ii} = 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

A_{i+} (total column) = The land area of LULC category i in T1 which is the sum of all j of A_{ij}

A_{+j} (total rows) = Land area of LULC category j in time 2 which is the sum of over all of i of A_{ij}

Losses ($A_{i+} - A_{ii}$) = Proportion of landscape that experiences gross loss of LULC category i , between T1 and T2

Gains ($A_{+i} - A_{ii}$) = Proportion of landscape that experiences gross gain of LULC category j , between T1 and T2

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.*, (2013) and Batar *et al.*, (2017).

$$r = (1 / (t_2 - t_1)) \times \ln (A_2 / A_1)$$

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

A_2 and A_1 are the class areas (ha) at time 2 and time 1 respectively and t is time (in years) interval between the two periods.

Comment [FC5]: I suggest the following wording: r is the annual rate of change for each class.

2.7 Gains and losses of LULC (Net change)

The difference between the gain and loss is the net change (Teferi *et al.*, 2013). The gains and losses in land use and land cover 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 ~~uses~~ Land Cover (LULC) map of Thavanur Grama Panchayath for the years 2008 and 2018 are shown in Fig. 3 and Fig. 4.

Comment [FC6]: Use

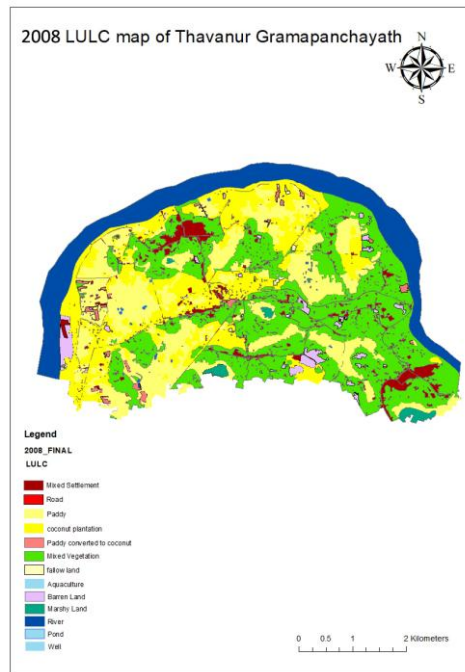


Fig. 3 LULC Map of Thavanur Grama Panchayath-2008

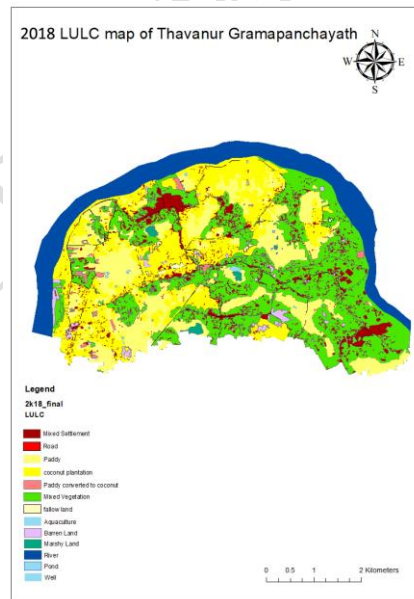


Fig 4. LULC Map of Thavanur Grama Panchayath-2018

The areas of LULC classes in 2008 and 2018 and its changes mapped by visual interpretation technique are shown in Table 5.

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

| LULC-I st level | LULC-II nd level | Area in 2008 (ha) | % Area in 2008 | Area in 2018 (ha) | % Area in 2018 |
|----------------------------|-----------------------------|-------------------|----------------|-------------------|----------------|
| Built up Land | Settlements (mixed) | 128.82 | 5.09 | 177.59 | 7.02 |
| | Road | 28.97 | 1.14 | 28.97 | 1.14 |
| Agricultural Land | Paddy | 568.25 | 22.45 | 506.63 | 20.02 |
| | coconut | 472.20 | 18.66 | 542.99 | 21.46 |
| | Paddy converted to coconut | 22.18 | 0.88 | 16.29 | 0.64 |
| | Mixed Vegetation | 854.65 | 33.77 | 829.14 | 32.76 |
| | Fallow Land | 3.25 | 0.13 | 6.78 | 0.27 |
| Wasteland | Aquaculture | 0 | 0 | 2.18 | 0.09 |
| | Barren Land / wasteland | 46.96 | 1.86 | 36.32 | 1.44 |
| | Marshy Land | 36.58 | 1.45 | 29.54 | 1.17 |
| Water Bodies | River | 372.98 | 14.74 | 374.34 | 14.79 |
| | Pond | 4.57 | 0.18 | 3.46 | 0.14 |
| | Well | 0.013 | 0.00 | 0.015 | 0.00 |
| | Total | 2530.893 | | 2530.893 | |

Nb: Negative value denotes the decline of area

Comment [FC7]: Applying the growth variation rate we can obtain positive values for growth and negative values for decrease

| LULC-I st level | LULC-II nd level | Area in 2008 (ha) [1] | % Area in 2008 | Area in 2018 (ha) [2] | % Area in 2018 | Rate of change (2008 - 2018) = [2] - [1] * 100 [1] |
|----------------------------|-----------------------------|-----------------------|----------------|-----------------------|----------------|----------------------------------------------------|
| Built up Land | Settlements (mixed) | 128.820 | 5.090 | 177.590 | 7.020 | 37.86 |
| | Road | 28.970 | 1.140 | 28.970 | 1.140 | 0.00 |
| Agricultural Land | Paddy | 568.250 | 22.450 | 506.630 | 20.020 | -10.84 |
| | coconut | 472.200 | 18.660 | 542.990 | 21.460 | 14.99 |
| | Paddy converted to coconut | 22.180 | 0.880 | 16.290 | 0.640 | -26.56 |
| | Mixed Vegetation | 854.650 | 33.770 | 829.140 | 32.760 | -2.98 |

Comment [FC8]: Suggest: consider the growth variation rate between 2018 and 2008, in new column and comment the results on text

| | | | | | | |
|--------------|----------------------------|----------|--------|----------|--------|--------|
| | Fallow Land | 3.250 | 0.130 | 6.780 | 0.270 | 108.62 |
| | Aquaculture | 0.000 | 0.000 | 2.180 | 0.090 | - |
| Wasteland | Barren Land / wasteland | 46.960 | 1.860 | 36.320 | 1.440 | -22.66 |
| | Marshy Land | 36.580 | 1.450 | 29.540 | 1.170 | -19.25 |
| Water Bodies | River | 372.980 | 14.740 | 374.340 | 14.790 | 0.36 |
| | Pond | 4.570 | 0.180 | 3.460 | 0.140 | -24.29 |
| | Well | 0.013 | 0.000 | 0.015 | 0.000 | 15.38 |
| | Total | 2530.893 | | 2530.893 | | 0.00 |

Nb: Negative value denotes the decline of area

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 in 2008 were 157.79ha, 1921.33 ha, 83.54 ha, 377.563 ha respectively, and the same in 2018 were 206.51 ha, 1904.01 ha, 65.86 ha, 377.815 ha respectively. Under built-up land, mixed settlements occupied an area of 128.82 ha (5%) in 2008 and the same 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.

Comment [FC9]: Northern

Under agriculture land use, the mixed vegetation occupied the largest area coverage compared to other classes with an area of 854.64 ha which represented 34% of the total area in 2008 and an area of 829.14 ha mixed vegetation were found in 2018. Paddy fields spread over 568.25 ha (22%) 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 in 2018). It was observed that there was no Aquaculture in the Panchayath during the same year 2008 but in 2018 the aquaculture area found that 2.18 ha.

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%) and 374.34 ha in 2018 is 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

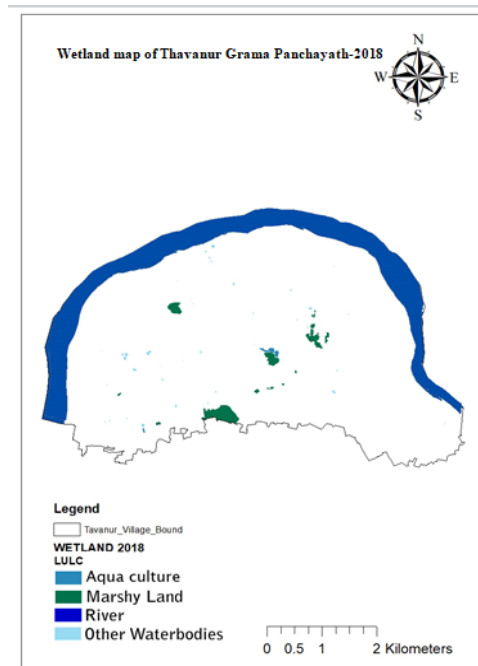


Fig. 6 Wetland map of Thavanur Grama Panchayath-2018

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 in 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 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 flood during 2018. The areas of all other wetlands were decreased significantly during the ten-year period. The Area of each wetland type in Thavanur Grama Panchayath is shown in the 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

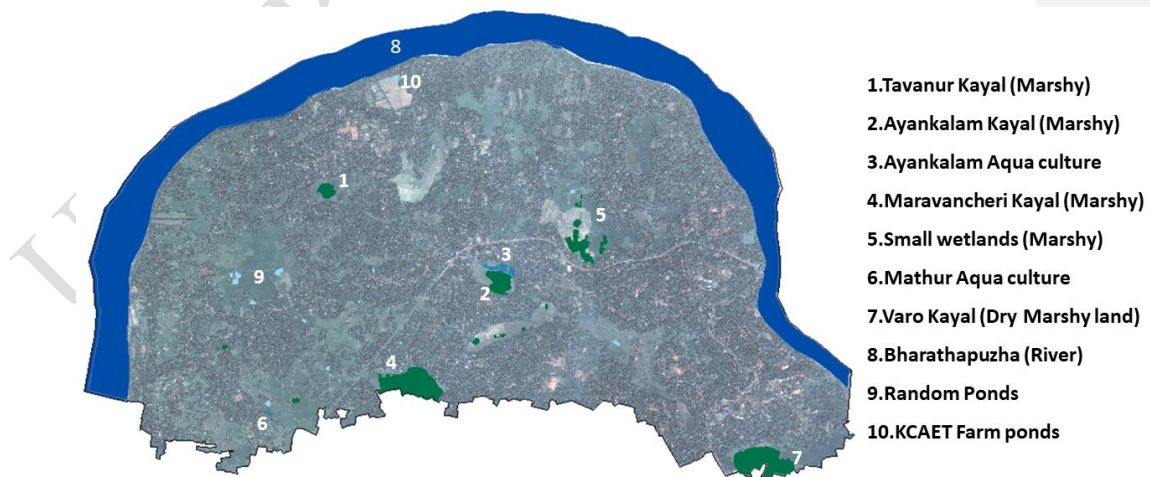




















Fig. 8 Name and location of wetlands - 2018

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 | <ul style="list-style-type: none"> 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 | <ul style="list-style-type: none"> Irrigation purpose |
| 3 | Ayankalam Fish farm Aquaculture 10°50'25.6"N 75°59'54.4"E | Nil | |  | 1.82 ha | <ul style="list-style-type: none"> 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 | <ul style="list-style-type: none"> 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 | <ul style="list-style-type: none"> Agriculture uses |
| 6 | Mathur Fish farm Aqua culture 10°49'38.2"N 75°58'37.6"E | Nil | 0 |  | 0.28 ha | <ul style="list-style-type: none"> 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 | <ul style="list-style-type: none"> • Agriculture purpose • Almost dried |
| 8 | Bharatha Puzha 10°51'41.9"N 75°59'08.5"E |  | 372.98ha |  | 374.34 ha | <ul style="list-style-type: none"> • Agriculture and livelihood of Tavanur and cheruthirunnava ya 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 |

3.4 Accuracy assessment

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

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 | | | | | | | | | | | | | | | |

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 extent from 2008 to 2018. Table 9 and Fig. 9 shows the LULC change trend and the annual rate of change.

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

| LULC | Area in 2008 ha | Area in 2018 ha | Change (%) ^b 2018-2008 | Annual rate r (%) ^c |
|----------------------------|-----------------|-----------------|--------------------------------------|--------------------------------|
| Settlements (mixed) | 128.82 | 177.59 | 27.46 | 0.0321 |
| Road | 28.97 | 28.97 | 0 | 0.0000 |
| Paddy | 568.25 | 506.63 | -12.16 | -0.0115 |
| coconut | 472.20 | 542.99 | 13.03 | 0.0140 |
| Paddy converted to coconut | 22.18 | 16.29 | -36.15 | -0.0309 |
| Mixed Vegetation | 854.65 | 829.14 | -3.08 | -0.0030 |
| Fallow Land | 3.25 | 6.78 | 52.06 | 0.0735 |
| Aquaculture | 0 | 2.18 | 100.00 | - |
| Barren Land / wasteland | 46.96 | 36.32 | -29.30 | -0.0257 |
| Marshy Land | 36.58 | 29.54 | -23.83 | -0.0214 |
| River | 372.98 | 374.34 | 0.38 | 0.0004 |
| Pond | 4.57 | 3.46 | -32.08 | -0.0278 |
| Well | 0.013 | 0.015 | 13.33 | 0.0143 |
| Total | 2530.893 | 2530.893 | 2530.58 | |

Comment [FC10]: Please see the "range of change", in pg12 comment.

Percentage change in LULC between 2008 & 2018

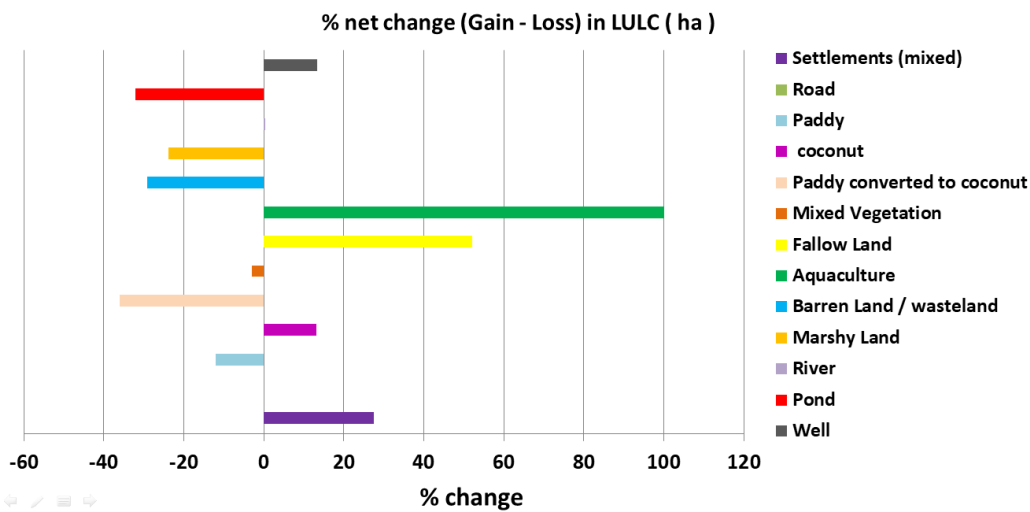


Fig. 9 LULC change trend and annual rate of change in Thavanur

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.

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 2008 | 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 |
| | 2018 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 |

4. CONCLUSIONS

The study was completely based on remote sensing and GIS analysis. For mapping and inventorying of wetlands GIS techniques was found very useful. 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.

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 percentage change in land use was found highest for aquaculture (100%) followed by fallow land (56.06%). The annual rate of change of land use was found highest for fallow land (0.074) followed by settlement (0.0321) and paddy converted into coconut (- 0.031). Paddy land experienced the highest transition among the different LULC classes. No appreciable transition was found in the case of river, pond, road and well.

Total area of wetland was estimated 414.17 ha (16.37 %) in 2008 and 409.52 ha (16.87 %) in 2018. Wetland decreased by 4.65 ha between 2008 and 2018. 10 major wetlands were identified and mostly marshy type. Total area of marshy wetland was estimated as 36.58 ha in 2008 (8.83 % of wetland area), 29.54 ha in 2018 (7.21 % of wetland area). There was no aquaculture in 2008, but aqua culture set up was found in 2018 (2.18 ha). The percentage change in wetland during the decade was found maximum for pond and well (-33.18%) followed by marshy land (-23.83%).

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 an urgent need to make aware of the importance and preservation of these wetlands to prevent further degradation

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