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Research paper

Change detection analysis of reservoirs and lakes in Multi-Temporal Landsat-7 (ETM+) data over the Indian sub-continent during 2008-2018

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Abstract

Remote sensing change detection techniques are extensively used in numerous applications such as land cover monitoring, disaster monitoring, and urban sprawl. The main motive of this paper study the change detection analysis of Land Use / Land Cover (LULC) in different lakes and Reservoirs, such as Chilika Lake, Pulicat Lake, Vembanad Lake, Penna Reservoir, and Nagarjuna Sagar Reservoir located in the Indian subcontinent region. The analyses and changes are evaluated during period of 2008 - 2018 in multi-temporal Landsat-7 (ETM+) data. The major disadvantage in Landsat-7 for data acquired from satellite sensor, is that it includes strips (gaps) in an image. On May 31, 2003 the Scan-Line-Corrector (SLC) failed completely, due to 22% of pixel information lost in the Landsat-7 data. The focal analysis method is applied to the required image for removing all strips (gaps). Change detection using Image Differencing technique, maximum changed area and unchanged area detect the different Lakes and Reservoirs in the period of 2008-2018. The unsupervised classification is used to compute the accuracy assessment analysis. Excellent results are obtained by using accuracy assessment for different Lakes and Reservoirs from 2008 to 2018, with the overall accuracy of 91.59%, and overall kappa statistics of 0.9032. The percentage of a decreased area is more in 2018 as compared to 2008 and it concludes that the percentage of decreased area is more as compared to the percentage of increased area for acquired Landsat-7 data.

Keywords: *Landsat-7 (ETM+), Scan-Line-Corrector (SLC), focal analysis, change detection, Lakes and Reservoirs, accuracy assessment.*

1. Introduction

Change detection analysis of Land Use / Land Cover (LULC) has played a vital role in current areas such as managing natural resources and monitoring changes in the environment. Digital change detection has formative the changes occurred in LULC with reference to multi-temporal remote sensing data. Change detection by Singh (1989) [1], and its used in many applications such as land use changes, habitat fragmentation, deforestation, coastal change, urban sprawl, and other cumulative changes. Remote sensing helps in obtaining multi-temporal data through satellite sensors, and it categorized into different classes such as water bodies, forest, agricultural lands, wetlands etc. [3]. Change detection techniques and their applications had reviewed by several researchers [1,4,14].

Recovery of absent data in a satellite image is essential and there are several reasons for incomplete data when acquired from Landsat-7. The main reason for incomplete data acquired while transferring data instrumentation errors and strips (gaps) occurred. NASA had tried to correct the SLC (Scan-Line-Corrector) but it fails [2], the problem appeared continuously. It is a major failure in Landsat-7 for data acquired from satellite sensors, and it includes strips (gaps) in an image. The SLC was completely failed on May 31, 2003. Due to that 22% of pixel information lost in the Landsat-7 data [5]. But remaining 78% of the original (without gaps) data acquired. The SLC is not operating perfectly, resulting image having strips (gaps) ranging as large as 14 pixels on the near edge [18]. To fill the gaps number of methods have been developed. Especially the focal analysis method used to fill the gaps and display images with better clarity, but it's not satisfactory for any further analyses. The focal analysis method gives good results in a color composite mode like images looks clean, to fill all gaps and remove noise.

Many techniques has used to implemented for change detection algorithms and, most commonly used algorithms are Image differencing, image rationing, post classification, PCA, ANN, LSMA, and GIS [12,13]. Which are used to improve change detection accuracy. Some of these algorithms are well known Unsupervised change detection methods [6-8]. Here image differencing algorithm implemented for different Lakes and Reservoirs in the period of 2008-2018 Landsat-7 images. Resulting from the maximum changed area (decreased or increased area) and the unchanged area was realized. The unsupervised classification involved to compute the accuracy assessment analysis. Based on accuracy analysis, the percentage of a decreased area more as compared to the percentage of increased area for acquired Landsat-7 data. Therefore, the percentage of decreased area is more in 2018 as compared to 2008.

2. Study area and collection of data set

The study area includes three Lakes and two Reservoirs, namely Chilika Lake, Pulicat Lake, Vembanad Lake, Penna Reservoir, and Nagarjuna Sagar Reservoir, located in the Indian subcontinent region and their path/ row, latitude and longitude as shown in Table 1.

Table 1: Location of different Lakes and Reservoirs over the Indian subcontinent

Lakes and Reservoir	Path/ Row	Duration	Latitude	Longitude	States and Country
Chilika Lake	140/46	2008 to 2018	$19^{0}46^{1}30.37^{11}$N	$85^{0}25^{1}4.85^{11}$E	Odessa, India
Pulicat Lake	142/51		$13^{0}24^{1}59.99^{11}$N	$80^{0}18^{1}60.00^{11}$E	Andhra Pradesh, India
Vembanad Lake	144/53		$09^{0}35^{1}48.00^{11}$N	$76^{0}23^{1}54.00^{11}$E	Kerala, India
Penna Reservoir	143/50		$14^{0}41^{1}53.00^{11}$N	$78^{0}44^{1}53.00^{11}$E	Andhra Pradesh, India
Nagarjun Sagar Reservoir	143/49		$16^{0}34^{1}55.60^{11}$N	$78^{0}24^{1}13.97^{11}$E	Telangana, India

The Landsat-7 data acquired is for the period of January 2008 to January 2018. These Landsat data were taken from the USGS portal, and all collected Landsat data were cloud free data only. The specification of bands and its wavelengths for Landsat-7 data are as shown in Table 2.

Table 2: Specifications of the Landsat-7 data

Satellite	Resolution (m)	Wavelengths (µm)
Landsat-7 ETM+	30	Band1:0.45-0.52 (Blue) Band2:0.52-0.60 (Green) Band3:0.63-0.69 (Red) Band4:0.76-0.90 (NIR) Band5:1.55-1.75 (SWIR-1) Band6:10.31-12.36 (TIR) Band7:2.08-2.35 (SWIR-2) Band8:0.51-0.89 (Pan)

3. Methodology

3.1 Focal Analysis algorithm

Focal analysis method helps to fill the gaps where missing data in Landsat-7 data. This method used to calculate the region of center pixels and it performed min, max, mean, median, sum, and standard deviation. These functions allow evaluating central pixels by selecting a pixel window size [20,21]. The focal analysis involved, median filter for reducing noise, such as dead sensor strips, random spikes, and other impulses. This method produced accurate results in color composite mode (such as the picture looks clean and gaps are removed) compared to other gap filling methods as shown in Fig.1.

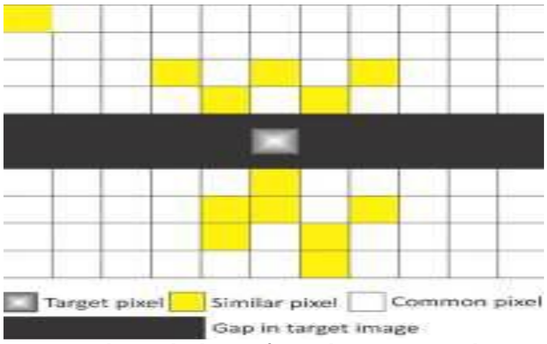

Fig. 1: Similar pixel selection for single image gap analysis

The focal analysis, median filter model is derived from the following an algorithm. 1. Put all pixel DNs with the selected moving window into numerical order. 2. Replace the pixel of interest with the DN values in the center of the ranking [19]. This algorithm is applied to required Landsat image to remove all gaps. In the first time, due to an applied algorithm, all gaps may not remove. Similarly, this algorithm applied to resultant images minimum 5 to 10 times, until unless to fill all gaps. This focal analysis algorithm applied to acquired satellite images, such as Chilika Lake, Pulicat Lake, Vembanad Lake, Penna Reservoir, and Nagarjuna Sagar Reservoir. The resultant output images as shown in Fig. 2-6.

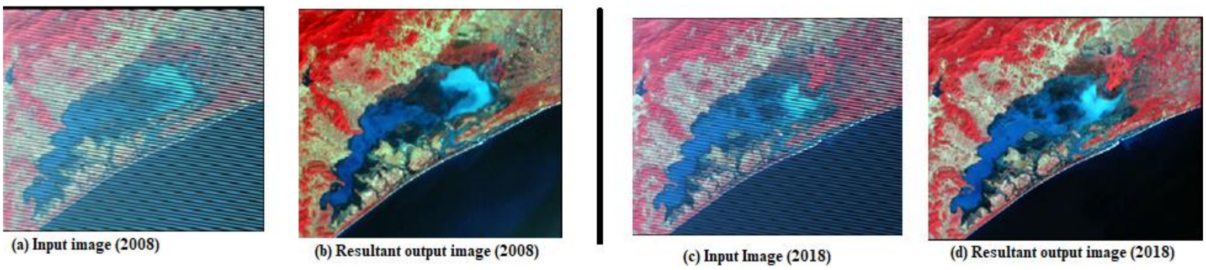

Fig. 2: Chilika Lake: (a) & (c) are applied before the focal analysis algorithm, and (b) & (d) are resultant images.

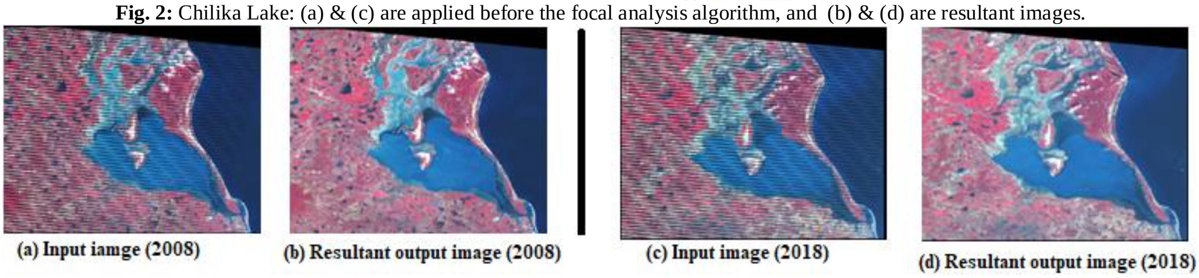

Fig. 3: Pulicat Lake: (a) & (c) are applied before the focal analysis algorithm, and (b) & (d) are resultant images.

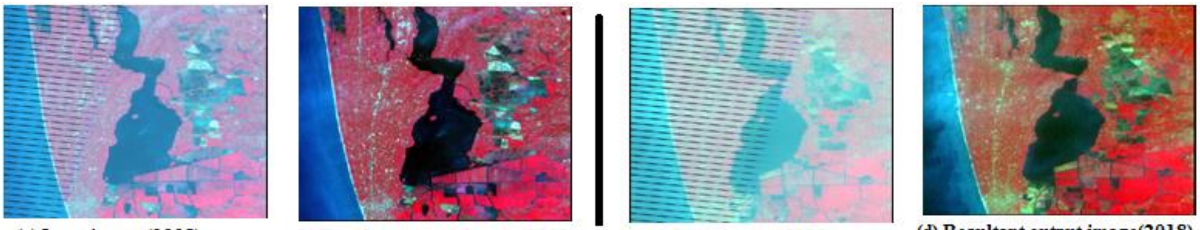

Fig. 4: Vembanad Lake: (a) & (c) are applied before the focal analysis algorithm, and (b) & (d) are resultant images.

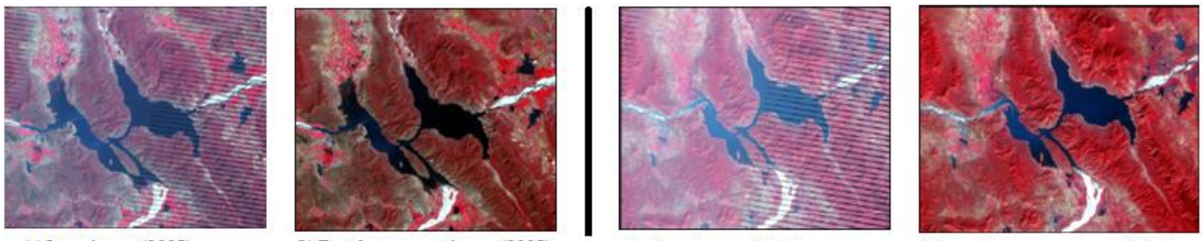

Fig. 5: Penna Reservoir: (a) & (c) are applied before the focal analysis algorithm, and (b) & (d) are resultant images.

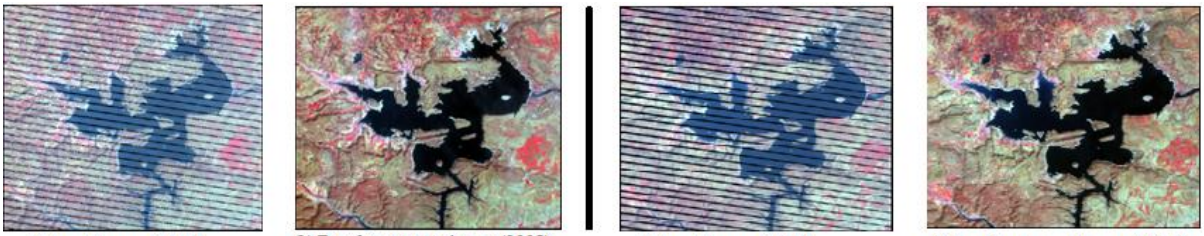

Fig. 6: Nagarjuna Reservoir: (a) & (c) are applied before the focal analysis algorithm, and (b) & (d) are resultant images.

3.2. Change detection

In general change detection involves the applications of multi-temporal Landsat data to quantitatively analyze the multi-temporal effects. Because of the advantages of recurring data acquirement, its synoptic observation, and digital arrangement appropriate for computer processing, remotely sensed data, such as the Thematic Mapper (TM), radar and the Advanced Very High-Resolution Radiometer (AVHRR), have become the most important data sources for altered change detection applications in recent decades. The change detection is useful in many applications such as land use changes, habitat fragmentation, the rate of deforestation, coastal changes, urban sprawl, and other cumulative changes.

3.2.1. Image differencing algorithm

The change detection technique used to group into two classes, such as unsupervised and supervised classification methods. The unsupervised change detection method includes Image differencing, image Rationing, PCA. Here image differencing algorithm was implemented for different Lakes and Reservoirs during the year of 2008-2018.

In image differencing method, consider two different multi-temporal images as input images of image date 1 and image date 2 as shown in Fig. 7. These two images are subtracted from one to another and pixel by pixel to produce the difference image. Pixels with radiance change are circulated in the tails of the distribution curve, whereas pixels showing no radiance change are circulated around the mean [1]. This algorithm follows that the difference of radiance values of pixels between two different image dates. From Fig. 7, zero indicates no changes between two image dates. When changes occurred between two image dates positive and negative values are interpreted and pick the threshold value for a change. The key factor of the image differencing algorithm identifies suitable image bands and its threshold values [15-17]. Change detection using image differencing algorithm applied for 2008 and 2018 images as input images and get the suitable results. Here Red color indicates that decreased area, Green color indicates that increased area and Block color indicates that unchanged area as shown in Fig 8-12. After applying an image differencing algorithm to required Landsat-7 images such as different Lakes and reservoirs, the obtained results as shown in Fig. 8-12.

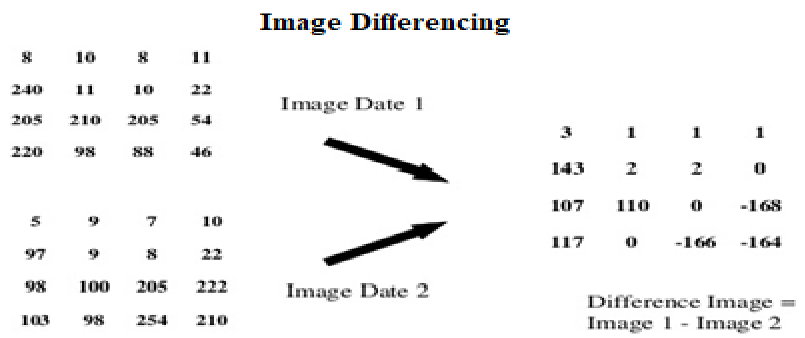

Fig. 7: Image differencing analysis for two different image dates.

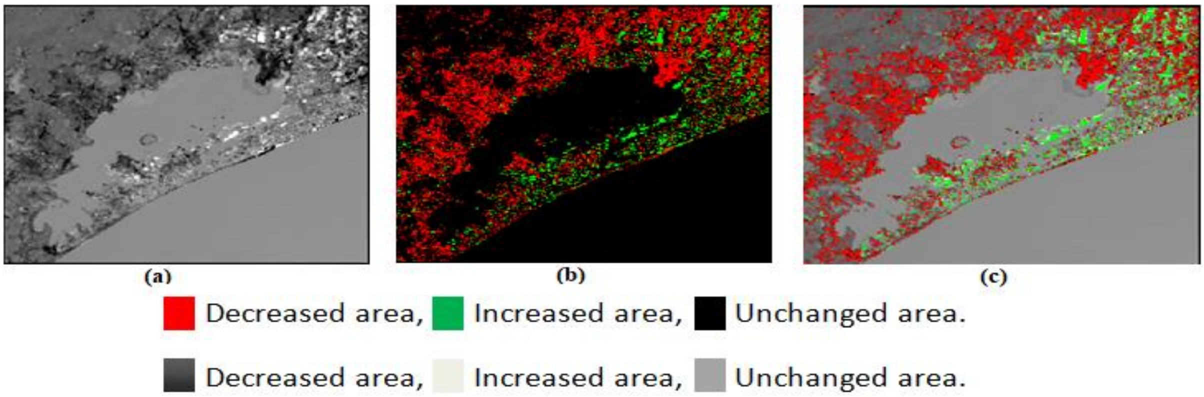

Fig. 8: Change detection using image difference results over 2008-2018 for Chilika lake:
(a). Image difference, (b). Highlight change, (c). Combined with image difference and highlight change.

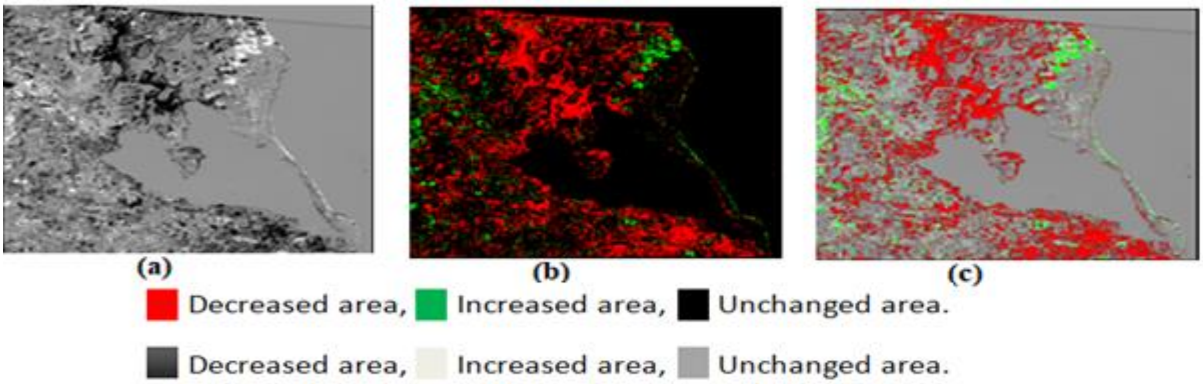

Fig. 9: Change detection using image difference results over 2008-2018 for Pulicat lake:
(a). Image difference, (b). Highlight change, (c). Combined with image difference and highlight change

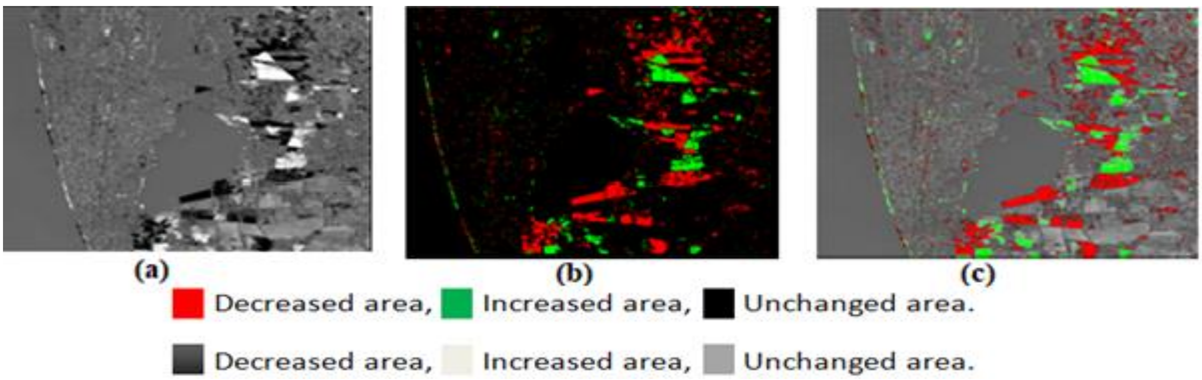

Fig. 10: Change detection using image difference results over 2008-2018 for Vembanad lake:
(a). Image difference, (b). Highlight change, (c). Combined with image difference and highlight change.

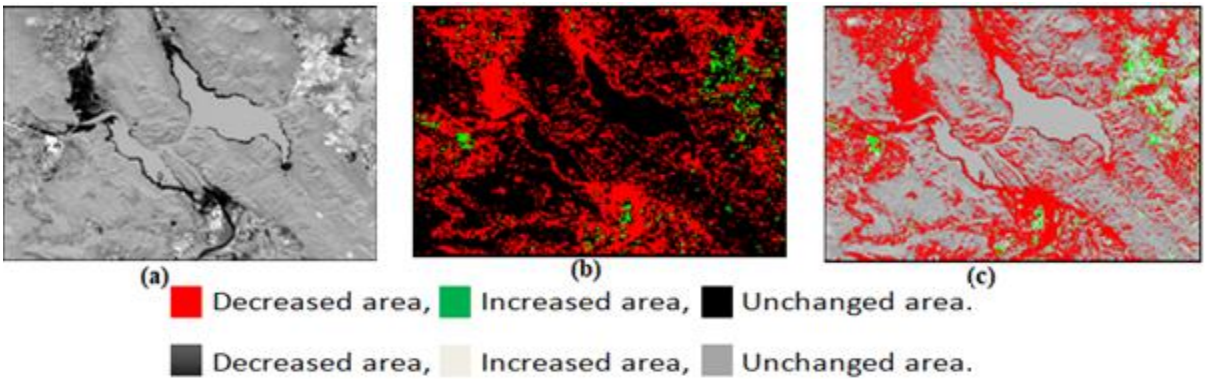

Fig. 11: Change detection using image difference results over 2008-2018 for Penna Reservoir:
(a) . Image difference, (b). Highlight change, (c). Combined with image difference and highlight change.

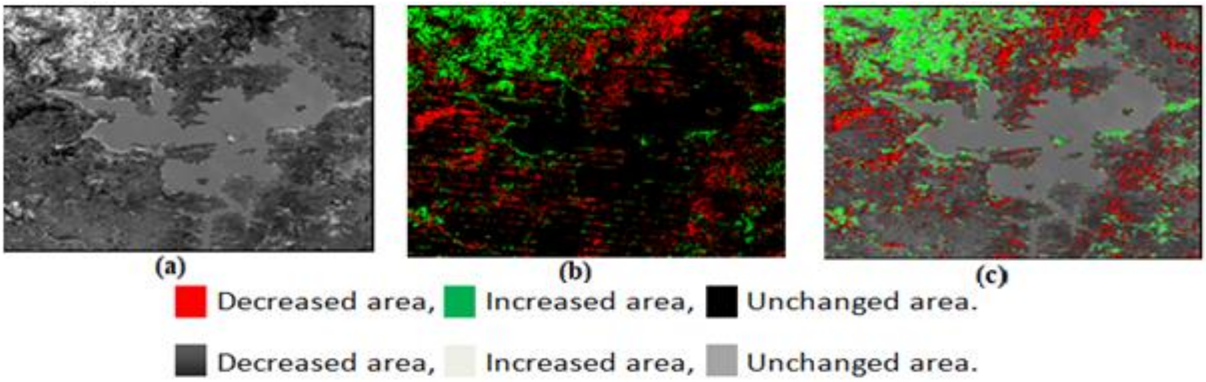

Fig. 12: Change detection using image difference results over 2008-2018 for the Nagarjun Sagar Reservoir: (a). Image difference, (b). Highlight change, (c). Combined with image difference and highlight change

Differences in the atmospheric situation, sensor calibration, moisture stipulation, and elucidation circumstance also influence the radiance of the pixels. Therefore, this algorithm is better suitable for changes in radiance in the object scene as compared to changes in other factors [10]. In image differencing algorithm all bands should be same for two different date multi-temporal images. A critical element in the image differencing change detection is defining threshold values that specify where significant change has occurred. Frequently, a standard deviation from the mean is used as the threshold value [9,11]. The merits of this algorithm are Simple and clear-cut, easy to interpret the results and demerits of this algorithm are it cannot provide a detailed change matrix and requires the selection of thresholds correctly.

4. Results and Discussions

In order to get change results from validation, the following factors can calculate for changed the area and unchanged areas. The validation dataset and training dataset are different, the unsupervised classification is used to measure accuracy assessment analysis. The maximum change in the area and unchanged area for different Lakes and Reservoirs are as shown in the Table 3. The maximum changes occurred in 2018 as compared to 2008 in the Chilika Lake area, 1300.845 Sq. miles are unchanged area and 319.579 Sq. miles are changed area (an increased area is 66.088 Sq. miles and the decreased area is 243.491 Sq. miles). Similarly, The minimum changes occurred in 2018 as compared to 2008 in the Vembanad Lake area, 318.758 Sq. miles are an unchanged area, and 31.385 Sq. miles are changed area (an increased area is 9.167 Sq. miles and the decreased area is 22.218 Sq. miles).

The accuracy assessment achieved by comparison between the classification map and reference map. To analyzed accuracy assessment, select 256 pixels randomly extracted from reference map and classification map with a comparison of each class. But it measures per-class classification accuracy the error matrix is used and also helps to measure the accuracy assessments, such as producer accuracy, user accuracy, overall accuracy, and overall kappa statistics. Excellent results are obtained by using accuracy assessment for different Lakes and Reservoirs 2008-2018 as shown in the Table 4.

Table 3: Results for changed area and unchanged areas of Lakes and Reservoirs

Lakes and Reservoirs	Duration	Changed Area (Sq. miles)		Unchanged Area (Sq. miles)
		Decreased Area	Increased Area	
Chilika Lake	2008-2018	243.491	66.088	1300.845
Pulicat Lake	2008-2018	140.123	24.167	760.091
Vembanad Lake	2008-2018	22.218	9.116	318.758
Penna Reservoir	2008-2018	212.14	12.453	448.665
Nagarjun Sagar Reservoir	2008-2018	34.813	28.588	299.742

Table 4: Accuracy assessment results for different Lakes and Reservoirs 2008-2018.

Lakes and Reservoirs	Duration	Producer accuracy (%)	User accuracy (%)	Overall accuracy (%)	Overall Kappa statistics
Chilika Lake	2008	80.54	87.27	91.43	0.8957
	2018	84.37	82.58	88.00	0.8394
Pulicat Lake	2008	91.10	90.21	90.48	0.8850
	2018	89.59	88.41	88.26	0.8529
Vembanad Lake	2008	92.67	91.34	91.59	0.9032
	2018	83.36	83.43	89.72	0.8699
Penna Reservoir	2008	86.74	83.47	91.00	0.9004
	2018	90.85	89.69	89.23	0.8818
Nagarjun Sagar Reservoir	2008	90.29	90.46	89.57	0.8666
	2018	85.94	85.90	86.96	0.8308

The overall accuracy is 91.59%, overall kappa statistics is 0.9032, Producer accuracy is 92.67%, and User accuracy is 91.34%. To obtain the accuracy assessment analyses, the comparison between 2008 and 2018 multi-temporal images. The maximum overall accuracy and maximum overall kappa statistics produced by the year of 2008 compared to 2018. Because in year 2018 the decreased area percentage is more as compared to the increased area percentage. These results show that the effectiveness of the change detection method in selected Landsat-7 images during the period of 2008-2018.

5. Conclusion

The image change detection using image differencing methodology is applied to the process of multi-temporal Landsat-7 images to investigate the changes occurred during 2008-2018. Focal analysis method is implemented to fill all gaps occurred in Landsat-7 data. Then image differencing algorithm is applied to resultant images, such as different Lakes and Reservoirs and achieved accurate results, to compare different Lakes and Reservoirs from 2008 to 2018 a lot of changes occurred. In fact, Chilika Lake area maximum decreased 243.491 Sq. miles in 2018 as compared to 2008. Similarly, Vembanad Lake area minimum decreased 22.218 Sq. miles in 2018 as compared to 2008. Excellent results are obtained by using accuracy assessment for different Lakes and Reservoirs 2008-2018, The overall accuracy is 91.59%, and overall kappa statistics are 0.9032. These results show that the effectiveness of the change detection method in selected Landsat-7 images in the period of 2008-2018.

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