IDENTIFICATION OF WATERLOGGED AREAS IN ROHTAK DISTRICT USING SATELLITE IMAGERIES

Suvrat Kaushik[1], Pankaj R. Dhote[2], Praveen K. Thakur[3]

Indian Institute of Remote Sensing, Indian Space Research Organization, Dehradun, 248001.

[1]suvrat.k007@gmail.com, [2]pdh@iirs.gov.in, [3]praveen@iirs.gov.in

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ABSTRACT:

Remote Sensing is a very reliable and expeditious technique for assessment and mapping of surface waterlogged areas. Several image processing techniques have been presented by researchers for the extraction of water features from satellite imagery. In this study band ratio based NDWI index (Normalized Difference Water Index) was used for extracting water pixels from optical imageries. To overcome the limitation of false positives and cloud penetration associated with optical imageries waterlogged areas was also extracted using SAR (Synthetic Aperture Radar) images. Thresholding of NDWI for optical image and Sigma0 for SAR images was done using respective histograms to distinguish water and terrestrial features. The elevation profile generated from DEM (Digital Elevation Model) showed that the northern and north-western parts of the district have higher elevations and slope towards the southern and central parts with lower elevations. Surface waterlogged areas change temporally from pre-monsoon to post-monsoon period in Rohtak district, Haryana. The results of integration of surface waterlogged areas extracted from both optical and SAR images is presented in this paper.

INTRODUCTION:

Waterlogging is a serious problem plaguing large parts of the country. Waterlogging in simple terms is defined as the condition of high sub-surface water table where the soil pores in the root zone become saturated with water, thus displacing air which in turn affects the normal growth and yield of crops. Surface waterlogging on the other hand is the accumulation and stagnation of surface water over depressed lands due to restriction of natural drainage (Lohani et al., 1999). Various causes of waterlogging include natural causes like poor drainage facilities, geological restriction to natural drainage, very high precipitation in the form of rainfall and flooding. Artificial causes of waterlogging comprise faulty irrigation practices resulting in loss of water, leakages from unlined canals and artificial storage structures, artificial restriction to natural drainage by construction of roads, railway lines etc. Haryana is one of the worst affected states in the country suffering acutely from this problem. According to a study conducted by Central Soil Salinity Research Institute (CSSRI) nine districts of Haryana are hit by the problem of soil salinity and waterlogging (The Tribune report, 16 January, 2016). Out of the nine districts, Rohtak district is worst affected by the problem of waterlogging. The geological location of Haryana with the Himalayan Mountains on the north-east and the Thar Desert on the south west leads to mainly inland drainage conditions and an extensively closed basin. There exists a topographical depression in the center of the state with its axis passing through Delhi-Rohtak-Hisar and Sirsa. Thus areas comprising mainly Rohtak, Jhaggar and Sonipat district form part of a saucer like depression. Both surface and sub-surface water flow towards this depression and eventually stagnate thus resulting in problems of a rising water table, waterlogging, flooding after heavy rainfall and soil salinization (Rathore et.al, 2001). Although the introduction of canal and modern irrigation practices have helped to increase agricultural production, losses from irrigation systems especially unlined canals have rendered large areas unproductive. This coupled with poor surface drainage facilities elicit waterlogging conditions. Rohtak district has an extensive coverage of canals, most of which are unlined. Leakages and losses result in accumulation of water in vicinity of canals.

PREVIOUS STUDIES:

The problem of waterlogging has been identified as critical by many researchers in the past. As a consequence, numerous studies have been devoted to understand the problem of waterlogging and to find appropriate remedial and management strategies. Narayan et al. (1989) classified the wastelands of the entire Indian territory (329 m ha) using Landsat- MSS FCC of 1:10,00,000 scale into various classes defined as salt-affected, gullied or ravined, waterlogged or marshy, undulating upland with or without scrub, jhum or forest blank, sandy areas (coastal or desert), barren hill ridge or rock outcrops and snow covered/glacial areas. Along with the use of satellite imageries their study also included intense mapping and ground data collection for classification of wastelands. It was found that an accuracy of 80 to 90 percent was achieved in the identification and mapping of wastelands when compared with the ground survey. Singh and Srivastava (1990) in their study used microwave radiometers for identifying waterlogged and salt affected areas in coastal regions. Various numerical calculations of brightness and temperature were carried out to distinguish waterlogged and salt affected areas. The results presented in this study showed the utility of microwave radiometers in mapping of waterlogged and salt-affected areas. Sidhu et al. (1991) proved that waterlogged areas in irrigated command areas can be mapped very efficiently using IRS data. Dwivedi et al. (1999) found that surface waterlogged areas in drainage congested areas can be monitored and mapped efficiently by using satellite remote sensing coupled with Geographical information system (GIS). Encouraging results based on the information provided for the spatial pattern of surface waterlogging have been obtained by using Remote Sensing data in the Visible, Near Infrared (NIR) and Short wave Infrared (SWIR) regions.

STUDY AREA AND DATA USED:

The study area chosen for the study is the Rohtak district of Haryana which lies between 28^{o} 40’ to 29^{o} 05’ north latitudes and 76^{o} 13’ to 76^{o} 51’ east longitudes. The total geographical area of the district is 1745 km^2. Rohtak district is located in the southeast of Haryana with Delhi to the north east. Plain and undulating sandy Indo-Gangetic alluvial plains of Quaternary age mark the overall topography of the area (CGWB, 2013). Clay group of minerals dominate over sand and silt in the area. There is a gentle slope of about 19 cm/ km from North-East to south-west in the district. The average annual rainfall is about 590 mm (CGWB, 2007). Out of this 10 % of the total rainfall occurs in Pre-monsoon (February-May), 80 % of the total rainfall occurs in monsoon season (June-September) and 10 % rainfall occurs in post-monsoon season (October-January)

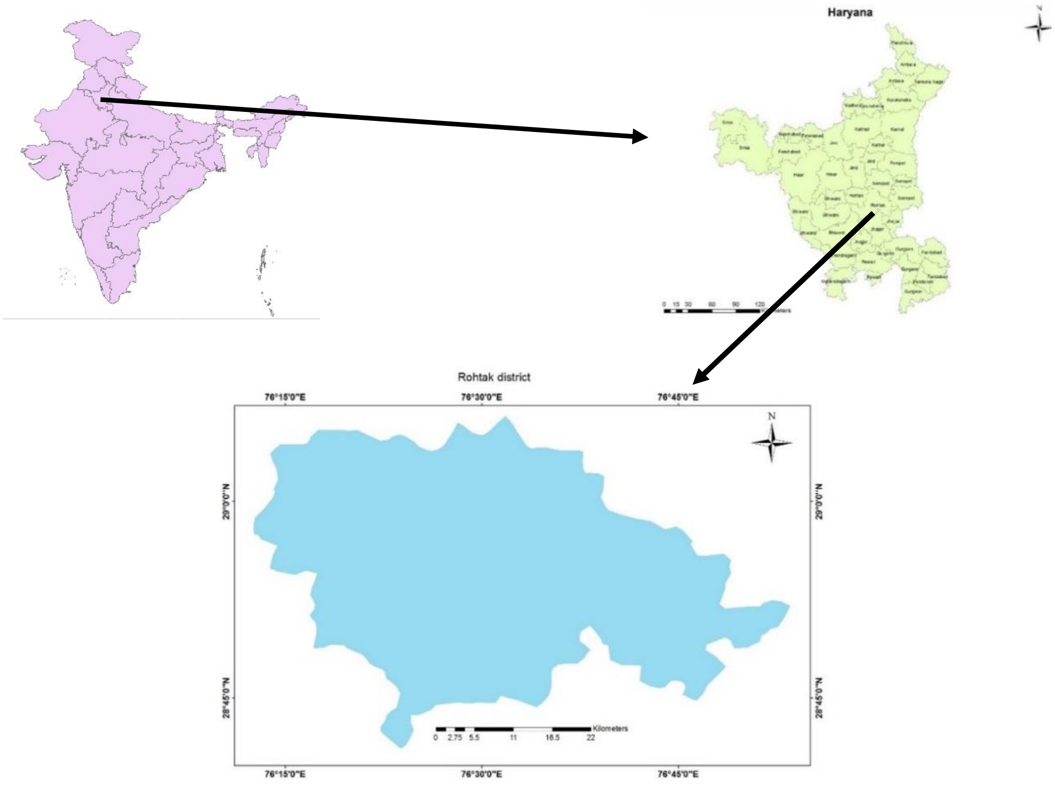

Fig 1: Study Area

Total irrigated area in the district is 97900 hectares. Out of which 66900 hectares is irrigated by the canals and 31000 hectares is irrigated by tube wells. Bajra/ Jawar/ Guar, Paddy, Cotton and Sugarcane are the major crops in kharif season (July to October). Wheat, Mustard and Sugarcane are the major crops during Rabi season (November to February) followed by other crops. The two main canals passing through the district are Jawahar Lal Nehru (JLN) feeder canal and Bhalaut Sub. Branch (BSB) which cover most of the district and spread a network of sub-branches, minors and distributaries. The canals provide adequate water for irrigation mainly in the Kharif season. The water is insufficient in other months and hence groundwater becomes the primary source for irrigation during most of the year. Groundwater in most parts of the district is available at very shallow depths within 5 mbgl. In many parts of the district very high sub-surface water table results in rendering the soil unfit for cultivation.

Sentinal-2 MSS Level 1C data was chosen for the study as it provided high spatial resolution images with good coverage on dates suitable for the study (Table 1). Four spectral bands of 10m resolution: Band 2 (blue), Band 3 (Green), Band 4 (Red) and Band 8 (NIR) were stacked to generate a standard False Color Composite (FCC) image using band combination 4, 3, 2. The images were corrected for radiometric errors in ERDAS IMAGINE. Sentinel 1A SAR images (Table 2) were downloaded and processed for almost similar dates to access the surface waterlogging conditions in the district using RADAR images.

Table 1: Sentinel 2 MSS data for water body mapping

Type of data	**Date of acquisition**	**Tile Number**	**Source**
Sentinel 2 MSS	21/12/2016	T43RFM	USGS Earth Explorer
Sentinel 2 MSS	21/03/2017	T43RFM	USGS Earth Explorer

Table 2: Sentinel 1A SAR data for water body mapping

Type of data	**Date of acquisition**	**Polarization**	**Path/Frame**	**Source**
Sentinel 1A	27/12/2016	VV+VH	136/496	Alaska Satellite Facility
Sentinel 1A	21/03/2017	VV+VH	136/496	Alaska Satellite Facility

Extraction of surface waterlogged areas from satellite images:

Sentinel 2 MSS standard FCC images for pre (Fig 3) and post monsoon (Fig 2) assessment are used to delineate surface waterlogged areas in the district. Multi-band rationing technique combines different relevant bands for improved extraction of water pixels from satellite images (Rokni et al., 2014). Normalized Difference Water Index (NDWI) developed by McFeeters (1996) was used to extract water pixels from the multispectral images and to enhance their presence in the imagery. NDWI is calculated as follows:

$$Normalised\ Difference\ Water\ Index\ (NDWI) = \frac{GREEN-NIR}{GREEN+NIR}$$

The values for NDWI range from -1 to +1. NDWI maximizes reflectance of water by using green band wavelengths and minimizes low reflectance of water in NIR spectrum by absorbing the maximum of wavelength. As a result, water features are enhanced owing to having positive values and vegetation and soil are suppressed due to having zero or negative values.

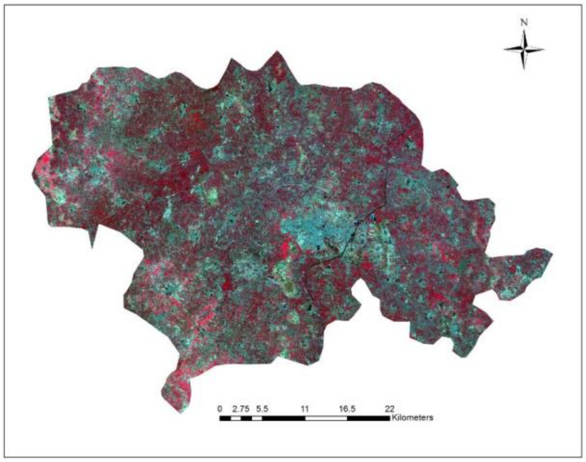

Fig 2: Sentinel 2 MSS (21/12/2016)

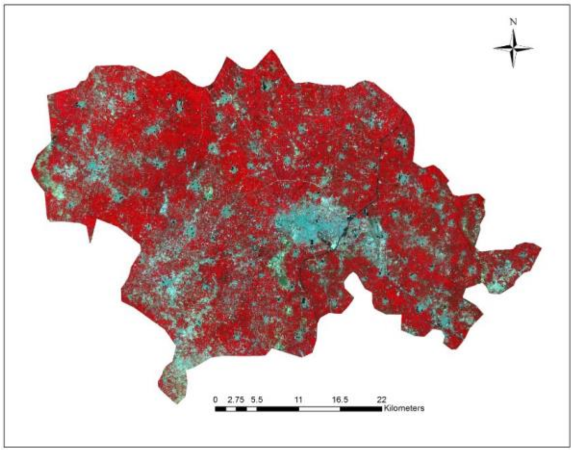

Fig 3: Sentinel 2 MSS (21/03/2017)

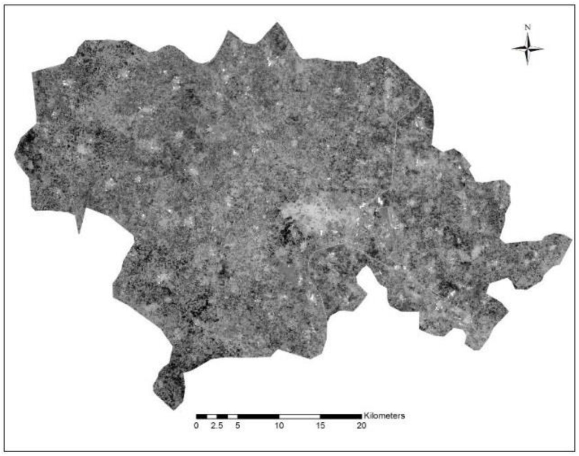

Fig 4: NDWI image (Post-monsoon)

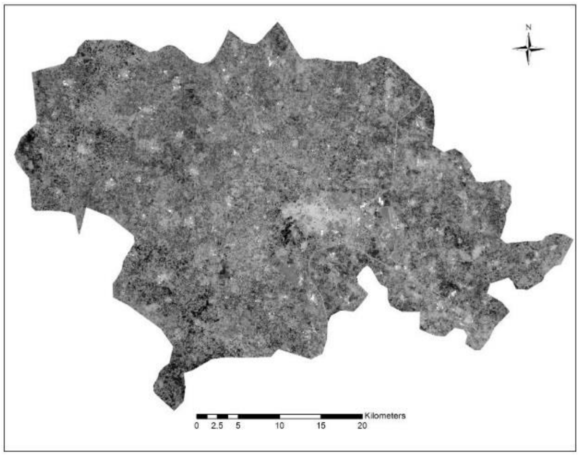

Fig 5: NDWI image (Pre-monsoon)

Thresholding of NDWI to extract water pixels:

The values of NDWI range from -1 to +1, with water pixels generally showing a higher positive value of NDWI. Thus to extract water pixels from the NDWI image it is important to define a threshold value that best extracts water pixels from the NDWI image. In both the images, it is found that the NDWI for water is greater than 0.20. The following threshold condition applied in ERDAS Model Maker:

EITHER $n7_ndwi IF ($n7_ndwi > 0.20) OR 0 Otherwise

The condition sets the threshold value of NDWI as greater than 0.20 for any pixel to be classified as water. All other pixels with values less than 0.20 will be classified as 0 and appear dark, while pixels above the threshold value appear bright and will be classified as water.

Extraction of surface waterlogged areas from SAR images:

Although NDWI extracts water pixels with great accuracy, it has limitations as in some instances the water features extracted using the NDWI also include false positives from built-up land as observed by (Rokni et al., 2014). During present study it was observed that NDWI thresholding extracted water pixels with sufficient accuracy, but some shallow water areas were not extracted. To overcome this problem Sentinel 1A Ground Range High-resolution Dual-polarization (GRD-HD) SAR images acquired for almost similar dates (Fig 6 & 7) were processed and analyzed. The images were calibrated and geocoded in SNAP. The output images were then converted to backscatter images by converting the band to Sigma0. The images were reprojected to UTM WGS 1984 Zone 43N. Median filter of 3*3 was applied to the images to separate features distinctly and for better extraction of water pixels. Image to image registration was performed on the Sentinel 1A images with respect to the Sentinel 2 MSS images in ERDAS IMAGINE. Due care was taken to keep the RMS error less than 1.

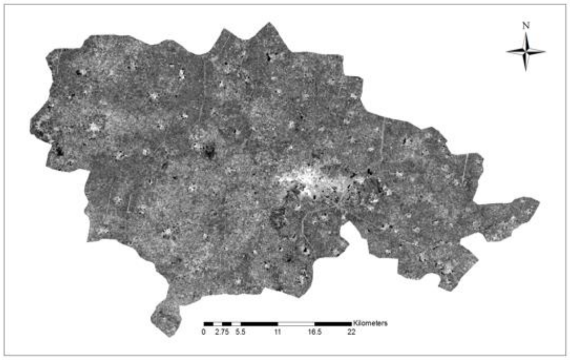

Fig 6: Sentinel 1A image (21/03/2017)

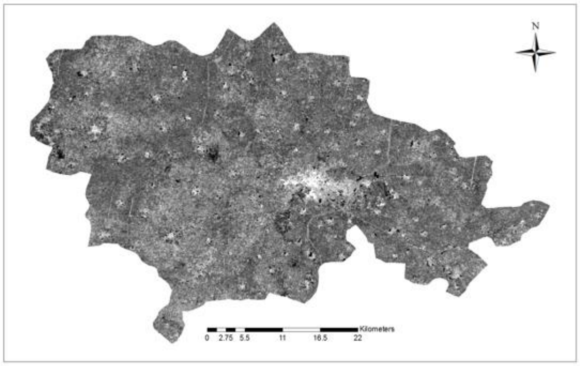

Fig 7: Sentinel 1A image (27/12/2016)

Calm water bodies appear very dark in microwave images since they behave as a specular reflector and direct all of the backscatter radiation away from the sensor. In the processed Sentinel 1A images the threshold of Db (backscatter coefficient) values to extract water pixels for both the images was set at -17. The following thresholding condition was applied in ERDAS IMAGINE:

EITHER 1 IF (Sentinel_1A Image <= -17) OR 0 Otherwise

The water body images extracted from Sentinel 2 MSS and Sentinel 1A SAR imagery was multiplied to obtain the combined water body map of the study area (Fig 8). The images were visually interpreted to separate surface waterlogged areas from other water bodies.

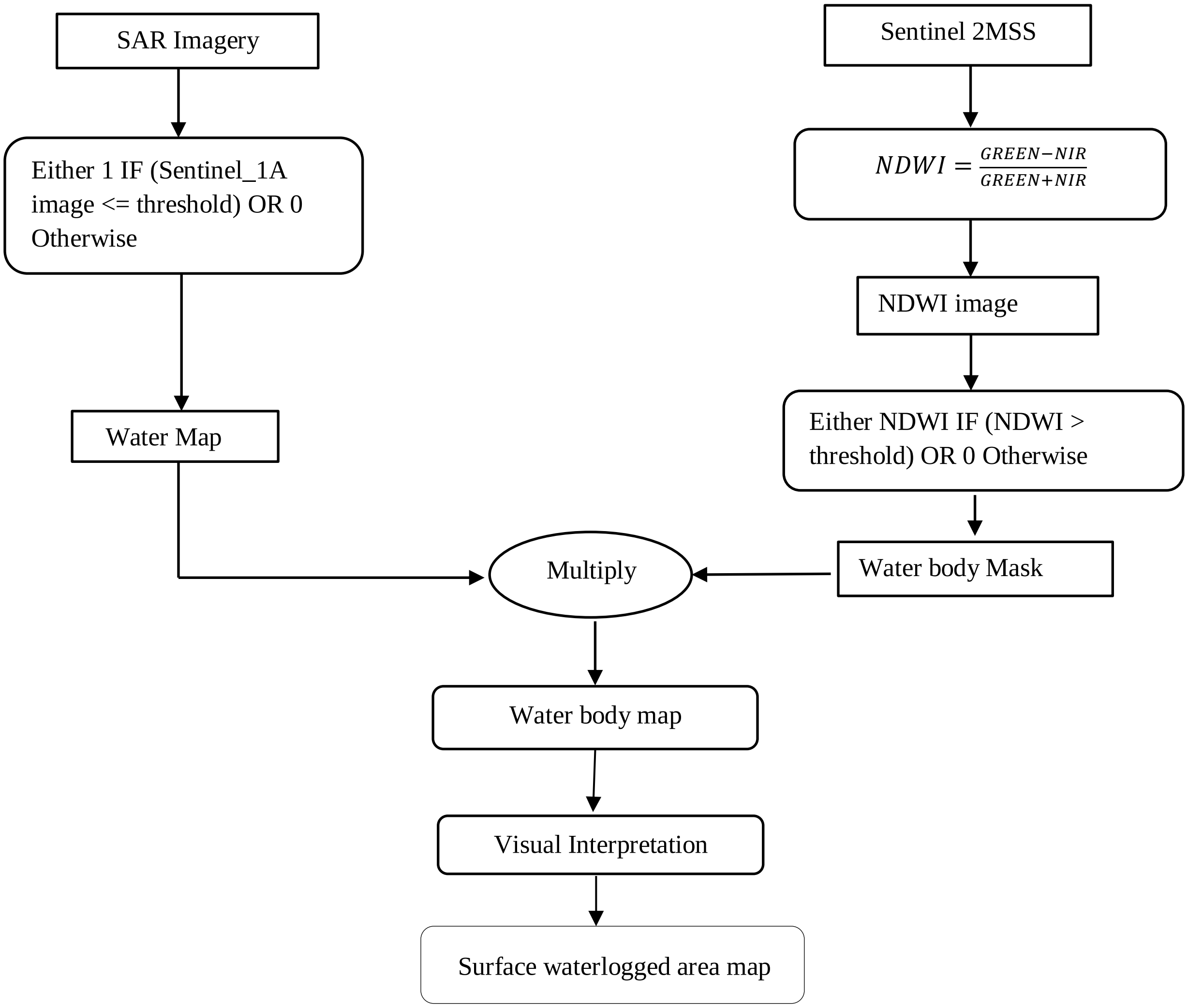

Fig 8: Algorithm used to extract water pixels

Visual Interpretation:

Visual interpretation was the most significant and tedious step in the extraction of surface waterlogged areas from satellite imagery. The study area comprises an extensive network of canals and drains that supply water for irrigation. Some artificial tanks or storage structures are also build near major canals to store water. Since thresholding of satellite images extracts all possible surface water bodies present in the FCC, it was imperative that man-made water areas were eliminated from the final estimation of surface waterlogged areas. For this purpose the raster image was converted to a vector image in ArcGIS and all artificial water bodies were manually edited and eliminated from the image. Visual interpretation skills of shape, size, and association were applied to identify artificial man made water structures. The total waterlogged area in the study area was calculated for both pre monsoon and post monsoon period from the vector images.

RESULTS AND DISCUSSION:

The vector images obtained after running the algorithm in Fig 6 is the surface waterlogged area map for both pre and post monsoon periods (Fig 9 & 10). The total area of the district that is surface waterlogged is calculated from these images. The blue patches in the images represent existing surface waterlogged areas. It was found that the total area of Rohtak district surface waterlogged is 17.86 sq. km for post monsoon period (Fig 9). This comprises around 1% of the total area of the district. The problem of surface waterlogging is more critical in the central and southern parts of the district with almost 65% of the total waterlogged areas spread in this region (11.75 sq. km). The total surface waterlogged area for pre monsoon period is 9.7 sq. km (Fig. 10). This comprises around 0.55% of the total area of the district. Surface waterlogged areas for pre monsoon period are almost half the total area in post monsoon period. In many parts of the district surface waterlogging conditions persist from post monsoon period to pre monsoon period. The summers in Rohtak are dry and very hot with maximum temperatures of 45^0 C recorded in some parts. The persistence of waterlogging from post monsoon to pre monsoon indicates towards permanent waterlogging condition in these areas. The problem of waterlogging is also severe in areas with lower elevation indicating a natural restriction to flow and stagnation of water in these parts of the district.

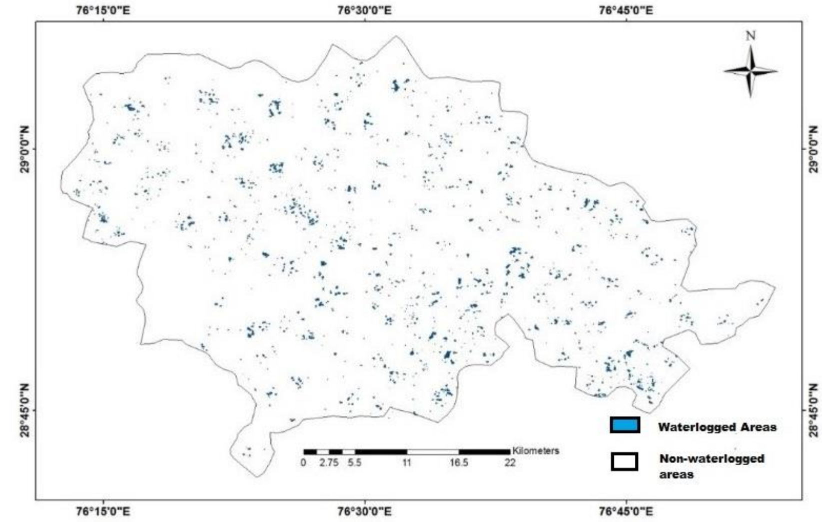

Fig 9: Surface waterlogged areas map (December, 2016)

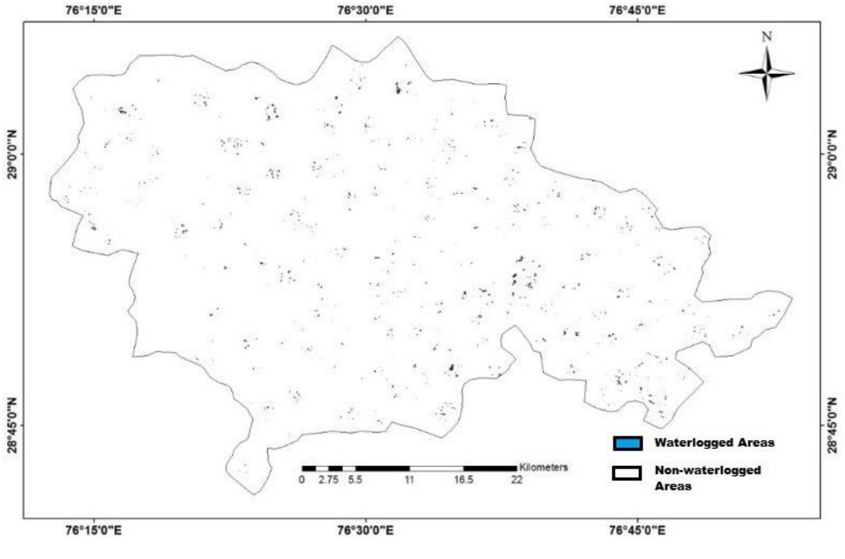

Fig 10: Surface waterlogged areas map (March, 2017)

CONCLUSION:

The study shows that waterlogging is a major problem in Rohtak district especially during post monsoon months. There are multiple factors that attenuate the problem of waterlogging in Rohtak. The geological setting of the district could be the most important cause. Rohtak district lies in a depression that is created in the central parts of Haryana with the Himalayas on the north-east and Thar Desert on the south west. This results in an extensively closed basin with inland drainage conditions. Water from the higher reaches of the state moves towards this topographical depression. Groundwater cannot flow out of the topographical depression and stagnates over land causing surface waterlogging conditions and flooding. Another reason for waterlogging is the advancement in agricultural practices. The district is well connected with canals. Leakages from canal network leads to accumulation and ultimately stagnation of water in vicinity of the canal. Faulty irrigation practices like over supply of water than required, use of pipes instead of sprinkle or drip irrigation methods also creates waterlogging conditions. This combined with poor drainage facilities aggravates the problem. Both preventive and curative measures have to be adopted for the management of waterlogged areas. Success of adopted measures depends on location specific conditions, which often vary according to the complex relationships among topography, soils, climate, geo hydrological conditions, sources and quantities of excess water and cropping patterns. Remote sensing and GIS have immense scope for providing quick inventory of waterlogged area and its monitoring. The present study validates this fact.

REFERENCES:

Central Ground Water Board (CGWB), 2007. Information booklet, Rohtak district, Haryana

Central Ground Water Board (CGWB), 2013. Information booklet, Rohtak district, Haryana

Dwivedi, R.S., Sreenivas, K. & Ramana, K.V. 1999. Inventory of salt affected soils and waterlogged areas: A remote sensing approach. International Journal of Remote Sensing, 20(8), pp. 1589-1599.

McFeeters, S. K., 1996. The use of Normalized Difference Water Index (NDWI) in the delineation of open water features. Int. J. Remote Sens. 17(7), pp.1425–1432.

Narayan, L.R.A., Rao, D.P & Gautam N.C. Wasteland identification in India using satellite remote sensing. International Journal of Remote Sensing, 10(1), pp. 93-106

Rathore, D.S., Sanjay K. Jain & Anju Chaudhry. 2000-01. Remote Sensing and GIS applications in zonation of waterlogging in irrigation command, National Institute of Hydrology, Roorkee.

Rokni, Komeil., Anuar Ahmad, Ali Selamat, & Sharifeh Hazini. Water Feature Extraction and Change Detection Using Multitemporal Landsat Imagery. Remote Sensing (6.5), pp. 4173-189.

Sidhu, P.S., Sharma, P.K. & Bajwa, M.S. 1991. Characteristics, distribution and genesis of salt affected soils in Punjab. Journal of the Indian society of Remote sensing, 19 (4), pp. 269-276.

Singh, R.P. & Srivastav, S.K. 1990. Mapping of waterlogged and salt-affected soils using micro wave radiometers. International Journal of Remote Sensing, 11(10), pp. 1879-1887.

Newspaper Reference: ‘Nine districts hit by soil salinity, waterlogging’, The Tribune, January 15, 2016