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Monitoring decadal changes in the Khudia Dam in the Central Indian State of Chhattisgarh through the application of Remote Sensing and GIS

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ABSTRACT

Dams and reservoirs are constantly threatened by sedimentation and human interference. The present study focuses on decadal variation of Khudia dam built on the Maniyari River in the Mungeli district of Chhattisgarh. IRS P6, LISS III satellite imagery for the years 2004 and 2013 has been used. During the year 2004, area covered by water was 53.57% which was reduced to 33.15% by 2013. Fluctuation in the spatial extents of the river bed has also been associated to the change in the water level/ rainfall. It has been observed that the agricultural land has appreciated over time (2.43%) while the cover of barren land has decreased. The LULC maps created will enable the local decision makers to adopt better land use planning and appropriate use and management of the region's water bodies.

Key words : *Reservoir, Maniyari River, LULC dynamics, Sedimentation*

Introduction

The central Indian state of Chhattisgarh abounds in water bodies, rivers, streams and lakes. Here, cultural heritage and lifestyle are associated with tanks and small water bodies. Though systems and practices have evolved over hundreds of years, people conserve water and use it judiciously and equitably. The dams / reservoirs in the rivers were designed for a continuous water supply of sufficient quality and quantity (Adediji and Ajibade, 2008)

Dams are large physical barriers that are built over rivers to withhold the flow of river water (Woldemichael *et al.,* 2012). The inundated area behind it forms an artificial lake or reservoir (Oxlade, 2006). The large volume of water retained in this reservoir has been used for various purposes including flood control, hydropower generation, irrigation and recreation (Gleick, 2009).

The average rainfall of the state is about 1400 mm, 90% of the total rainfall is confined to the monsoon season, i.e. from mid-June to September. Due to the varying amount of rainfall, the state's agricultural production, which consists mainly of rice, is being adversely affected. Most of the rivers in the state have a torrential regime that is characterized by high water flow for 3-4 months during monsoon, which accounts for about 80% of the annual runoff. Storage reservoirs play a very important role in the efficient use of the available surface water resources.

In the state of Chhattisgarh alone, there are reported 11 large dams/reservoirs, 33 medium-sized reservoirs and numerous small reservoirs for water conservation, hydropower generation and irriga-

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tion.

The Maniyari River is one of the important sub-tributary of Mahanadi River Basin. The Khuria dam known as Maniyari Tank/ Sanjay Gandhi Dam is a medium irrigation project built on the river Maniyari. It is located 45 km from Mungeli city. The National Register of large dams has categorized it as a large dam. It is an earthen dam for hydropower and irrigation purposes which was completed during 1925-1930. The canal system used to cover an area of 29,150 hectares, which grew to 40,485 hectares in 1964-65. 44,000 hectares area are currently being irrigated (http://www.cgwrd.in).

Apart from the river Maniyari, other smaller streams and nalas (Birija Nala, Sarpani Nala, Chakda Nala, Koyalar Nala, Handikhundi Nala, Bhuku Nala, Bamhni Nala and Jhigiya nala) flow from the ATR area as well as from outside ATR area drain their water into Khudia Dam.

RS & GIS is increasingly used and most reliable to study the dynamics of land use change detection and silting of large dams around the world (Alans and Thomas, 2003; Dimitrics *et al.*, 2003; Paoshan *et al.*, 2003; Muhammed *et al.*, 2003; Adediji and Ajibade, 2008).

The present study focuses on the assessment of the decadal change of the water coverage area of Khudia Dam in the years 2004 to 2013 and the creation of thematic maps for the change. The overall aim of this study is to produce LULC change maps that can be used efficiently by land use planners and dam management teams to prevent sedimentation and enhance the reservoir capacity.

Study area

The river Maniyari originates from Sihawal Sagar of Achanakmar tiger reserve and flows through Lormi tehsil of Mungeli districts for approximately 105 km and meets river Seonath, a tributary of Mahanadi river basin near Madku island of Bilaspur district.

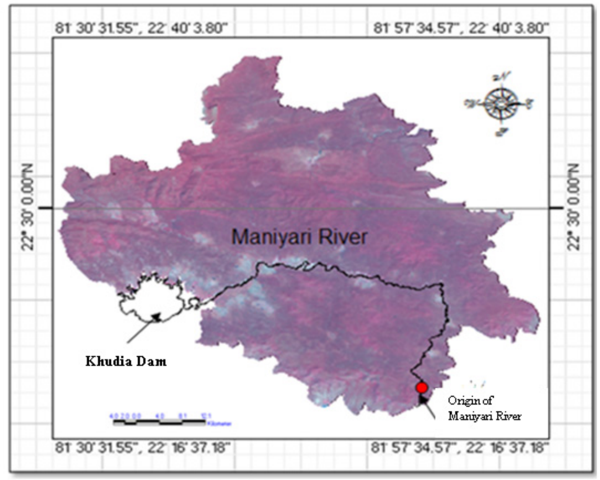

Fig. 1. Location map of Khudia Dam

Within the tiger reserve, it flows about 61.80 km from south to west and flows into Khudia dam outside the ATR.

Geographically the dam is located between the co-ordinates of 22°39'13.95'' N and 81°59'66.43'' E at a distance of 45 km from Mungeli city of Central Indian state of Chhattisgarh. The dam is 2095 m in long and its maximum height is 28.96 m above the foundation. The full reservoir level (FRL) and live capacity of Khudia dam are 358.14 m and 147.72 m respectively.

Data used

Remote Sensing satellite (IRS P6) imageries for the year 2004 and 2013 have been used for change detection and analysis.

Methodology

The choice of years is mainly to highlight the decadal variations that have taken place in the region. The imageries used for the analysis were se-

Table 1. Details of satellite images and other datasets used in the study

Satellite	Meta data		
	Sensor	Date of Image acquisition	Path/ Row
IRS P6	LISS 3	29^{th} Feb 2004	102/56
IRS P6	LISS 3	5^{th} Feb 2013	102/58

Survey of India (SOI) topographic maps of 64F10, 64F11, 64 F14 and 64F15 on 1:50,000 scales published by SOI, Dehradun were used for digitalization.
Google map images have also been used to justify the change in the dam area

lected during the month of spring to minimize seasonal fluctuation during the study. The study area was identified and the area of interest (AOI) was digitalized using SOI toposheet having 1: 50,000 scale. Using an image processing subset tool the study area was extracted from the imageries. The supervised classification was carried out using the maximum likelihood method. Normalized Difference Vegetation Index (NDVI) analysis of the area has also been done to examine changes in vegetation over10 years period.

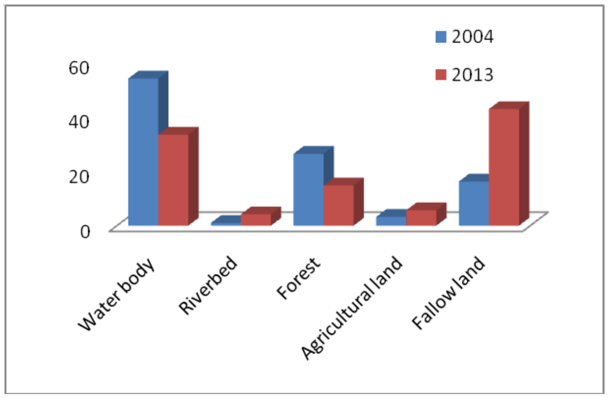

Fig. 1. Percentage of area covered by different LULC classes

The obtained images have been registered to the Universal Transverse Mercator (UTM) map projection with a datum of WGS-84. The study area is located in zone 43 (N) of the UTM. Before the image was classified, satellite data's has been re projected into the Projected Coordinate System (PCS) in order to maintain uniformity within the data base generated. The study includes the LULC change analysis in the Khudia dam area by considering five land use land cover classes. Various scene elements like size, shape, tone, texture and associations etc. are used for visual interpretation to identify and delineate objects.

IGIS Version 1.0, GIS software has been used for image classification and analysis.

Results

Spatio-temporal change detection and analysis of Khudia dam was carried out for the year 2004 and 2013. The supervised classification of the satellite

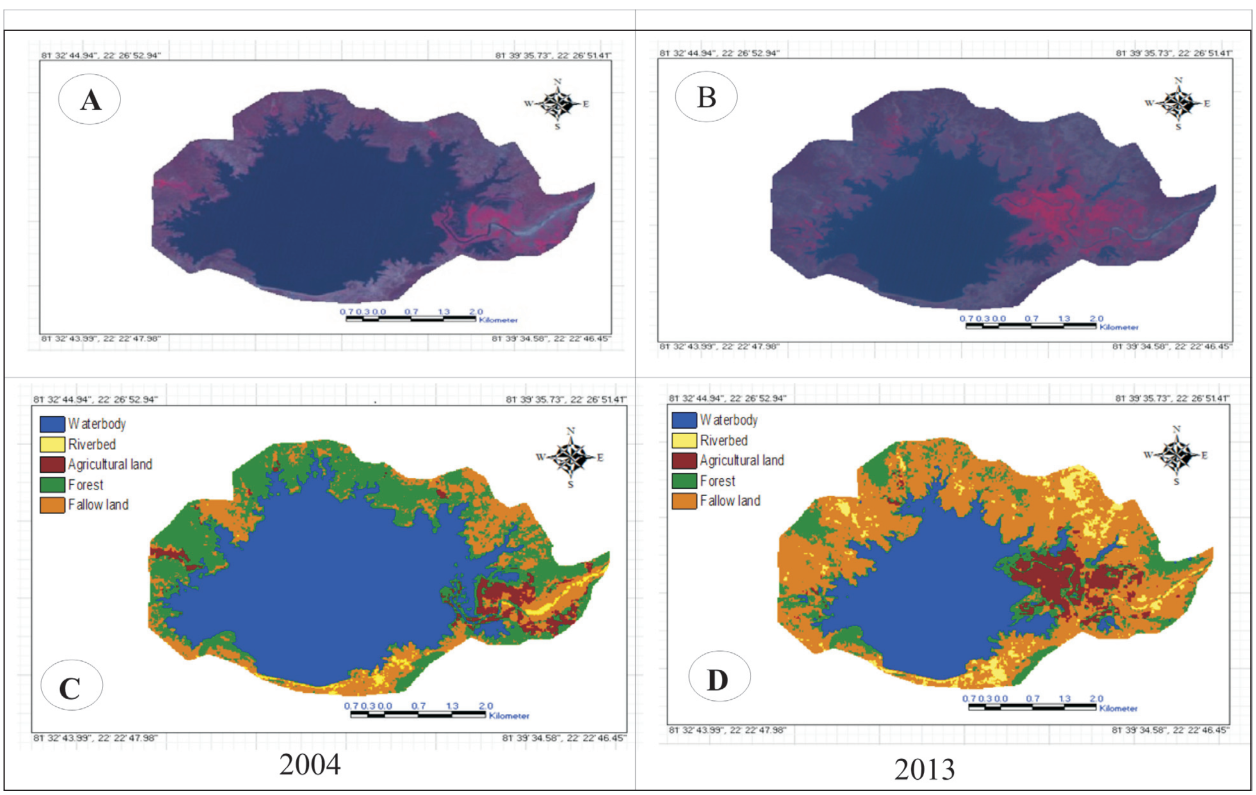

Fig. 2. Spatio temporal LULC analysis of Khudia Dam for the year 2004 and 2013.
A and B False Colour Composite (FCC) of Maniyari Tank for the year 2004 and 2013. C and D is the supervised image of Maniyari Tank for 2004 and 2013 respectively

imageries depicts the dynamics of LULC classes.

The reservoir area of 35.75 km^2 was selected to evaluate the variation in different LULC classes. In 2004 the area covered under water body was 53.57%, which was reduced to 33.15% by 2013. There is a fluctuation in the spatial extents of the water body, riverbed, agricultural land and forest area which can be associated to the change in the water level/ rainfall. The area of riverbed (3.16%) and agricultural land (2.43%) has increased substantially. Nevertheless, a negative change can be observed in fallow land area (26.38%) which is likely to be converted into agricultural land. Increased agricultural activity has been reported on the eastern side of the reservoir area.

(Source: Google earth)

Fig. 3. Google earth image showing Khudia Dam (A) and its conversion into agricultural land (B).

The nearby forest areas have decreased (11.55%), possibly due to deforestation and other natural and anthropogenic reasons. Reduction in maximum NDVI values from 0.41 to 0.38 during the period of 10 years justified the decline in vegetation coverage. Google earth images of the study area ensure the reliability of the derived LULC maps.

Discussion

Recent technology of RS & GIS has been widely used by researchers (Mathodi *et al.*, 2019; Shuaihu *et al.*, 2016) to study and monitor the changes in water bodies and its impact on surrounding environment.

The study confirms the findings of various researchers (Mironga, 2004 and Adediji and Ajibade, 2008) that rapid population growth goes hand in hand with the increase in settlement/ built up area and intensive land use farming. Rawat and Manish (2015) also reported that anthropogenic influence such as urbanization, expansion of agricultural activities, deforestation which led to temporal and spatial changes in LULC has affected water flow paths and water balance of dams.

The result of the present study reported reduction in the water body area of the Maniyari dam by 20.42 percent between the year 2004 and 2013. Decline in water coverage area of the reservoir is due to variation in rainfall and increased in irrigation needs which directly or indirectly consume dam water to meet the water needs. This situation further exposes the area around the dam to direct rain drop impact and thus enhanced accelerated erosion into the study reservoir.

The increase in reservoir sedimentation due to accelerated erosion from agricultural land and open soil surface in the interfluvial area around the dams has became as endemic problem in the tropical countries including India (Adediji, 2005, Faniran and Jeje, 1982). Vanmaercke *et al.* (2010) assessed that the life expectancy of many reservoirs in the catchment area of rivers that are built for irrigation or water supply in the dry season are threatened by massive sedimentation.

As Maniyari River is alluvial in nature, increased sedimentation of the reservoir may be one of the factor for reduction in the surface area, the other factors may include variation in rainfall pattern, decrease in areas covered by vegetation thereby exposing the top soil for erosion. The colonization by weeds along the edges is enhanced by the deposited sediments from the interfluvial area around the dams.

Previous researchers (Dewaangan and Ahmad, 2020, Dadoria and Tiwari, 2017, Jaiswal *et al.*, 2009) also reported the sedimentation of dams in Chhattisgarh state. Jaiswal *et al.* (2009) examined and evaluated the sedimentation of Ravi Shankar Sagar Reservoir in the catchment of Mahanadi river basin. Dadoria and Tiwari (2017) assessed the sedimentation of Murrumsilli dam, which was built on the Sillari River in the Mahanadi river basin. Their study concluded that 29.956 MCM of sedimentation deposits resulted in 18.37% decrease in reservoir capacity between 1923 to 2015.

Welde and Gebremariam (2017) examined the land use land cover dynamics of Tekeze dam in Northern Ethiopia. Simulation results for the Tekeze dam indicated that the increase in bare land and agricultural land resulted in increased annual and seasonal stream flow and sediment yield in volumes. Wu *et al*. (2016) studied the decadal changes in Yangtze River Estuary due to enhanced human activities. In the year 2002 to 2013, severe erosion of the river channel was observed on the middle and upper reaches, which led to salt water intrusion into the estuary. A large amount of the eroded sediment appeared to be trapped downstream, causing overall channel bed accretion in the lower river mouth reach of the estuary. Xing *et al*. (2009) reported that river flow and sediment yield of a catchment depends on LULC change. The changes in LULC are one of the important parameters which depict changes in an area over a period of time. Sedimentation and nutrient enrichment in the water reservoir are the result of land erosion in its catchment area (Upadhyay and Bajpai, 2012).

Conclusion

The principle objective of this study is to evaluate the changes in the water inundated area and to study the LULC dynamics of the Khudia dam and its nearby catchment area. The present study has shown significant changes in the LULC pattern of the reservoir area.

It can be observed that the spatial expansion of agriculturally used areas and barren classes has increased over time, while the water inundated area has decreased in value. The changes in the area of the water bodies will be helpful in making decisions regarding management of reservoir performance. The LULC maps produced for this study area will enable local decision makers to undertake better land use planning and appropriate protection measures that will contribute to a sustainable future. In conclusion, the life span of the dam can be prolonged by dredging the area around the reservoir edges so as to remove the silt deposition and also the hydrophytes. Agricultural activities must be restricted on the area because it may hamper the sole objective of storage reservoir. Apart from this reservoir water are also under the constant threat of pollution due to use of agro-chemicals.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this article.

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