MINING AND RECOGNITION OF SURFACE WATER AREA OVER NAGARJUNA SAGAR RESERVOIR AND CHILIKA LAKE

B. Chandrababu Naik[1], B. Lalitha[2], B. Ravi Kumar[3], K. Sai Venu Prathap[4], M. Murali Naik[5]

Article History: Received: 12.12.2022 **Revised:** 29.01.2023 **Accepted:** 15.03.2023

Abstract

Today's recent application for extraction and detection of spreading surface water area is done by remote sensing Landsat-7(ETM+) satellite images data. The main objective of this proposed method is to analysis for change detection of Land Use / Land Cover (LU/LC) in Nagarjuna Sagar Reservoirs and Chilika Lake which is located in India. The change detection analysis was done to Nagarjuna Sagar Reservoir and Chilika Lake for the period from January (2008 – 2018). The multi-spectral and temporal Landsat-7 (ETM+) dataset were used for analysis of change detection. The focal analysis algorithm is applied for recovery of 22%-pixel information that has lost in the Landsat-7 (ETM+) on May 31, 2003 and obtained the required image (complete image) for removing all the strips (gaps). Image differencing algorithm is applied to obtain change detection of surface water area of Nagarjuna Sagar Reservoir and Chilika Lake. The Performance analysis of accuracy assessment was done to the output image (differencing algorithm) and ground truth data.

Keywords: Landsat-7 (ETM+) satellite images, Image Differencing, Land Use/Land Cover (LU/LC) and change detection.

[1]Dept. of ECE, NIT-Tiruchirappalli, Tamil Nadu, India. chandrababu@nitt.edu.
[2]Dept. of ECE, Sree Rama Engineering College, Tirupati, A.P, India. lalitha.rohit@gmail.com.
[3]Dept. of ECE, Institute of Aeronautical Engineering, Hyderabad, T.S, India. rav.kumar37@gmail.com.
[4]Dept. of ECE, Aditya College of Engineering, Madanapalle, A.P, India. venu9459@gmail.com.
[5]Dept. of Chemical Engineering, Engineering, JNTUACEA, A.P, India. muralinaik117@gmail.com

DOI: 10.31838/ecb/2023.12.s3.111

1. Introduction

Remote sensing is the process of deriving objects information by detecting and monitoring the characteristics of an area by sensing reflected or emitted energy. The sensors were used to acquire data in various frequency ranges along with electromagnetic spectrum. Landsat satellites acquires data in four ranges (bands) using Multispectral Scanner (MSS). The Landsat-4 and Landsat-5 includes Thematic Mapper sensors to collect data in thermal and a shortwave infrared band. Enhanced Thematic Mapper Plus (ETM+) sensor includes panchromatic band. All these sensors use different media such as magnetic fields, sound waves, etc. to sense the objects in respective media [4].

Change detection algorithm plays an important role in various disciplines, such as video surveillance [1]–[3], remote sensing, [4]–[6], medical diagnosis and treatment [7]–[11], civil infrastructure [12], [13], underwater sensing [14]–[16], and driver assistance systems [17], [18]. Change detection algorithm works on the principle of detecting regions of change in images of the same scene taken at different times. In remote sensing change detection algorithm is used to detect land-use changes, coastal change, urban sprawl, monitoring shifting cultivation, habitat fragmentation, assessment of deforestation, damage assessment, crop stress detection, changes in vegetation phonology, disaster monitoring, seasonal changes took place in pasture production, thermal characteristics, and other environmental changes [2]. There are different change detection algorithms for detecting changes in remote sensed images such as image differencing, image mining, image rationing, post-classification, vegetation index differencing, change vector analysis, PCA, ANN, LSMA and GIS [11, 12].

The basic principle of change detection algorithm is given a set of similar image for different time slots. This algorithm classifies a set of pixels which are extensively different between the present and past image sequence. The shape changes of objects, motion of objects relative to the background, appearance or disappearance of objects and set of pixels are considered as change mask. The stationary objects can experience changes in color or brightness. Change mask should not include unimportant changes such as non-uniform attenuation, illumination variation, atmospheric absorption, camera motion and sensor noise. The first step of change algorithm is to estimate the change mask using required tool based on particular application. The main motivation of the proposed method is Nagarjuna Sagar Reservoir and Chilika Lake has shrink gradually in recent decades. Therefore, regular and reliable measurements of the reservoir and lake area are necessary to monitor the dynamic changes of reservoir and lake water area for water resource balance analysis. Previous studies of the reservoir and lake area were based on visual interpretation and manual digitization of satellite data [20], [21]. In this paper, the image differencing algorithm is applied for reservoir and lake in the period of 2008 and 2018 from Landsat-7 (ETM+) images and also extracted maximum changed area and the unchanged area. Our algorithm contributes to the effectiveness of Accuracy quality evaluation of satellite images. Accuracy provides simple qualitative metrics by comparing both ground truth (high spatial resolution Google Earth images) and derived image using proposed algorithm.

2. STUDY AREA and DATA SET

Nagarjuna Sagar Reservoir and Chilika Lake were (Fig.1 and 2) located in the Indian subcontinent region. The Reservoir was built across the Krishna River, which is located in Nalgonda District at Telangana state. Generally, water spread surface area of Nagarjuna Sagar Reservoir is 285 km^2 at Full Reservoir Level (FRL), the catchment area is 214.185 km^2 (82.697 Sq. miles) and it has a gross storage capacity of 312 TMC at FRL. Nagarjuna Sagar Reservoir is the second biggest water reservoir [26]. The Chilika Lake is the largest coastal lagoon in the odisha state, India and also the second largest brackish water lagoon in the world [27]. The Location of Nagarjuna Sagar Reservoir and Chilika lake are as shown in fig.(1, 2).

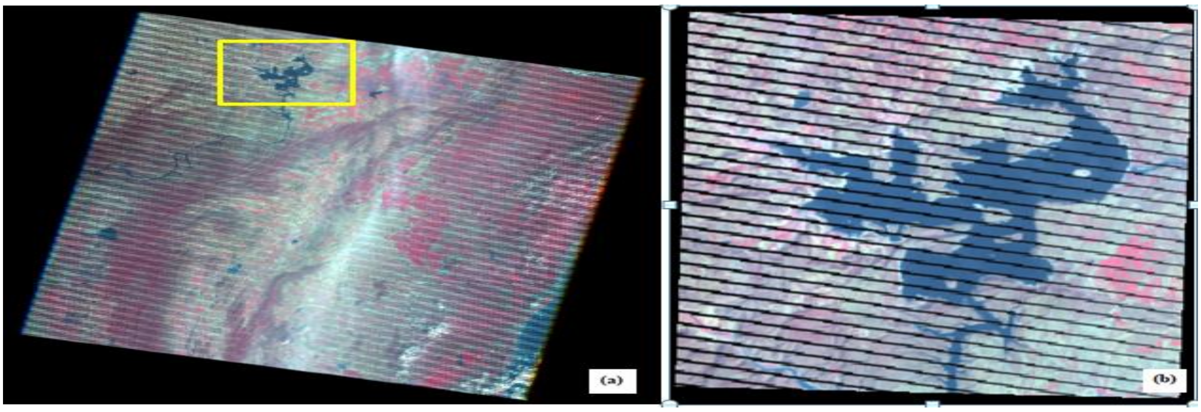

Fig. 1. (a) Location of Nagarjuna Sagar Reservoir 15-01-2008 and (b) Subset image

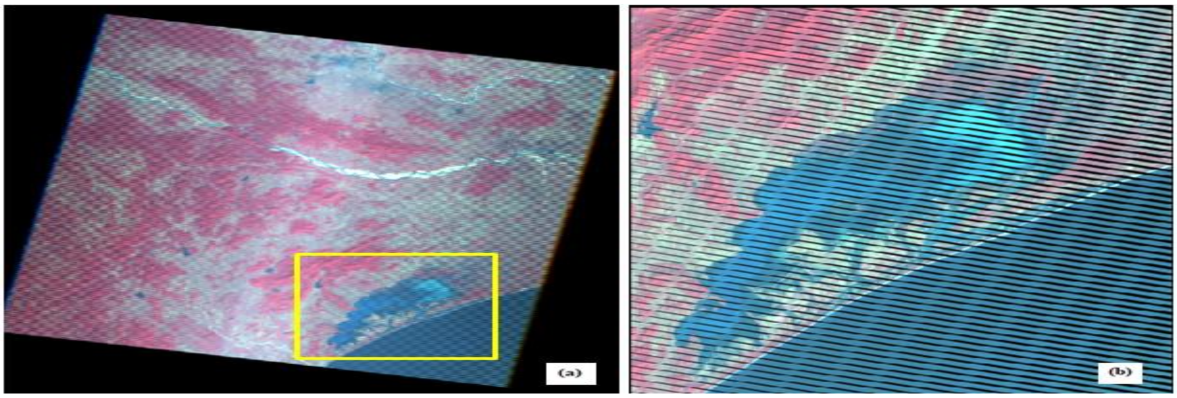

Fig. 2. (a) Location of Chilika lake 15-01-2008, and (b) Subset image

Table 1 indicates about latitude, longitude and path/row of Chilika Lake and Nagarjuna Sagar Reservoir. The proposed algorithm used Landsat-7 data set for January 2008 and January 2018. The subset images were cloud free data set was downloaded from USGS Earth Explorer website (www.usgs.gov).

Table 1. The Path /Row and location of reservoir and lake

Reservoir and Lake	Path/ Row	Duration	Latitude	Longitude	State and Country
Nagarjuna Sagar Reservoir	143/49	2008 -2018	$16^{0}34^{1}55.60^{11}$N	$78^{0}24^{1}13.97^{11}$E	Telangana, India
Chilika Lake	140/46		$19^{0}46^{1}30.37^{11}$N	$85^{0}25^{1}4.85^{11}$E	Odisha, India

This study uses EARDAS -16 Imaging software to evaluate the changes occurred in LU/LC of Nagarjuna Sagar Reservoir and Chilika Lake. Further the results of this study help organizers for management in the study area. Main objective of this proposed algorithm

- To prepare temporal LU/LC maps of the study area.
- To analyze the nature and degree of LU/LC changes in the study area.
- To detect the major components and encourage the trend changes in the LU/LC.

3. METHODOLOGY

In order to attain the objective of the proposed algorithm, the following steps were performed: define study area, data collection, image pre-processing using focal analysis, comparison of different satellite images for surface water detection using image differencing algorithm, extraction of the lake and reservoir water surface area in each image, Accuracy assessment for extracted image. The overall methods adopted to detect the reservoir and lake water surface area changes as shown in fig.3.

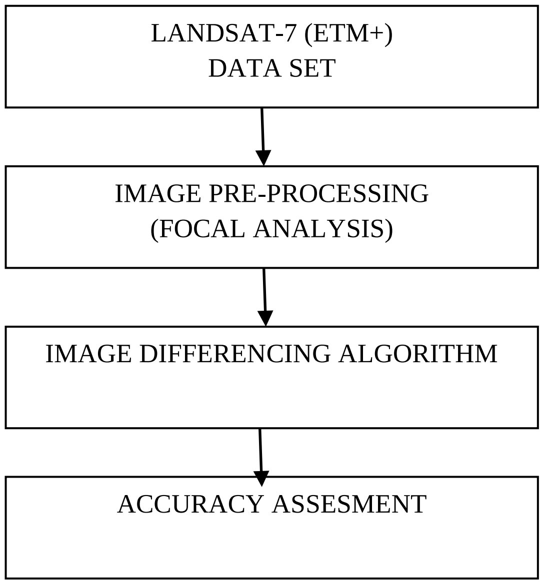

Fig. 3. Flow chart for the workflow.

3.1 Focal Analysis Technique

Landsat-7 (ETM+) data set obtained from satellite sensor has strips(gaps) in the images, due to failure of Scan-Line-Corrector (SLC) and hence there is a 22% of pixel information loss in Landsat-7 data[13]. To recover the lost information, the focal analysis technique is applied for Landsat-7 (ETM+) images for removing or filling all strips and gaps. Focal analysis technique is applied to fill all strips or gaps to missing pixels in Landsat-7 image. The image pixels are represented in DN value. By choosing an appropriate pixel window size centre pixel was estimated. Median filter used for reducing the noise (stripes, impulses, dead sensor and random spikes) in focal analysis algorithm. From the comparative analysis with other gap filling algorithms, focal analysis provides accurate results for filling the gaps in Landsat-7 images as shown in fig.(4).

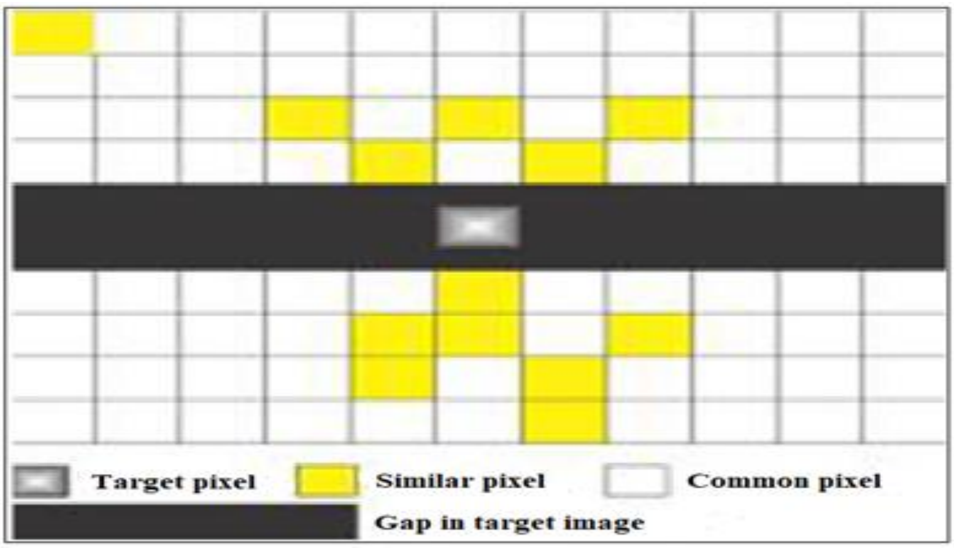

Fig. 4. Similar pixel selection for single image gap analysis.

Steps involved in focal analysis, median filter are

1. Arrange Digital Numbers (DNs) pixels in numerical order by moving window.
2. Substitute the pixel of interest with the DN values in the centre of the ranking.

Focal analysis algorithm is applied to the Landsat-7 images of both Nagarjuna Sagar Reservoir and Chilika Lake for filling all the gaps. In this study, Focal analysis algorithm is iterated 5 times to fill all gaps and provide an output for the years 2008 &

2018. The resultant pre-processed subset image of Nagarjuna Sagar Reservoir on 15-01-2008 are shown in fig. 5(a-f), where all gaps and noise are removed for 5th iteration. Simlarly, fig. 6(a-f) shows the output subset images of Nagarjuna Sagar Reservoir on 15-01- 2018. From the resultant output, for 5th iteration it is clear that all the gaps as well as strips were filled and removed the noise. fig. 7(a-f) & fig.8(a-f) depicts the results obtained after applying focal analysis algorithm of Chilika Lake subset images on 20-01-2008 &15-01-2018.

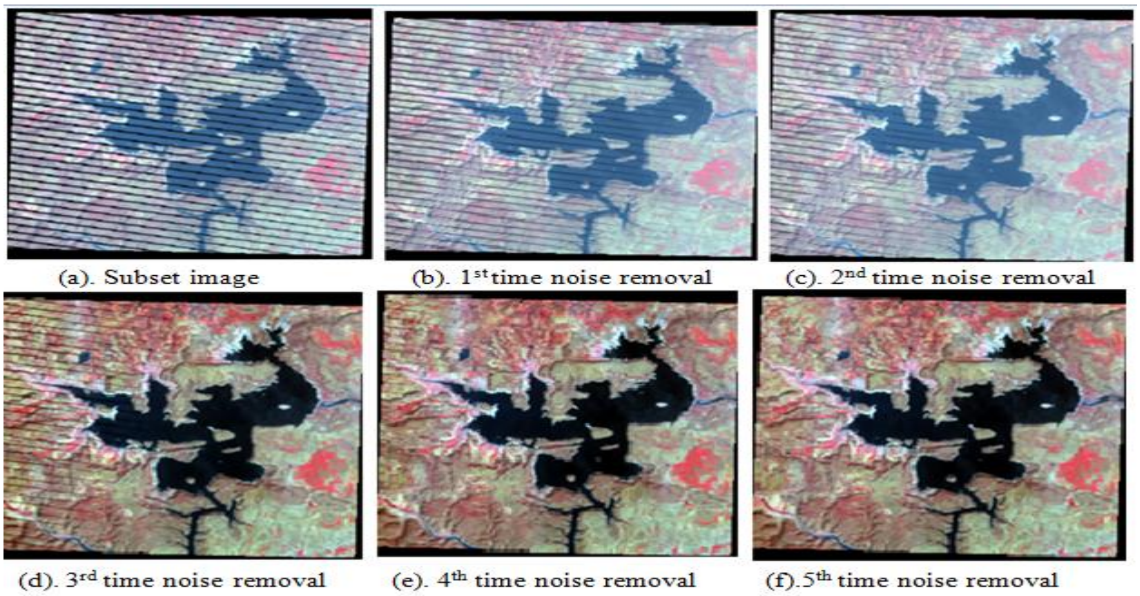

Fig. 5. Outputs of noise removal by focal analysis technique of Nagarjuna Sagar Reservoir on 20-01-2008.

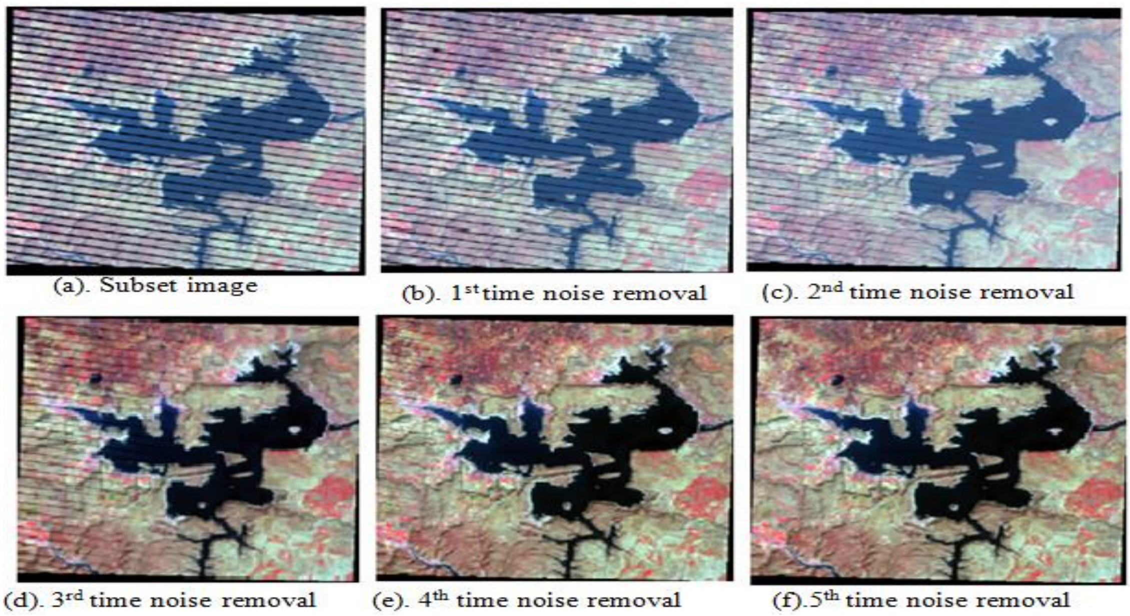

Fig. 6. Outputs of noise removal by focal analysis technique of Nagarjuna Sagar Reservoir on 15-01-2018.

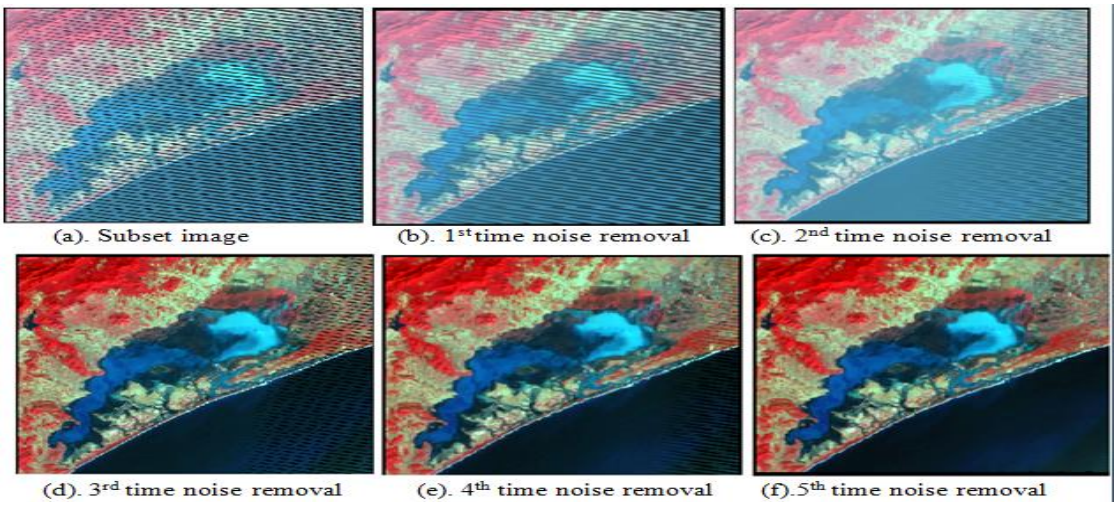

Fig. 7. Outputs of noise removal by focal analysis technique of Chilika lake on 20-01-2008

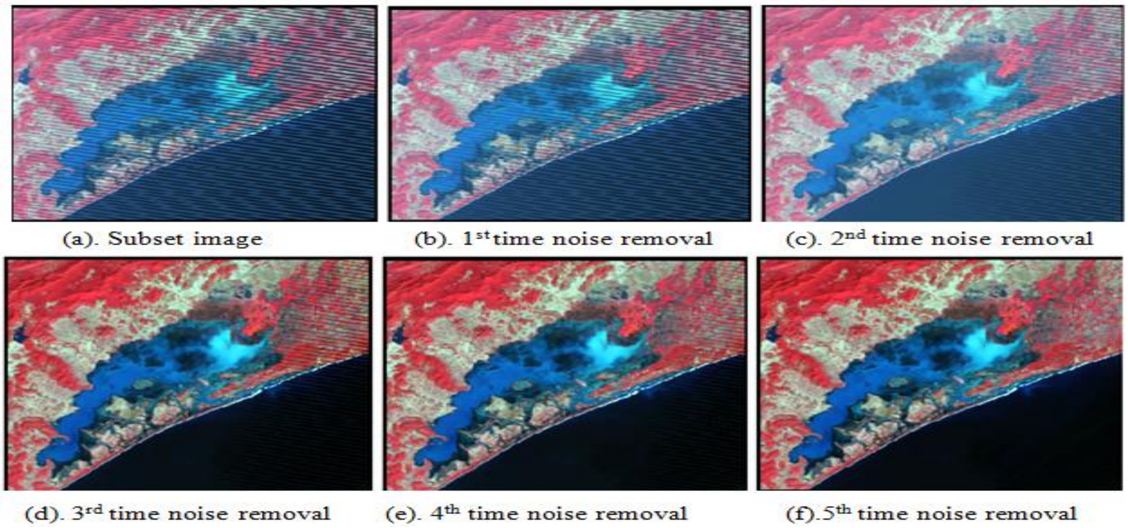

Fig.8. Outputs of noise removal by focal analysis technique of Chilika lake on 15-01-2018

3.2. Image Differencing Algorithm

Image differencing algorithm is applied for output images of Fig.7.(a-f)& Fig.8.(a-f) to minimize variation in an adjacent pixel starved of blurring the edge of features an image if any and to detect change for the year 2008 and 2018. The principle involved in this algorithm is consider two different multi-temporal satellite images as input like, image date 1 and image date 2 as shown in fig. 9.

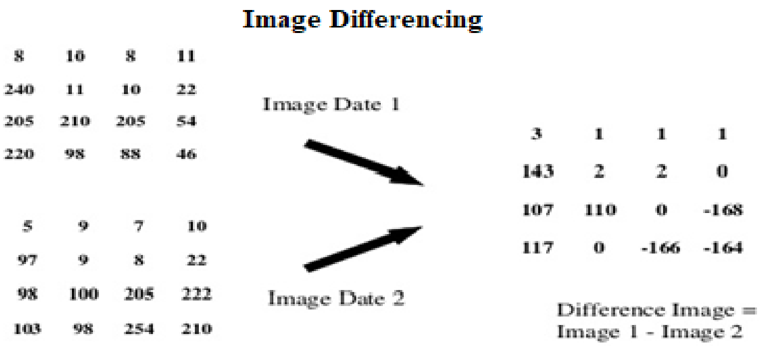

Fig. 9. Image differencing analysis for two different images.

Comparison is done pixel by pixel to produce difference image [15,17] by taking the difference of radiance values of pixels between two different image data set. In the present work, DN (Digital Number) value of one data set is subtracted with other for the same pixel and same band which gives a new image. Image differencing algorithm is represented mathematically as follows.

$$I_d(x,y)=I_1(x,y)-I_2(x,y) \qquad \ldots\ldots\ldots\ldots(1)$$

Where I_1 and I_2 represents images of Landsat-7 data set for January 2008 and January 2018(Nagarjuna Sagar Reservoir and Chilika Lake) i.e taken for two different periods and x,y are coordinates of respective images. In order to obtain better results the data sets are taken for the same month with same climatic condition. Finally, a set of threshold value is obtained based on values obtained from statistical parameters such as standard deviation and mean. Based on the obtained threshold value a change mask B(x,y) is created using mathematical equation represented below

$$B(x,y) = \begin{cases} 1 & if\ I(x,y) > \tau \\ 0 & otherwise \end{cases} \qquad \ldots\ldots.(2)$$

A zero in the change mask represents there are no changes between two images of Landsat-7 data set for January 2008 and January 2018 (Nagarjuna Sagar Reservoir and Chilika Lake). A one is representing when changes were determined, from two images Landsat-7 data set for January 2008 and January 2018. Then check, whether positive or negative values, and accordingly a proper threshold values are chosen to detect for a change. Later, colours are used to the output of differencing algorithm. A red colour in the output image represents a change occurred in that area and black colour represents there is no change detected.

Algorithm of present work

Step1: Apply the Landsat-7 (ETM+) image with two different dates of images as input, and then pre-processing techniques are applied on Date 1 image and Date 2 image to make further operation easier.

Step 2: Then apply the image differencing algorithm for input image to detect the changes and stored in the output folder.

Step 3: In image differencing algorithm used random threshold value, for finding optimal threshold using an unsupervised classification based on Euclidian function between two different images.

Step 4: Which distance value is minimum that value considers as the new threshold value. So that output of change detection achieved better accurate results.

.

4. Results

The present work used Landsat-7 data set of Nagarjuna Sagar Reservoir and Chilika Lake for periods 2008 & 2018. As a pre-processing step focal analysis method was used for filling all the gaps present in the subset images of Nagarjuna Sagar Reservoir and Chilika Lake 2008 & 2018. For validation purpose both test and training dataset were given to unsupervised classifier to measure accuracy. Accuracy assessment analysis is performed for change detected results (calculation of changed area and unchanged areas). The results of maximum changed water surface area over Nagarjuna Sagar Reservoir and Chilika Lake for 2008 & 2018 as shown in fig. 10 and 11. fig.10.a shows the subset of Image of Nagarjuna Sagar Reservoir on 15-01-2008. fig.10.b shows the subset of Image of Nagarjuna Sagar Reservoir on 15-01-2018 respectively. Now, fig .10.c shows the results of change extracted image using image differencing algorithm. In this, results red colour indicates change occurred in the area and black colour indicates there is no change occurred in same area. Similarly, fig.11.a shows subset image of Chilika lake on 15-01-2008 & fig.11. b. shows subset image of Chilika lake on 15-01-2018 respectively. The resultant output image after image differencing algorithm is shown in fig.11. c. From the fig.10.c & fig.10.c it is clear that more accurate results were obtained due to image differencing algorithm applied in present research work.

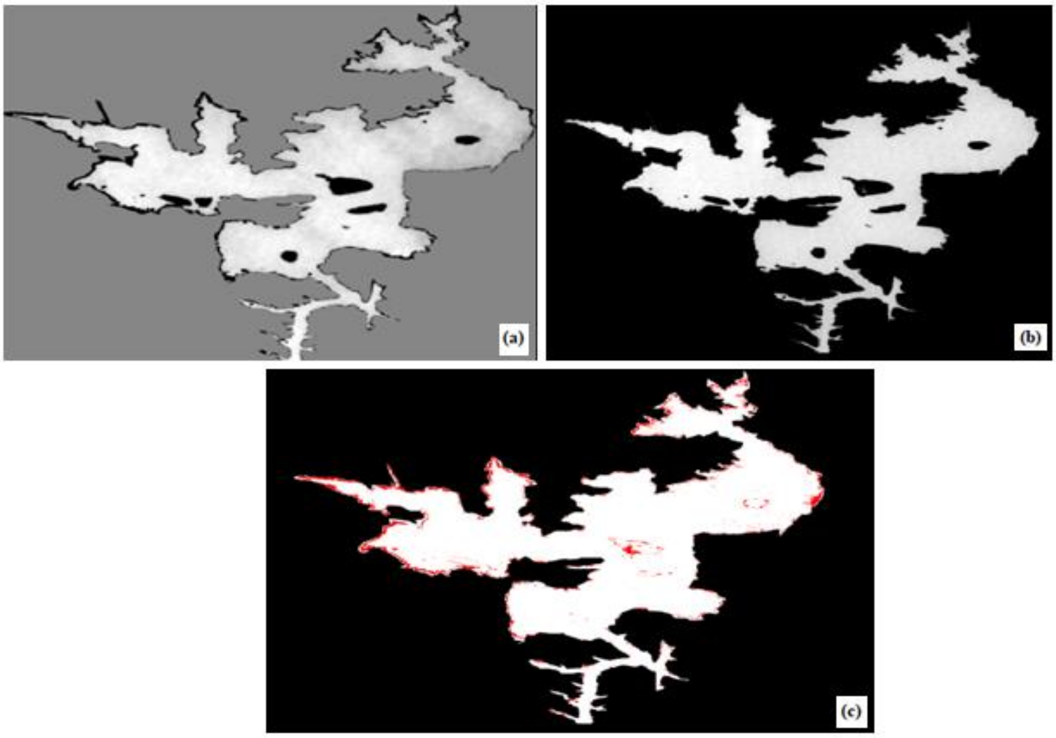

Fig. 10. Change detection output of Nagarjuna Sagar Reservoir: (a) subset Image 2008, (b) subset Image 2018, (c) resultant output image for 2008 & 2018

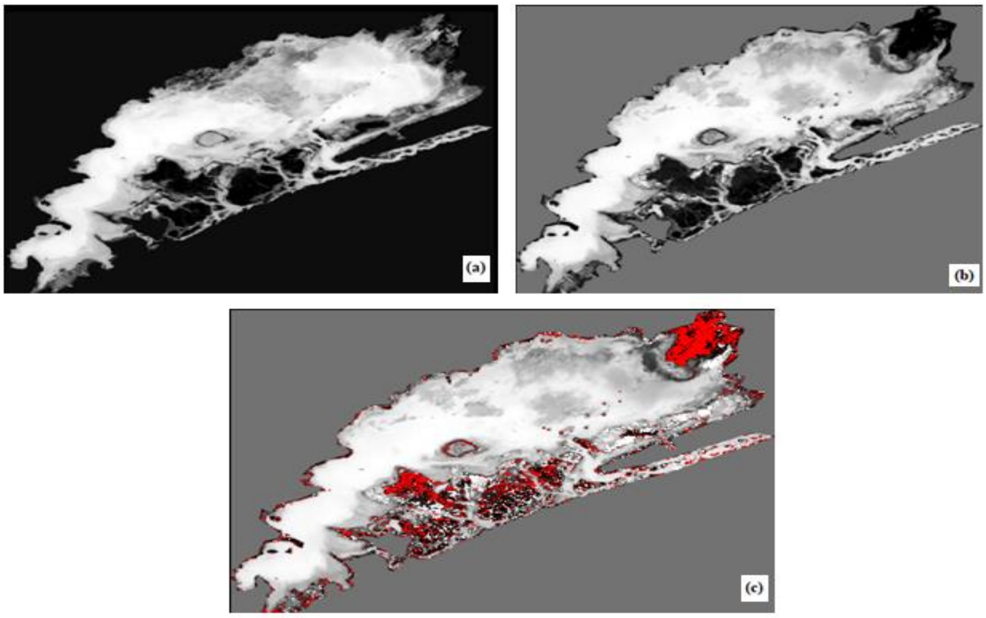

Fig. 11. Change detection output of Chilika lake :(a) subset Image 2008, (b) subset Image 2018, (c) resultant output image for 2008 & 2018.

As a performance metrics three statistical parameters of mean, standard deviation, histogram pixels along minimum, maximum threshold, and surface water area in km^2 for Nagarjuna Sagar Reservoir and Chilika lake on 15-01-2008 & 15-01-2018 were calculated and values of same are depicted in table 2.

Table 2. Performance evaluation of water body extraction using image differencing algorithm.

Reservoir and Lake	Year	Min Threshold	Max Threshold	Mean	Standard Deviation	Histograms (Pixels)	Area (km^2)
Nagarjuna Sagar Reservoir	2008	0.08	0.96	0.632	0.191	698679	157.92
	2018	0.03	0.99	0.602	0.219	744681	**167.38**
Chilika Lake	2008	0.05	0.96	0.741	0.119	3819214	**859.32**
	2018	0.10	0.94	0.517	0.138	3667967	825.28

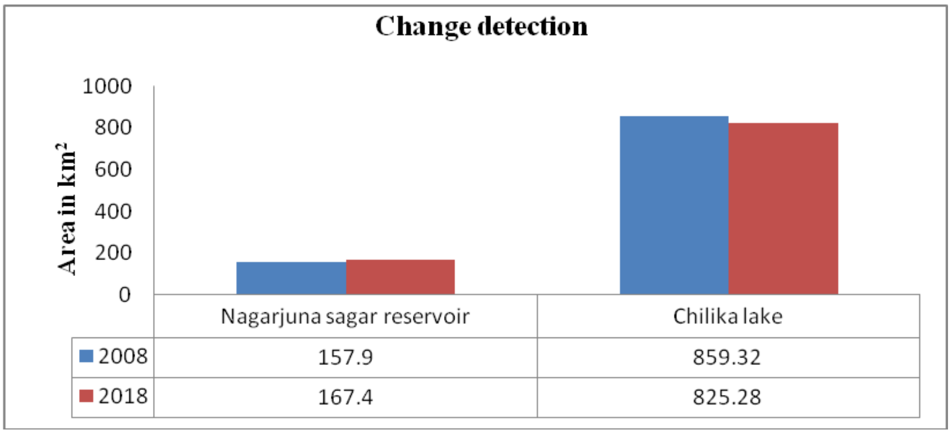

Fig. 12. Results of change detection method.

The change detection graph of maximum surface water area for both Nagarjuna Sagar Reservoir and Chilika lake on 15-01-2008 & 15-01-2018 as shown in fig. 12. Table 3. Indicates the values of spread surface water area of Nagarjuna Sagar Reservoir for 2008 & 2018 achieved as 157.92 km^2 and 167.38 km^2, similarly the spread surface water area of Chilika Lake for 2008 & 2018 achieved about 859.32 km^2 and 825.28 km^2. The maximum changes occurred in the Nagarjuna Sagar Reservoir area for 2008 & 2018 is about -9.46 km^2 and the maximum changes occurred in the Chilika Lake area for 2008 & 2018 about 34.04 km^2.

Table 3. Statistics of the Reservoir and Lake surface water area changes.

Reservoir and Lake	Year	Surface water area (km^2)	Surface water area change (km^2)
Nagarjuna Sagar Reservoir	2008	157.92	**9.46**
	2018	167.38	
Chilika Lake	2008	859.32	**34.04**
	2018	825.28	

4.1 Accuracy Assessment

For evaluating the results**,** accuracy assessment was calculated for the periods 2008 & 2018 in the Nagarjuna Sagar Reservoir and Chilika Lake and values are depicted in Table 4. Accuracy assessment was done by comparing reference map and classification map. The analysis was done by selecting 256 pixels randomly from the reference map and classification map. The value in table shows highest accuracy is obtained for Nagarjuna Sagar Reservoir and Chilika Lake for periods 2008 & 2018.

Table 4. Statistical parameters of Accuracy Assessment Analysis

Reservoir and Lake	Year	Producer's accuracy (%)	User's accuracy (%)	Overall accuracy (%)	Kappa Coefficient
Nagarjun Sagar Reservoir	2008	90.29	90.46	89.57	0.8666
	2018	92.67	91.34	**91.59**	**0.9032**
Chilika Lake	2008	86.74	83.47	91.00	0.9004
	2018	91.10	90.21	90.48	0.8850

It is clear that maximum overall accuracy of Nagarjuna Sagar Reservoir in 2018 is 91.59% and the coefficient of kappa is 0.9032. Similarly, the maximum overall accuracy of Chilika Lake in 2008 is about 91.00%, and the kappa coefficient is 0.9004 as shown in fig. 13. To obtain the accuracy assessment analyses, the comparison is done for the years 2008 and 2018 multi-temporal Landsat images. The obtained results show the effectiveness of the change detection method in selected Landsat-7 images of years 2008 and 2018.

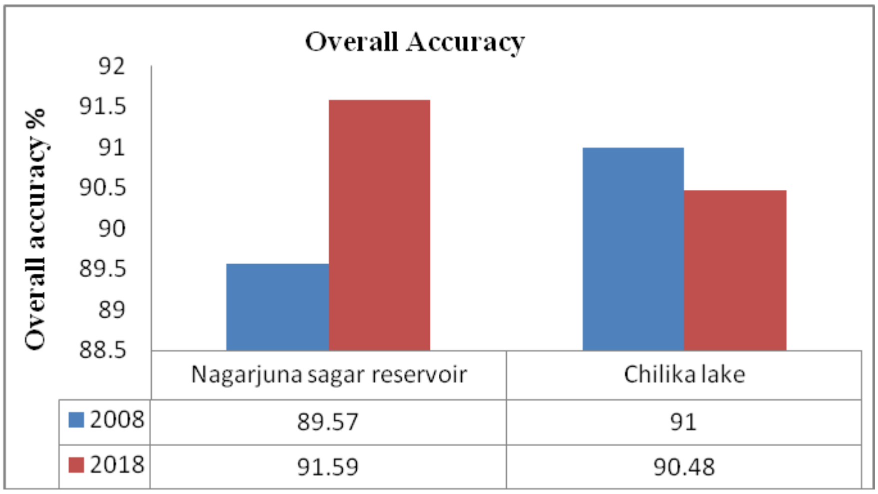

Fig. 13. Results of accuracy assessment

5. Conclusion

The main motivation of this study is to make change detection analysis of Land Use / Land Cover (LULC) in Nagarjuna Sagar Reservoirs and Chilika Lake located in India. The change detection analyses are extensively used in several applications such as land cover monitoring, disaster monitoring, and urban sprawl. The image change detection by using image differencing algorithm is functional to the process of multi-temporal Landsat-7 (ETM+) images for exploring the changes of surface water areas which occurred during January 2008 and January 2018 over Nagarjuna Sagar Reservoir and Chilika Lake. The Focal analysis method was employed to fill all the gaps which is occurred in Landsat-7 (ETM+) images. The image differencing algorithm was applied to Landsat-7 (ETM+) resultant images, such as reservoir and lake attained accurate results. Chilika Lake area reduction of 34.04 km^2 was observed in 2018 as compared to 2008 and the Nagarjuna Sagar Reservoir area increased 9.49 km^2 as observed in 2018 as compared to 2008. The overall accuracy of the results is 91.59% and overall kappa coefficient is 0.9032. These results show high effectiveness of the change detection method for the Landsat-7 images.

6. References

ASHBINDU SINGH. (1989) Review Article Digital change detection techniques using remotely-sensed data, "International Journal of Remote Sensing", 1989, 10:6, 989-1003, DOI: 10.1080/01431168908903939

MUCHONEY, D. M., and HAACK, B. N., 1994, Change detection for monitoring forest defoliation. Photogrammetric Engineering and Remote Sensing, 60, 1243–1251.

MANAVALAN, P., KESAVASAMY, K., and ADIGA, S., 1995, Irrigated crops monitoring through seasons using digital change detection analysis of IRD–LISS 2 data. International Journal of Remote Sensing, 16, 633–640.

Schott, John Robert (2007). Remote sensing: the image chain approach (2nd ed.). Oxford University Press. p. 1. ISBN 978-0-19-517817-3

Schowengerdt, Robert A. (2007). Remote sensing: models and methods for image processing (3rd ed.). Academic Press. p. 2. ISBN 978-0-12-369407-2

Zhang, C., Li,W., & Travis, D.:Gaps-fill of SLC-off Landsat ETM plus satellite image using a geostatistical approach. International Journal of Remote Sensing, Vol 28, pp. 5103–5122, 2007. Congalton, R. G. & Green, K. 2008. Assessing the accuracy of remotely sensed data: principles and practices. CRC press

Feyisa, G. L., Meilby, H., Fensholt, R., & Proud, S. R, "Automated Water Extraction Index: A new technique for surface water mapping using Landsat imagery", Remote Sensing of Environment, 140, 23–35. http://doi.org/10.1016/j.rse.2010.08.029.

ZHOU Huiping, JIANG Hong, HUANG Qinghua, Landscape and Water Quality Change Detection in Urban Wetland: A Post-classification Comparison Method with IKONOS Data, 2011 3rd International Conference on Environmental Science and Information Application Technology (ESIAT 2011)", 10 (2011) 1726 – 1731

Q. He, B. Shan, H. Ma, Y. Chen, and X. Wang, "Research on algorithms for recovering Landsat-7 gap data," in Proc. IEEE Int. Conf. Autom. Sci. Eng., Jul. 2011, pp. 1–4.

Charles Verpoorter, Tiit Kutser,and Lars J. Tranvik Automated Mapping of Water Bodies Using Landsat Multispectral Data." Limnology and oceanography", November 2012.

Eric K Forkuo, Adubofour Frimpong, "Analysis of Forest Cover Change Detection",International Journal of Remote Sensing Applications, Vol.2 Issue. 4, 2012.

Feng Chen, Xiaofeng Zhao and Hong Ye, Making Use of the Landsat 7 SLC-off ETM+ Image Through Different Recovering Approaches, "Data Acquisition Applications", 2012, http://dx.doi.org/10.5772/48535.

S. Poongothai.S, N. Sridhar, R. Arun Shourie, Change Detection of Land use/ Land Cover of a Watershed using Remote Sensing and GIS, "International Journal of Engineering and Advanced Technology (IJEAT)", ISSN: 2249 – 8958, Volume-3 Issue-6, August 2014

Water Body Extraction And Change Detection Based on Multi-Temporal SAR Images. Available online: http://adsabs.harvard.edu/abs/2009SPIE.7498E..96Z (accessed on 21January 2014).

Ivan Potić, Simple ETM+ gap fill techniques review, "Environment Science and Policy for Sustainable Development", January 2015

Mohammad Ashraf, Rabeya Nawaz, (2015) A Comparison of Change Detection Analyses Using Different Band Algebras for Baraila Wetland with Nasa's Multi-Temporal Landsat Dataset, Journal of Geographic Information System, Vol.7 No.1, January 27, 2015

Naveena, R., Wiselin Jiji, G., "Change Detection Techniques – A Survey", International Journal on Computational Sciences & Applications (IJCSA) Vol.5, No.2, April 2015.

Asmaa S. Abdul Jabar, et.al, Reconstruction the Missing Pixels for Landsat ETM+SLC-off Images Using Multiple Linear Regression Model, "ARO-The Scientific Journal of Koya University", Volume IV, No 2(2016), DOI: 10.14500/aro.10147

Elsahabi, M., Negm, A., & El Tahan, A.H.M. (2016). Performances evaluation of surface water areas extraction techniques using Landsat ETM+ data: case study Aswan High Dam Lake (AHDL). Procedia Technology, 22, 1205-1212.

M. Christy Rama, D. S. Mahendran, T. C. Raja Kumar, A Survey on Land Cover Change Detection Techniques in Remote Sensing, "International Journal of Innovative Research in Science, Engineering and Technology", Vol. 5, Issue 7, July 2016

Nafisa Mohamed, Babikir Mobarak, "Change Detection Techniques using Optical Remote Sensing: A Survey", American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS) (2016) Volume 17, No 1, pp 42-51.

Praveen Kumar Rai A, Varun Narayan Mishra B, Changes of Glacier Lakes Using Multi-Temporal Remote Sensing Data: A Case Study from India, "Geographica Pannonica", Volume 21, Issue 3, 132–141 (September 2017).

Amin, Abd Rahman Mat, Fathinul Najib Ahmad Sa'ad, Adida Muhammud, Wan Farahiyah Wan Kamaruddin, Mohd Rivaie Mohd Ali, Asmala Ahmad, and Nor Haniza Bakhtiar Jemily. "Tracking Coastal Change Over Kuala Terengganu Using Landsat." In Intelligent and Interactive Computing, pp. 265-273. Springer, Singapore, 2019.

Yashon O. Ouma & R. Tateishi, "A water index for rapid mapping of shoreline changes of five East African Rift Valley lakes: an empirical analysis using Landsat TM and ETM+ data", International Journal of Remote Sensing, 27:15, 3153-3181, 2006

Bhagat, V. S., & Sonawane, K. R, " Use of Landsat ETM+ data for delineation of water bodies in hilly zones", Journal of Hydroinformatics, 13(4), 661. http://doi.org/ 10.2166/ hydro.2010.018

https://en.wikipedia.org/wiki/Nagarjuna_Sagar_Dam.

https://en.wikipedia.org/wiki/Chilika_Lake