Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 171 (2020) 2645–2654

Procedia Computer Science

www.elsevier.com/locate/procedia

Third International Conference on Computing and Network Communications (CoCoNet'19)

Analysis of Surface Water Resources Using Sentinel-2 Imagery

Ujwala Bhangale, Swapnil More, Tanishq Shaikh, Suchitra Patil, Nilkamal More

K.J. Somaiya College of Engineering, Vidyavihar, Mumbai- 400077

Abstract

Water is one of the most important resources for sustainability of most organisms on this planet. The most accessible form of water for the living creatures is surface water bodies. These water bodies should be monitored because they have a significant impact on any surrounding ecosystem. In Maharashtra, India, the drought condition has worsened with many areas suffering from water paucity and poor crop yield. Therefore, monitoring of these resources by using satellite images and spectral indices is of cardinal importance. In this study, we have targeted the identification of water bodies using spectral indices and comparison with pre-existing data about the surface water bodies. The spectral index chosen for detection of water content is Normalized Difference Water Index (NDWI). The results have shown that there is inconsistency in remote sensed data captured by the Sentinel- 2 and the pre-existing data about the surface water bodies.

Keywords: Normalized Difference Water Index (NDWI), Surface water resources, Geographic Information Systems (GIS), Sentinel-2, Satellite images, Image processing, Water indices

1. Introduction

Water plays an important role in the survival of many living creatures. Water is available in many forms including ground water, surface water bodies, and frozen water bodies and so on. Therefore, it is important to conserve and preserve this natural resource because ecosystems depend on it arrantly. The shortage of water can cause many problems for both humans as well as other organisms. These water resources need effective management to prevent environmental casualties. The drought situation has gone worse in the recent past in Maharashtra and Karnataka states of India with 80% of areas in Karnataka and 72% in Maharashtra experiencing water shortage and dearth yield. Therefore, there is a need for mass assessment of the surface water resources by using an efficient and

10.1016/j.procs.2020.04.287

feasible technology. In this study, we aim to find differences between the geo-spatial data about the water bodies compiled by official agencies and present data calculated using image processing on remote sensed data. The objective is to process the satellite imagery and provide accurate information to the authorities which will be then able to adaptively supply water to the drought stricken areas. In this work, the remote sensed satellite data is collected from the Sentinel-2 satellite of European Space Agency (ESA), it is an Earth observation satellite (EOS) that covers large geographical region, hence enables to detect waterbodies from large geographical area. Also, water body detection can be further extended for flood detection and monitoring

2. Related Work

The study area of surface water bodies using satellite imagery is not barren, and research has been performed on this subject which proved relevant and conducive to this study. A research study was DWI is more proficient and therefore, is adopted in this study. Sekertekin, Cicekli and Arslan (2018) have performed the analysis on the reservoir of Çatalan and Yedigöze Dam, Turkey to find out which spectral index between NDWI and Modified Normalised Difference Water Index (MNDWI) presented water body more precisely using Sentinel-2 imagery [1]. Using remote sensing, we can access satellite data and calculate water content using spectral indices such as NDWI and MNDWI[14], MNDWI provides more efficient water features for Landsat data by eliminating the noise introduced because of built-up regions, soil and vegetation. The work is performed to classify water bodies using a combination of pixel-based and object-based to improve the accuracy [2]. Other studies performed research on detecting the changing features of surface water bodies due to various natural and non-natural factors [3][4]. Further, using Sentinel-2 dataset, water quality parameters are evaluated by Tomming et al. [5]. A research was conducted in Malaysia in order to compare NDWI, Normalized Difference Vegetation Index (NDVI) and MODIS NDVI to find out which spectral index is more reliable and accurate in measuring correlation with the rainfall of the region [6]. The results showed that NDWI gave a better relationship considering the annual rainfall, as compared with the other two. This result was helpful in this study because the main source of water in the region under study is rainfall. In [7], the downscaling of spectral indices, namely, NDWI and NDVI, to the resolution of 1 km is performed. Du et al. [8] have computed six water indexes (NDWI, MNDWI) by applying four different pan-sharpening methods on Sentinel-2 imagery with different resolutions, NDWI with 10 meter resolution, MNDWI with 20 meter and 10 meter resolution.

In [9], LANDSAT data is used for computing several indexes such as NDWI, MNDWI, NDVI, Automated Water Extraction Index (AWEI) and Water Ratio Index (WRI). They have observed that NDWI is the more efficient as compared to other techniques, hence used it for water change detection. NDWI is also used in [10] for detection of the swimming pools which is an essential step for mosquito control. NDWI is also used for vegetation Water content computation using LANDSAT data [11], Wang et al. [12] have used Enhanced Water Index (EWI) for surface water estimation. To detect the Urban surface waterbodies, Sentinel – 2 multispectral images are used to compute NDWI at 10 meter resolution [13].

The state of art approaches discussed above are used as a basis in this work to detect the water bodies, and further identify the differences between two different data sets of surface water bodies, where one dataset is captured by the Sentinel- 2 satellite and the other dataset is publically availed by the Maharashtra Government to indicate the water bodies of the specific regions.

3. Area of Study and Data

3.1. Area of study

The area for study chosen was the state of Maharashtra which lies in central west India. It is one of the most populated states in the country and also one of the largest in terms of land size. The interior of the state occasionally suffers from droughts. The district of Jalna in Maharashtra is considered for deeper and more specific study.

3.2. Data

The data used is gathered from two main sources. The expected data is collected from the Sentienl-2 satellite mission of ESA. The observed or existing data is gathered from the Government of Maharashtra, under the project of Soil and Water Conservation Department (SWCD) of Maharashtra, India (https://wcd.maharashtra.gov.in). The period from which both the data have been collected is June-July, 2018. Using satellite imagery, satellite data captured by Sentinel-2B were used to identify the water bodies. Two satellites, namely, Sentinel-2A and Sentinel-2B, together form the Sentinel-2 mission. With the combination of these two satellites, the temporal resolution becomes 5 days that enables efficient temporal analyses. The satellites use a versatile instrument called the multispectral instrument (MSI) for analyzing different aspects of the Earth like water, vegetation and so on using different bands of the electromagnetic spectrum. There are a total of 13 different spectral bands on the instrument [1]. The RGB colour bands, i.e., Band 2 to 4, and the near infrared band, i.e., Band 8, have 10 m resolution. These bands are primarily used in this study for NDWI calculation. The vegetation red edge bands have 20 m resolution. The short wave infrared bands, i.e., Band 10, Band 11 and Band 12 have 20 m or 60 m spatial resolution. The Sentinel-2 data is presented in the table I.

Table I. Specifications of Sentinel-2 Bands.

Band Name	**Band Characteristic**	**Spatial Resolution(m)**
Band 1	Coastal Aerosol	60
Band 2	Blue	10
Band 3	Green	10
Band 4	Red	10
Band 5	Vegetation Red Edge	20
Band 6	Vegetation Red Edge	20
Band 7	Vegetation Red Edge	20
Band 8	NIR	10
Band 8a	Vegetation Red Edge	20
Band 9	Water Vapour	60
Band 10	SWIR	60
Band 11	SWIR	20
Band 12	SWIR	20

4. Methodology

The study region is the entire state of Maharashtra which has an area of 307,713 km2. However, the images which can be downloaded individually from the Sentinel-2 captured in May 2018 is a grid of 100 km x 100 km. Therefore, a python library called sentinelsat is used which makes the downloading of data and metadata of Sentinel-2 images from the open access hub easily. Using the python API, the downloading of 100 individual grids which make up the total area of Maharashtra and some area beyond was completed. The coordinates for the input data was provided using JSON format. The JSON format is obtained by using an online tool which converts a draw able polygon to GEO-JSON data. The spectral index used to calculate the water content is Normalized Difference Water Index (NDWI). The spectral index is computed as[1] [13],

$$NDWI= (\rho Green-\rho NRI) / (\rho Green+\rho NRI) \quad \text{… Eq. (1)}$$

From the Sentinel-2 spectral imagery, the two bands used are band 3 and band 8. Band 3 is the green colour band and band 8 is the Near Infra-Red band. The digital interpretation of the output raster image should be around 0.5 to represent water. If the value is lesser then it can be non-water regions such as vegetation or build- up area. In figure

1 (a) the NDWI is calculated for a particular region in Maharashtra and it can be observed that surface water bodies are depicted by a distinct blue colour as shown in figure 1.

In the next step, another script is coded in python to process the huge amount of data gathered. The GDAL and gdal_array classes from the OSGeo library were used. Using the formula mentioned in Eq. 1, the NDWI is calculated using raster calculations for all the given grids. The script also saves the individual NDWI of each grid and also merges all the grids together to generate a TIF file and form an NDWI layer for the state of Maharashtra.

The geo-PDFs were downloaded from the official site of Government of Maharashtra consisting of water bodies present in the Jalna District for the period 2017-2018 under the project of Soil & Water Conservation Department (SWCD). This project was headed by the Government of Maharashtra with the objective of providing a long-term solution to tackle the severe drought problem in Maharashtra. The approach was to test the consistency of this data by overlaying these geo-PDFs over the real-time satellite data obtained from open access hub of Sentinel-2. To overlay the geo-PDFs over the satellite spectral index data, the files need to be converted to TIF files.

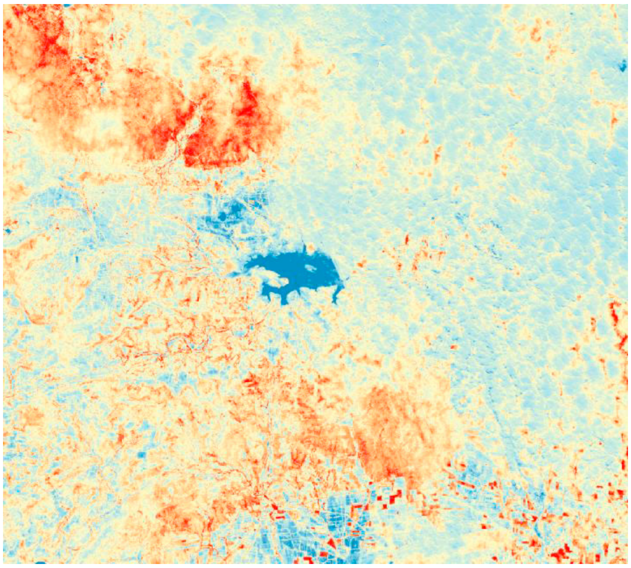

Fig. 1. NDWI of Chandrabhaga Dam in Badnapur, Maharashtra

These geo-PDFs were first converted into GeoTIFF files using gdal_translate command. Once the GeoTIFF files were obtained from the previous step, the trimming of the white border of the images needed to be done. Hence, the command gdalinfo is used to obtain the co-ordinates of the neatline polygon. After getting the co-ordinates of the required polygon, the gdalwarp command is used to crop the white borders and only a TIF file of the data is obtained. These tasks are automated for the state of Maharashtra using bat scripting. The bat script converts the geo-PDFs to TIF files without any white border and it corresponds to the same geographic region represented by the geo-PDFs. This bat script is executed in the OSGeo4W shell which is a part of the QGIS software. The geo-PDFs can now be overlaid onto the NDWI layer.

The overlaying of the two raster layers is done using QGIS software. An important point to note is that the layer made from SWCD data should appear on top of the NDWI layer. This makes comparison of the two layers convenient and facilitates the finding of inconsistencies between the two layers. The overlaying process is well depicted in figure 2, 3 and 4 for Shrikushnagar village and figure 5, 6, and 7 for Sirasgaon Waghrul village.

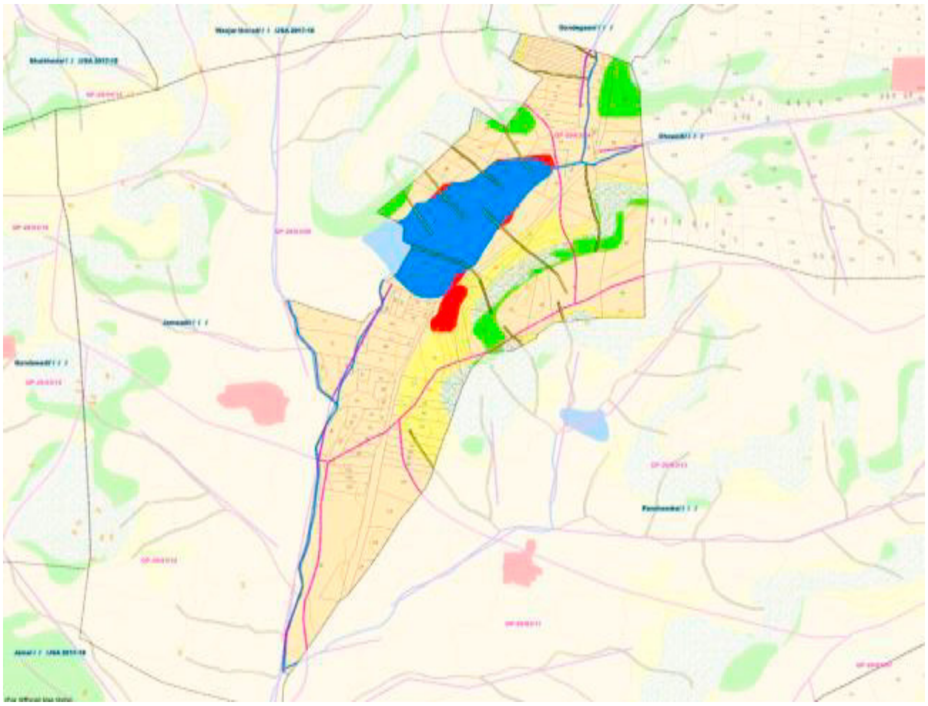

Fig. 2. SWCD data of Shrikushnagar, Jalna, Maharashtra.

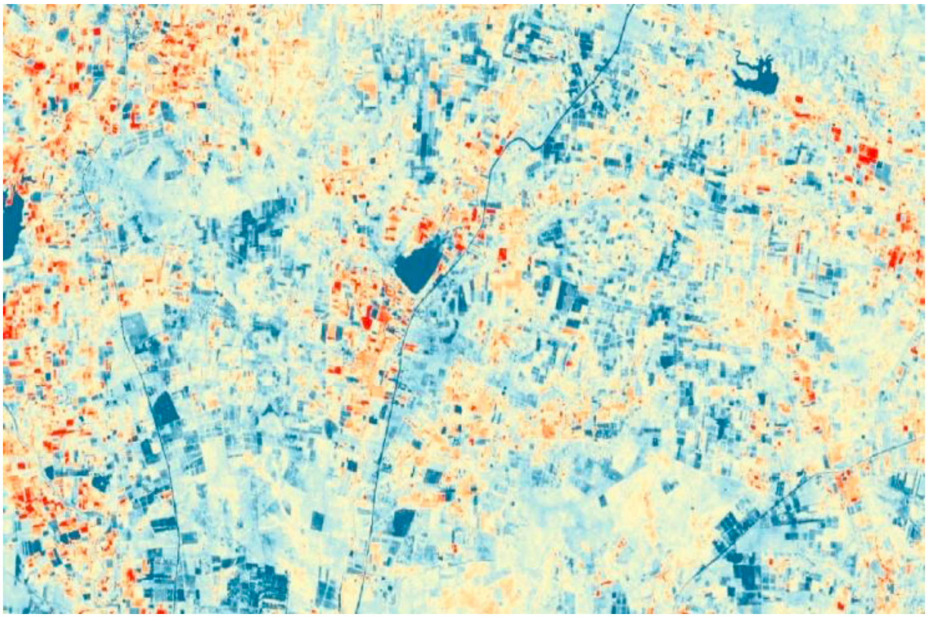

Fig 3. NDWI data of Shrikushnagar, Jalna, Maharashtra.

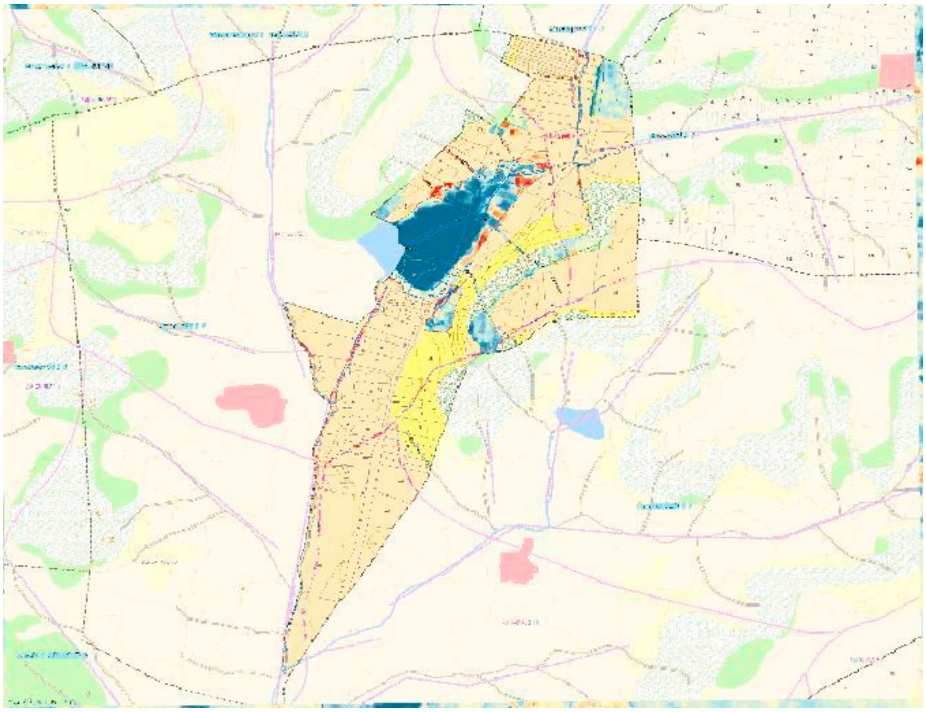

Fig 4. Overlaying of SWCD data of Shrikushnagar, Jalna, Maharashtra on NDWI data.

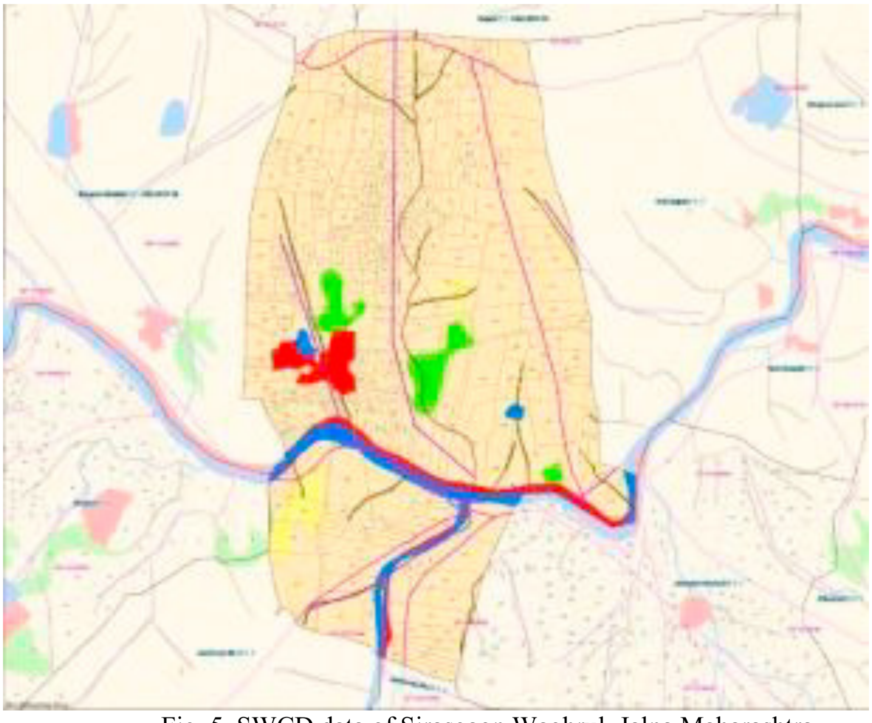

Fig. 5. SWCD data of Sirasgaon Waghrul, Jalna,Maharashtra

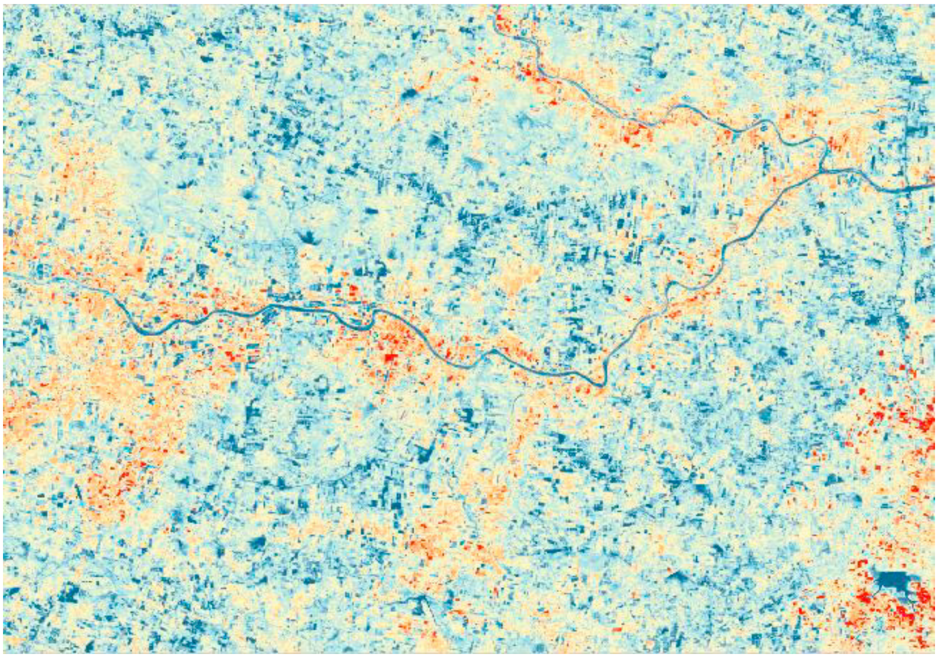

Fig 6. NDWI data of Sirasgaon Waghrul, Jalna, Maharashtra

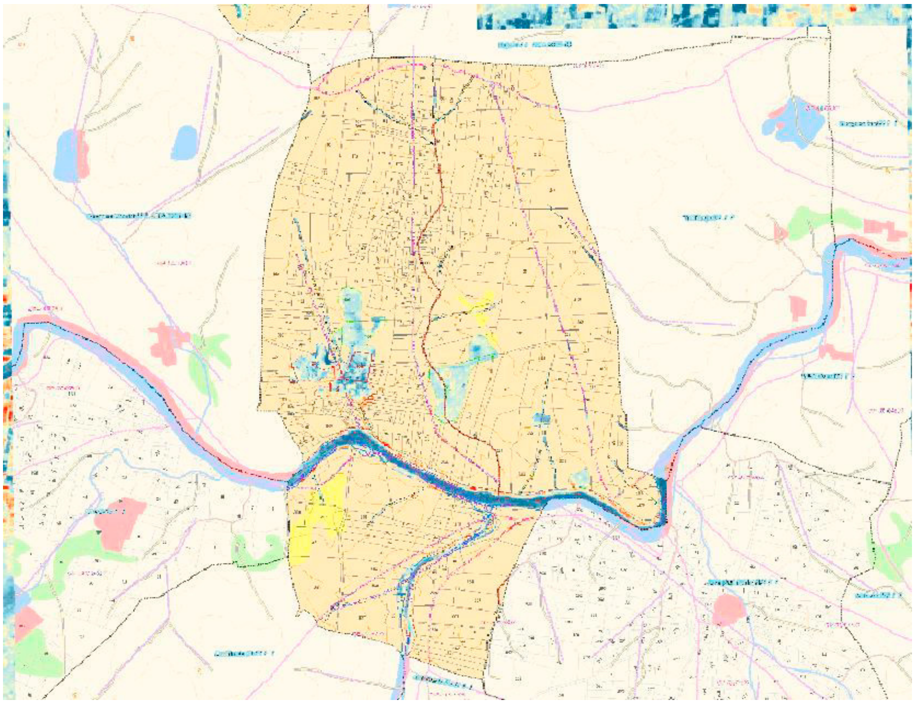

Fig. 7. Overlaying of SWCD data of Sirasgaon of Sirasgaon, Waghrul, Jalna, Maharashtra on NDWI data.

In the last step, the overlaid layers are analyzed and inconsistencies are found using the following metric:

- The presence of a water body in SWCD data layer and absence in the NDWI layer.
- The absence of a water body in SWCD data layer and presence in the NDWI layer.
- The presence of a water body where the shape and size are not coherently represented by the two layers.

Using the above mentioned metric, the inconsistencies are found by manual comparison of the significant surface water bodies. A database is prepared in QGIS which contains two tables called match and nomatch. Using QGIS shape tool, polygons were drawn where the data from the two layers' match and where it does not. These shape files are stored in the database and can be overlaid. The shape files from the match table are represented by a green color and the shape files from the nomatch table are represented by a red color.

5. Results

By overlaying the two data layers, we can easily identify the differences present in the shape and size of the surface water bodies. From the results, it can be observed that here are many inconsistencies present between the two sources of data. Fig. 8 depicts an area in Maharashtra, Chandrabhaga Dam in Badnapur where the shape and size of the water body matches in the two data layers. Fig. 9. represents the data gathered by SWCD, Maharashtra for the same area. From the above mentioned figures, it can be observed that the uppermost part of the water body is consistent between the two layers. Similarly, Fig. 10 is an example of the case where the data in both the layers does not match and the red polygon is drawn to visualize the mismatch.

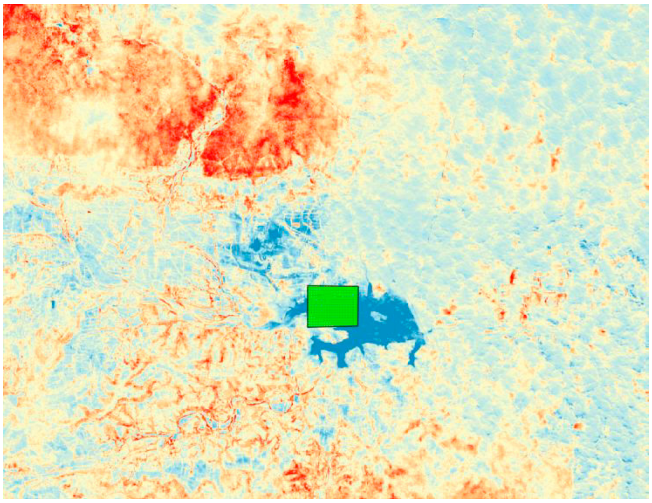

Fig. 8. NDWI of Chandrabhaga Dam in Badnapur, Maharashtra with green polygon from match table.

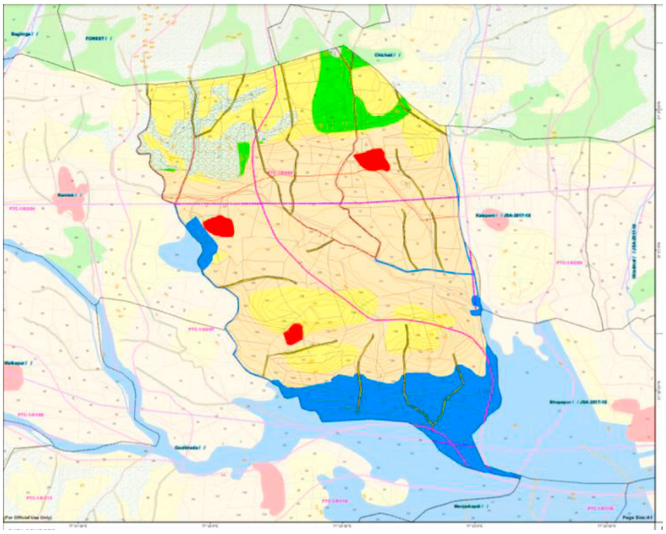

Fig. 9. SWCD data of Chandrabhaga Dam in Badnapur, Maharashtra.

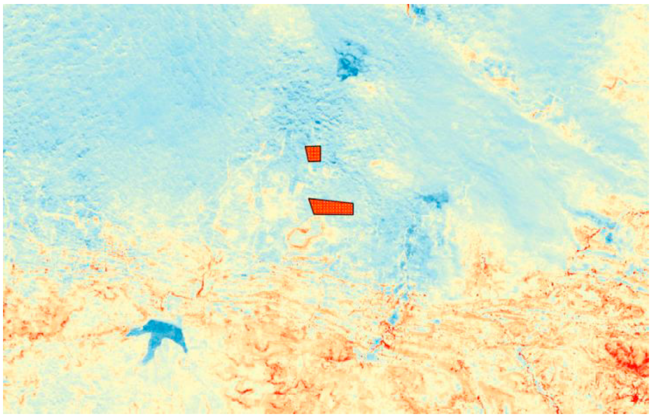

Fig 10. Red polygon to represent incoherent data from nomatch table.

Few villages are listed below which indicates absence of water bodies when compared with the SWCD data, Nandgaon Khandeshwar-Jamathi , Nandgaon Khandeshwar-Inzala, Dharni –Sawalkheda, Dharni -Rohinikheda Dharni -Rangubeli (River passing) ,Dharni-Kadhava etc.

6. Conclusion

In this study, the NDWI layer was generated with the help of new-age ESA Earth observation satellite Sentinel-2. Using this layer images, the water bodies were prominently detected for the state of Maharashtra, India. On this NDWI layer, the geo-PDF layer obtained from the survey data of Soil and Water Conservation Department of Maharashtra, was overlaid. From this overlaying, it became easier to visualize the consistencies between the two data and hence verify the presence or absence of water bodies in certain regions. The govermenrt authorities can be able to adaptively plan the water conservation or supply to the drought stricken areas.

Future work includes the temporal analysis of the available data to evaluate the sesonal availability of the amount of water.

7. Acknowledgement

The authors are grateful to the European Space Agency (ESA) for making the satellite data from Sentinel-2 mission open source and accessible to all. The QGIS software, which was used extensively throughout the study, is a good application for GIS work and the authors would like to thank the developers of the same.

References

[1] Sekertekin, Aliihsan, Sevim Yasemin Cicekli, and Niyazi Arslan. (2018) "Index-Based Identification of Surface Water Resources Using Sentinel-2 Satellite Imagery." *In 2018 2nd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT*), pp. 1-5. IEEE.

[2] Kaplan, Gordana, and Ugur Avdan (2017). "Object-based water body extraction model using Sentinel-2 satellite imagery." *European Journal of Remote Sensing 50*, no. 1: 137-143.

[3] Singh, Mohit, S. N. Mohapatra, and Monika Sharma. (2016) "Normalised difference water index based water surface area delineation and assessment." *International Journal of Environmental Sciences 6, no. 5* : 634-645.

[4] Şekertekin, A., A. M. Marangoz, and H. Akçin. (2017) "Extraction of surface water resources using remote sensing indices and Landsat 8 Data." *In Int. Symp. GIS Appl. Geogr. Geosci, vol.* 288.

[5] Toming, Kaire, Tiit Kutser, Alo Laas, Margot Sepp, Birgot Paavel, and Tiina Nõges. (2016) "First experiences in mapping lake water quality parameters with Sentinel-2 MSI imagery." *Remote Sensing 8, no. 8*: 640.

[6] Sheriza Mohd Razali1 and Ahmad Ainuddin Nuruddin (2011), "Assessment of Water Content using Remote Sensing Normalized Difference Water Index: Preliminary Study," *Proceeding of the 2011 IEEE International Conference on Space Science and Communication (IconSpace) 12-13 July 2011, Penang, Malaysia*. : 265-268

[7] Hicham Ezzine, Ahmed Bouziane, Driss Ouazar, and Moulay Driss Hasnaoui (2017) "Downscaling of TRMM3B43 Product Through Spatial and Statistical Analysis Based on Normalized Difference Water Index, Elevation, and Distance From Sea*," IEEE Geoscience and Remote Sensing Letters (vol. 14 , issue. 9 , Sept. 2017*), pp. 1449 – 1453.

[8] Du, Yun, Yihang Zhang, Feng Ling, Qunming Wang, Wenbo Li, and Xiaodong Li. (2016) "Water bodies' mapping from Sentinel-2 imagery with modified normalized difference water index at 10-m spatial resolution produced by sharpening the SWIR band." *Remote Sensing 8, no. 4* : 354.

[9] Rokni, Komeil, Anuar Ahmad, Ali Selamat, and Sharifeh Hazini. (2014) "Water feature extraction and change detection using multitemporal Landsat imagery." *Remote sensing 6, no. 5 (2014*): 4173-4189.

[10] Stuart K. McFeeters (2013), "Using the Normalized Difference Water Index (NDWI) within a Geographic Information System to Detect Swimming Pools for Mosquito Abatement: A Practical Approach," *Remote Sens., 5*: 3544-3561.

[11] Daoyi Chen, T.J. Jackson, F. Li, M.H. Cosh, C. Walthall, M. Anderson (2003), "Estimation of Vegetation Water Content for Corn and Soybeans with a Normalized Difference Water Index (NDWI) Using Landsat Thematic Mapper Data, "*IEEE International Geoscience and Remote Sensing Symposium. Proceedings* (*IGARSS*): 2853-2856

[12] Shudong Wang, Muhammad Hasan Ali Baig, Lifu Zhang, Senior Member, IEEE, Hailiang Jiang, Yuhe Ji, Hengqian Zhao, and Jingguo Tian (2015), "A Simple Enhanced Water Index (EWI) for Percent Surface Water Estimation Using Landsat Data*," IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing , vol. 8 , issue: 1* :. 90-97.

[13] X. Yang, S. Zhao, X. Qin, N. Zhao, and L. Liang (2017) "Mapping of Urban Surface Water Bodies from Sentinel-2 MSI Imagery at 10 m Resolution via NDWI-Based Image Sharpening," *Remote Sens., vol. 9, no. 6*, : 596.

[14] Xu, Hanqiu. (2006) "Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery." *International journal of remote sensing 27, no. 14* : 3025-3033.