DE GRUYTER OPEN

Environmental & Socio-economic Studies

DOI: 10.1515/environ-2017-0017

Environ. Socio.-econ. Stud., **2017, 5, 4: 18-28**

Original article

Submergence analysis of the proposed Ken Betwa Dam (Madhya Pradesh) India, using geospatial technology in Environmental Impact Assessments

Laxmi Goparaju[1]*, Firoz Ahmad[1], Himanshu Thakkar[2]

[1]Vindhyan Ecology and Natural History Foundation, Mirzapur, Vindhya Bachao Secretariat, 36/30, Shivpuri Colony, Station Road, Mirzapur-231001, Uttar Pradesh, India
[2]South Asia Network on Dams, Rivers & People, 86-D, AD block, Shalimar Bagh, Delhi 110088 India

*E–mail address (*corresponding author): goparajulaxmi@yahoo.com*

ABSTRACT

This study has analysed the Landsat 8 OLI data (December 2016) to delineate the various land use/land cover classes of the area which will be submerged by the proposed Daudhan/Greater Gangau Dam, which is part of the proposed Ken Betwa River Link Project (in the Madhya Pradesh state of India) and also the area likely to be submerged in the Panna Tiger Reserve (PTR). The proposed area of submergence was computed at various full reservoir lengths (FRL), 278 m, 283 m, 288 m, 289 m and 293 m. Similarly the area of submergence for the Panna Tiger Reserve was computed at the mentioned FRLs. It was concluded that a large part of the Panna Tiger Reserve would be submerged and habitat of various animals and plants would be under threat. In comparison with the figures given in the Environmental Impact Assessment certain serious discrepancies and weaknesses were detected and it was felt that they should have been addressed. The results were compared with the EIA – EMP report of the Ken-Betwa link project, Phase 1, prepared by Agricultural Finance Corporation Limited for the National Water Development Agency (Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India). A proper evaluation of the negative impacts would help when making relevant decisions and appropriate steps to ensure that the loss is kept to a minimum. Safeguarding the biodiversity of forests and wildlife habitats should be the priority as their loss is irreplaceable. Geospatial technology helps in studying the overall spatial view of the proposed submergence area and the visualization gives a clear picture of the likely scenario in the future. It would assist in decision making and mitigation measures.

KEY WORDS: Geospatial, Ken, Betwa, Panna Tiger Reserve, Landsat, submergence, Full Reservoir Level

ARTICLE HISTORY: received 5 October 2017; received in revised form 28 November 2017; accepted 7 December 2017

1. Introduction

India is one of the megadiverse countries of the world blessed with abundant natural resources and fresh water rivers. The land with rivers like the Ganga, Brahmaputra, Godavari and Krishna is now in danger for various reasons such as over damming, lack of freshwater flow, pollution, diversion, encroachment, mining, neglect and natural disasters. The Government of India has come up with a proposal to link various of the country's rivers through interlinking canal systems and the construction of several dams (IWRS, 1996). The present scale and concept of linking rivers in India is unprecedented. In 1858, Sir Arthur Thomas Cotton, a British Irrigation Engineer was one of the first to introduce the concept of river interlinking (ILR: Interlinking of Rivers as it is known) in India (KRUEGER ET AL., 2007).

The main objective of ILR is to transfer water from one basin (called Surplus Basin) to another basin (called Deficit Basin) to achieve irrigation, water supply and hydropower generation. Another of claim of the ILR is to control floods and combat drought. The government of India and the nodal organization, the National Water Development Agency, have proposed a massive project where they wish to interlink some major rivers and some 30 interlinkages have been proposed. In this regard, one of the projects is Ken-Betwa River interlink in the states of Madhya Pradesh and Uttar Pradesh and is one of the first to be initiated.

A proper impact assessment is required to analyse the various impacts it will have on land use, land cover and on the overall environment. The negative impacts cannot be overlooked which include submergence of large areas including the habitat of tigers, gharials, vultures, mahaseers and other species, submergence of forests, destruction of rivers, displacement of people, the precarious swing between floods and droughts and also the huge costs associated with such infrastructure.

Satellite remote sensing data offers the scope of analyzing large spatial views at different time periods and at various resolutions. In this respect satellite remote sensing and GIS provide the potential to analyse the spatial extent of the area to be submerged and the proposed increases for various proposals of FRLs (Full Reservoir Level). It will be necessary to calculate the reservoir storage capacity and the likely submerged area before the project is brought into action such that the negative impacts can be analysed and the loss can be minimized. Usually in such cases, inadequate baseline data about the likely impacts hampers the decision making process. The role of hydrological models and GIS is vital in order to obtain the desired results to a high degree of accuracy (CHOWDARY ET AL., 2012). Some techniques in GIS such as overlay analysis, decision support systems and spatial analysis have been found to be capable of studying river interlinking as they provide a wide range of cost effective and innovative options (CHIGBU & ONUKAOGU, 2013).

2. River linking and the two basins

At the village of Ahirgawan situated on the northwest slopes of the Kaimur hills in the Katni district of Madhya Pradesh, the Ken River has its source. It stretches along a length of 427 km from its origin to its confluence with River Yamuna, a part of it, about 84 km lies in Uttar Pradesh and another 51 km forms the border between Uttar Pradesh and Madhya Pradesh. Thus, Ken River is one of the interstate rivers which, the states of Madhya Pradesh and Uttar Pradesh share. The river basin is located between the latitudes of 23^{0}12’ N and 25^{0}54’ N and longitudes of 78^{0}30’ E and 80^{0}36’ E. This river link project aims to transfer the so called surplus water of the Ken Basin to the Betwa Basin which is assumed to be water deficit. It is proposed that three districts of Madhya Pradesh namely Chhatarpur, Panna and Tikamgarh and in Uttar Pradesh the Banda, Jhansi and Mahoba districts will benefit. A population of about 16.98 hundred thousand in both of the states it is claimed will benefit from the drinking water supply. The false color composite of the study area is given in Fig. 1.

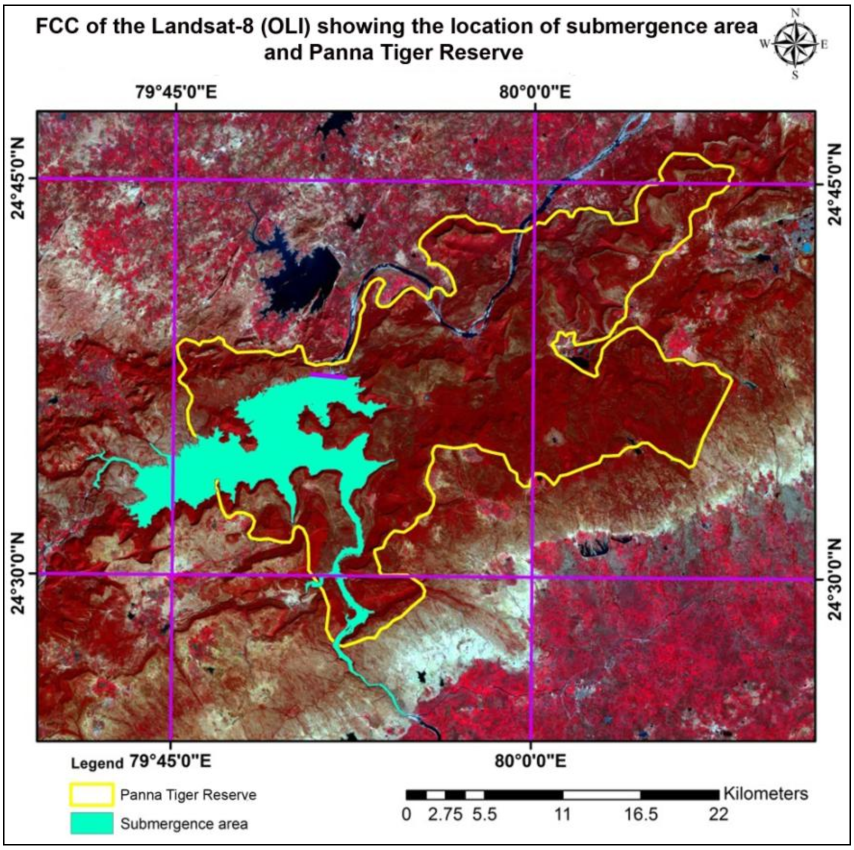

Fig. 1. Location of the study area: False color composite of Landsat data

The aims of the study are: 1) the generation of various thematic layers using Landsat satellite remote sensing data; 2) contour generation using ASTER DEM; 3) the visualization of the submergence area at full reservoir level (FRL); 4) statistics of various land use and land cover classes in submerged areas at various FRLs; 5) generation of the land use and land cover statistics of the portion of the Panna Tiger Reserve (PTR), which will be submerged (at various FRLs).

Along with this analysis, some of the shortcomings in the EIA (Environment Impact Assessment) are reported which should have been addressed for an informed decision about the project.

3. Study area: proposed Dam site

The site for the proposed dam is located about 162 km from the source of Ken River near Daudhan village in Chhatarpur district of Madhya Pradesh (MP). The geographical location of the main dam site is 24^{0}36'51" N and 79^{0}50'30" E and is located about 2.5 km upstream of the existing Gangau weir. The dam site is located in the vicinity of a tourist place named Khajuraho, in Chhatarpur district of MP. It is proposed that it will impound water up to +288 m and will divert 1074 MCM (Million Cubic Metres) of water to the River Betwa Basin via a link canal 218.7 km in length. The live storage capacity of the reservoir is assessed by EIA as 2683.74 MCM, gross storage capacity of 2853 MCM and a total dam length of 2031 m (EIA/EMP Report, 2015). The dam site also falls within the PTR and part of the core area of PTR will be submerged due to the proposed project (Figs 1 and 2).

Panna Tiger Reserve is one of the 22 tiger reserves of India. It is located in one of the mountain ranges named Vindhyans and extends from the Panna and Chhatarpur districts situated in the north of the state. The area is dominated by teak forests and axlewood (*Anogeissus latifolia*) which are naturally occurring. The major physical features of the terrain are plateaus and gorges.

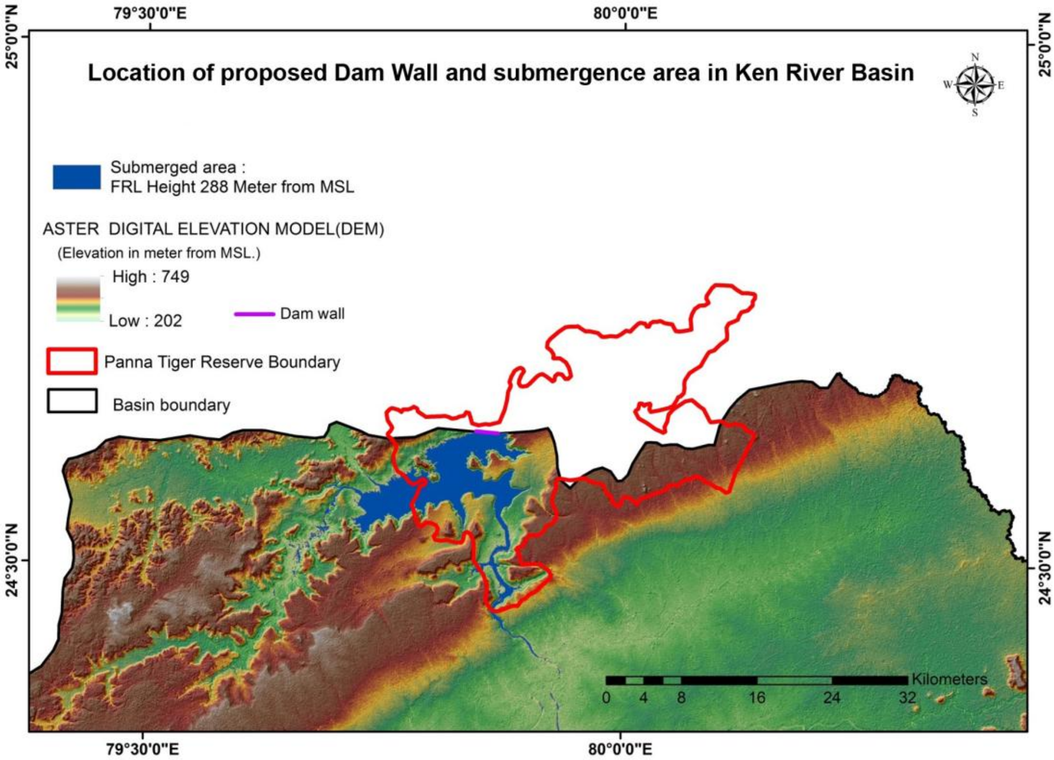

Fig. 2. Proposed Dam Wall and submergence area in Ken River Basin (upstream)

The Ken River flows through the reserve and is its lifeline. It provides habitat for gharial and mugger crocodiles and other aquatic fauna. Some of the wildlife species found in PTR are leopard (*Panthera pardus*), tiger (*Panthera tigris tigris*), sambar (*Cervus unicolor*), mountain gazelle (*Gazella gazelle*), spotted deer (*Axis axis*), four-horned antelope (*Tetraceros quadricornis*) and around 200 species of birds thrive there, including some rare and endangered vulture species. A number of fish (including Mahaseer), snakes and reptiles are also found here. Major tree species found here are: *Tectona grandis*, *Diopsyros melanoxylon*, *Lannea coromandelica*, *Boswellia serrata*, *Lantana camera*, and *Madhuca indica*. Ken Ghariyal Sanctuary, also managed by the PTR office, is situated close by in the area downstream and will also be affected.

The study area is tropical, semi-arid to dry sub-humid. Summers are very hot and winters are generally mild. The average maximum temperature is 44^0C and average minimum temperature is 6.7^0C. During the monsoon, the area receives 90-95% of rainfall from June to October.

The study area is located north of the Son-Narmada fault and is dominated by massive sandstones. Undulating hill ranges and occasional plains consisting of Bijawar and Vindhyans formations along with Bundelkhand granites describe the geology of this region. The highest elevation is supposed to be 491 m above MSL. The Ken River flows in a northerly direction in this area and many tributaries join the river along its course.

4. Materials and methods

4.1. Data acquisition

The satellite data used for the study was downloaded from the USGS website of Landsat 8 OLI on 17th December 2016 (Path/Row = 144/43). The details of the satellite data are given in Table 1. The satellite data was selected in a way so that it was free from cloud cover. The winter season data was chosen because the vegetation is fully developed in this season after the monsoons especially in dry deciduous forests. In such forests, the season plays a major role in the phenology of plants. The bands used for analysis are NIR (5), red (4), and green (3). Other details are Projection UTM, Zone 44 (http://geokov.com/education/utm.aspx; Source metadata); Spheroid, WGS 84; Datum, WGS 84. The data was obtained in 11 bands as a TIFF file. It was layer stacked and converted into *. IMG format for further digital processing. It was a geometrically and radiometrically corrected dataset. ASTER DEM was also downloaded from the USGS website for delineating the drainage, slope and elevation for the study area.

The project proponent analysis states that (EIA/EMP Report, 2015, pg no. 178): "Following information was collected to assess the baseline land environment of the study area: Digital Satellite data IRS 1D LISS-III from NRSA was used to study physiography, land use/land cover, lithology, drainage pattern, slope characteristics and soils. Survey of India (SoI) 1:50, 000 scale Toposheets were used for this study. (…) Geometric Correction: The SOI Topographic Sheets of 1:50,000 scales were developed on polyconic and projection and datum. The sheet was geo-coded using ERDAS with 0 RMS value. The sheet was then re-projected into MGS 84 and UTM projection system, in which the study area falling into zone 46. It was further georeferenced using points from the ground. High resolution multiband image was geocoded SOI topographic sheet by image to image geo-coding process using ERDAS"." The resolution of IRS-LISS III is 23.5 m and Landsat 8-OLI/TIRS is 30 m.

The EIA/EMP deficiencies in this regard are: 1) the date and time of satellite data, which is not reported. It influences the analysis, especially in the case of forests, vegetation and water; 2) path row of the satellite data procured is not mentioned; 3) the image processing technique has been inappropriately explained; 4) the study area does not fall in zone 46, as claimed.

Table 1. Details about Landsat - 8 OLI/TIRS

Landsat 8 (Operational and Imager, OLI) and Thermal Infrared sensors (TIRS)			Resolution (m)
Launched Febraury 11, 2013		Wave length (micrometer)	
Band 1	Coastal aerosol	0.43-0.45	30
Band 2	Blue	0.45-0.51	30
Band 3	Green	0.53-0.59	30
Band 4	Red	0.64-0.67	30
Band 5	NIR	0.85-0.88	30
Band 6	SWIR 1	1.57-1.65	30
Band 7	SWIR 2	2.11-2.29	30
Band 8	PAN	0.50-0.68	15
Band 9	CIRRUS	1.36-1.38	30
Band 10	TIRS	10.60-11.19	100 m (resampled to 30)
Band 11	TIRS	11.50-12.51	100 m (resampled to 30)

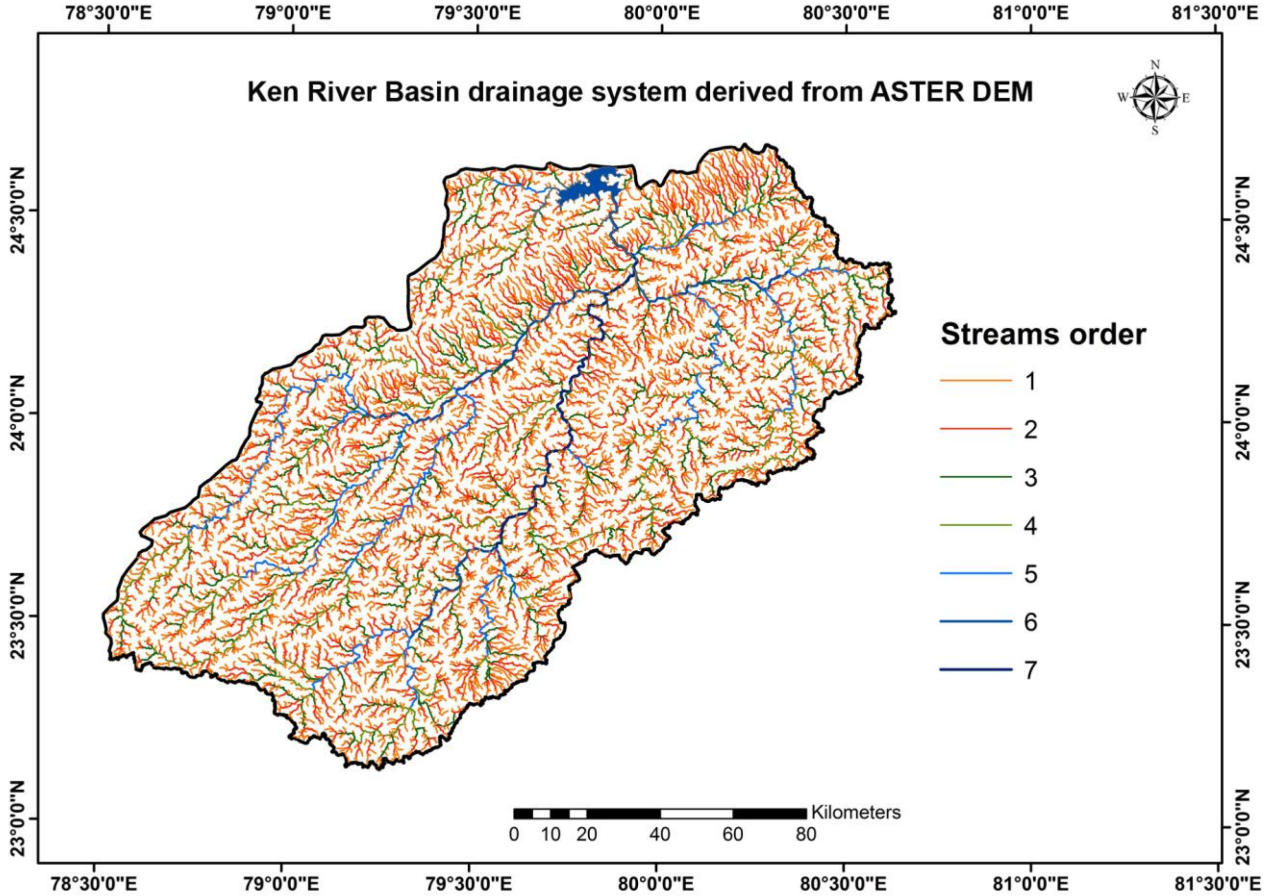

Fig. 3. Ken River Basin (upstream from the proposed dam site).

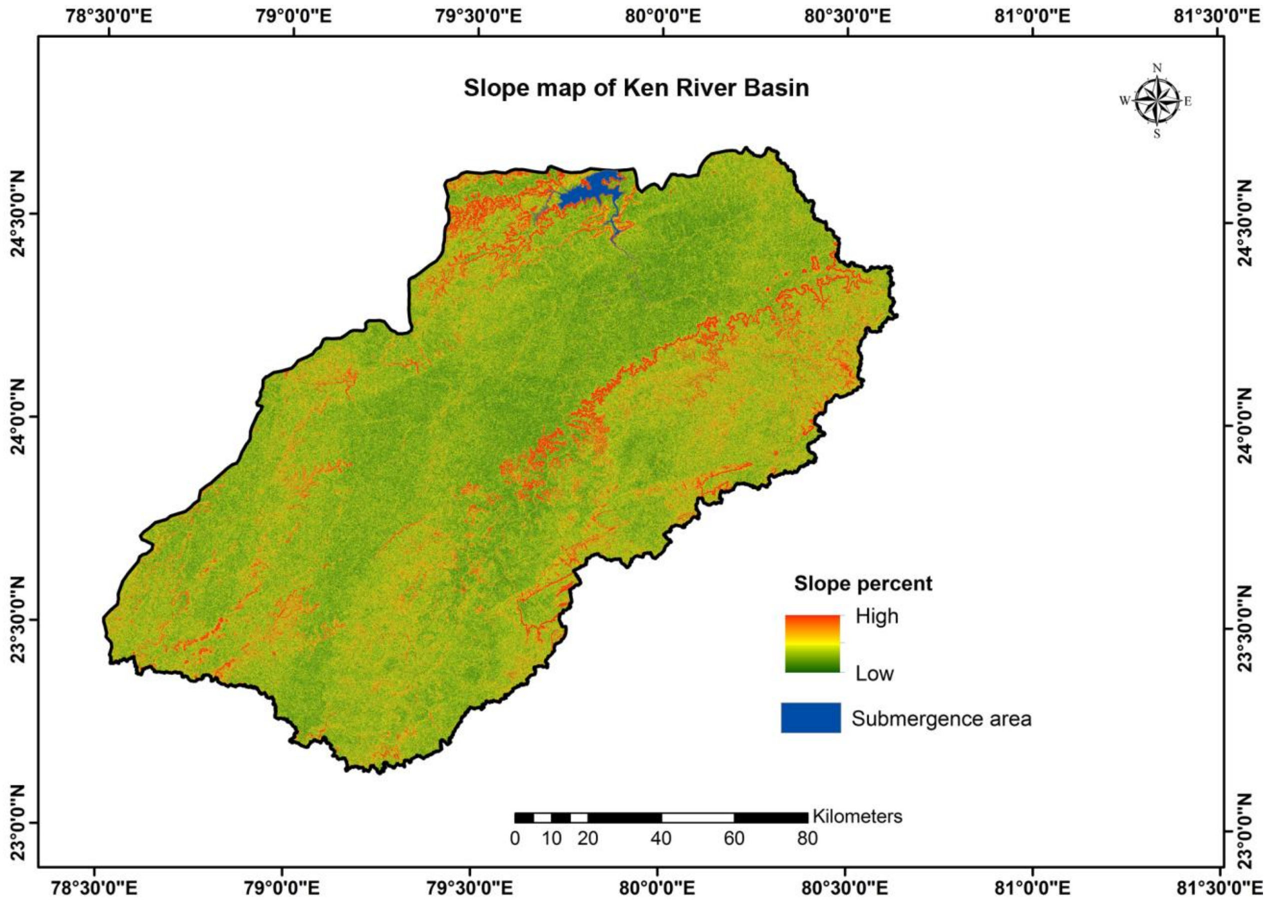

Fig. 4. Slope map of Ken River Basin (Upstream from the proposed dam site)

4.2. Image processing and classification for land use and land cover

The false colour composite of the study area was extracted from the whole scene. There are two basic types of image classification techniques used for classifying the satellite data (LILLISEND & KEIFER, 2004) which are unsupervised and supervised classification. The unsupervised classification is a technique which segregates the image or the scene into pure spectral classes. Some predefined parameters rule the statistical properties of the clusters and association among them. A comprehensive data about the spectral characteristics of the area can be derived. The analyst has the opportunity to group similar clusters into fewer classes or categories and then assign the information to each class (CIHLER ET AL., 1998).

This technique was utilized to classify the present dataset. Initially it was subjected for delineation of twenty classes (using K-means; maximum convergence 0.95). Later, they were clubbed to obtain 11 LULC classes. The classes are dense forest, medium forest, open forest, agriculture, water, degraded forest, scrub/grass, fallow, mixed fallow, fallow/degraded land, open area. Further, accuracy assessment of the classified dataset was achieved by generating 250 random sampling points and assigning them to their respective classes. Area statistics were calculated for each land use and land cover. According to ANDERSON (1976), a classified data is good enough wherein the accuracy of the class/classes interpreted from remote sensing should be a minimum of 85%. The drainage, slope and elevation were derived from ASTER DEM using Hydrology tools in Arc GIS. Fig. 3 shows the drainage of the Ken River Basin upstream from the proposed dam site and Fig. 4 shows the Ken River Basin upstream from the proposed dam site.

The EIA consultant in the EIA-EMP REPORT (2015) mentions that (pg no. 178): "This image interpretation key was developed by NRSA based on the spectral response of surface features observed on IRS (LISS-III) standard FCC with a band combination of 2, 3, and 4. This process helps to get an accurate signature of the surface or area of interest / classes. Ground truthing was done in the month of November 2009. Signature extraction is a very crucial part in image classification methods, image characteristics comprise of various elements of image interpretation such as i) tone or colour ii) size iii) shape iv) texture v) pattern vi) location vii) association viii) shadow ix) aspect x) resolution."

It is worth noting that:

- Ground truthing was done during November 2009, which means the data acquired must be of that time period but nothing specific is mentioned. It should be added that this makes the EIA ineligible for consideration for Environment Clearance, since, as per the norms of the Union Ministry of Environment and Forests, all data in EIA must be less than 3-4 years old when the project is considered for Environmental Clearance.
- No mention of classification technique and Accuracy assessment of the classified dataset.
- No False Colour Composite of the study area is enclosed, though a map of LULC in the submergence area is produced, another one with a buffer of 10 km.
- Computation of submergence area is not mentioned.

4.3. Our Computation of the Submergence area:

Using the ASTER DEM, the watershed was delineated in Arc GIS (using hydrology tools). Further, basin was also extracted. As per the requirement, an area less than <288 m would be submerged (as proposed). Utilizing the model maker, this area was extracted. It was made into a thematic class and further converted into a vector layer to derive the area statistics. A polygon representing the specific contour was used for analysis. Such polygons were developed for various contour levels to assess the FRL at various heights such as 278 m, 283 m, 289 m[i], 293 m and the area statistics were computed. The vector layer of such polygons was used to extract the land use and land cover statistics for each case.

Similarly, the vector layer (shape file) of Panna Tiger Reserve was used to extract the land use and land cover for each FRL. Volume for the reservoir was also computed (for every FRL level) in Arc GIS (3D Analyst).

5. Results and Discussion

The overall accuracy of the classified dataset is 91% and kappa statistic is 0.852. The description of the eleven classes is given in Table 2. The land use and land cover (LULC) which are going to be submerged if the Dam comes up was computed at various FRLs and tabulated (Table 3 and Fig. 5). The EIA/EMP states that the land use and land cover of the submergence area are as follows (pg no. 290) (Table 4).

Table 2. A brief description of the land use and land covers (LULCs)

S. No.	LULC Class name	Description (as visible on FCC)
1	Dense forest	Dark red in color, medium texture, contiguous patches with irregular shape. Canopy cover >70%
2	Medium Dense forest	Red in color, with little openings in the canopy, Canopy cover 50-70%; Small openings in between
3	Open forest	Canopy cover 10-20% with large openings, light red in color, along the margins of dense and medium dense forest
4	Degraded forest	Canopy cover <10%, very light red to brownish in color, outskirts of forest area
5	Scrub/grassland	Very less vegetation mainly of shrubs and small trees at large distance, less dense forest, little shade and more sunlight
6	Agriculture	Plots of specified geometrical shapes and sizes, appear pink, magenta color with smooth to medium texture
7	Water	All lakes, river and other water bodies
8	Fallow/degraded land	Fallow land and at places land in a bad condition, appears as cyan in FCC, irregular in shape
9	Fallow mixed	Fallow area along with land showing scarce vegetation
10	Open Fallow	White, greyish patches of land as visible on FCC, medium to smooth texture, irregular in shape
11	Open area	Open areas in between other land uses, appears as shiny white on FCC

Table 3. LULC of the submergence area (in ha) at different FRL (m)

S. No.	Class names	278	283	288	289	293
1	Dense forest	354.24	434.34	450.54	523.17	585.45
2	Medium dense forest	1664.28	1846.26	1970.46	2054.52	2222.19
3	Water	1359	1420.02	1442.61	1463.04	1490.67
4	Degraded forest	626.58	686.43	753.03	783.81	866.43
5	Agriculture	1123.29	1124.01	1125.18	1125.09	1126.26
6	Fallow mixed	542.88	610.74	698.04	746.46	865.44
7	Open area	207.36	217.08	222.03	229.77	236.25
8	Open forest	492.66	517.77	548.73	547.47	569.97
9	Scrub/grassland	361.71	366.21	374.49	374.04	380.61
10	Fallow/degraded land	1156.23	1258.47	1350.63	1388.07	1501.74
11	Open fallow	114.21	118.71	121.32	121.59	124.47
	Total	8280.44	8600.04	9057.06	9357.03	9969.48

Table 4. LULC of submergence area (EIA/EMP report)

S. No.	Land use	Area [ha]	% of the area
1	Built up land	89	0..99
2	Arable land	2171.24	24.12
3	Water Bodies	1571	17.46
4	Open scrub	150	1.67
5	Dense forest	590	6.56
6	Open forest	261	2.9
7	Scrub forest	4168	46.31
	Total	9000.24	100.01

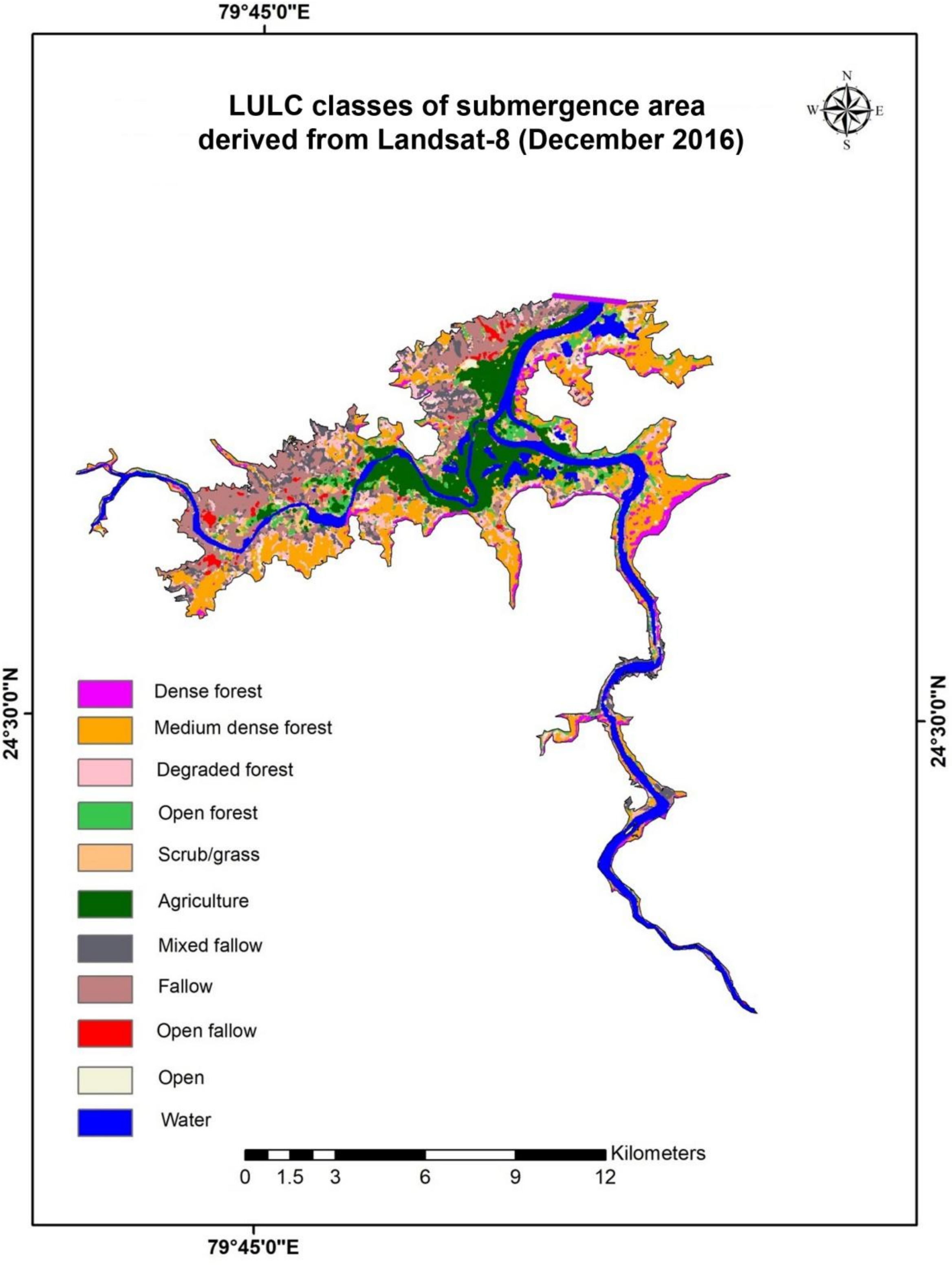

Fig. 5. LULC classes of submergence area derived from Landsat-8 image (December 2016)

Similarly the extent of Panna Tiger Reserve which would be submerged was computed at various FRLs (Table 5 and Fig. 6)[1]. To analyse the spatial view of the submergence area is a necessity before any dam is constructed (MEHMOOD ET AL., 2014). The volume of the reservoir proposed was computed at various FRL levels (Table 6).

[1] We would have liked to compare the land under various land uses, between EIA and our assessment, both for total submergence area and also for submergence area under PTR, but that is unfortunately not possible as EIA does not provide the details of various standard land use categories and have not been defined properly

Table 5. LULC of submergence area (in ha) in Panna Tiger Reserve (PTR) at various FRL (m)

S. No.	Class names	278	283	288	289	293
1	Dense forest	327.33	389.25	401.67	457.11	501.75
2	Medium dense forest	1291.14	1404.9	1493.19	1543.61	1664.37
3	Water	1052.82	1064.88	1072.26	1074.06	1077.12
4	Degraded forest	444.33	489.51	542.7	567.72	632.34
5	Agriculture	991.35	992.07	993.15	993.97	994.05
6	Fallow mixed	330.3	371.88	430.74	460.98	554.13
7	Open area	172.53	175.23	176.58	178.29	180.36
8	Open forest	360.45	380.16	407.25	407.54	424.53
9	Scrub/grassland	240.3	242.46	246.06	246.88	247.32
10	Fallow/degraded land	591.39	608.31	624.42	630.27	642.78
11	Open fallow	51.75	52.2	52.65	52.74	52.92
	Total area	5853.69	6170.85	6440.67	6613.17	6971.67

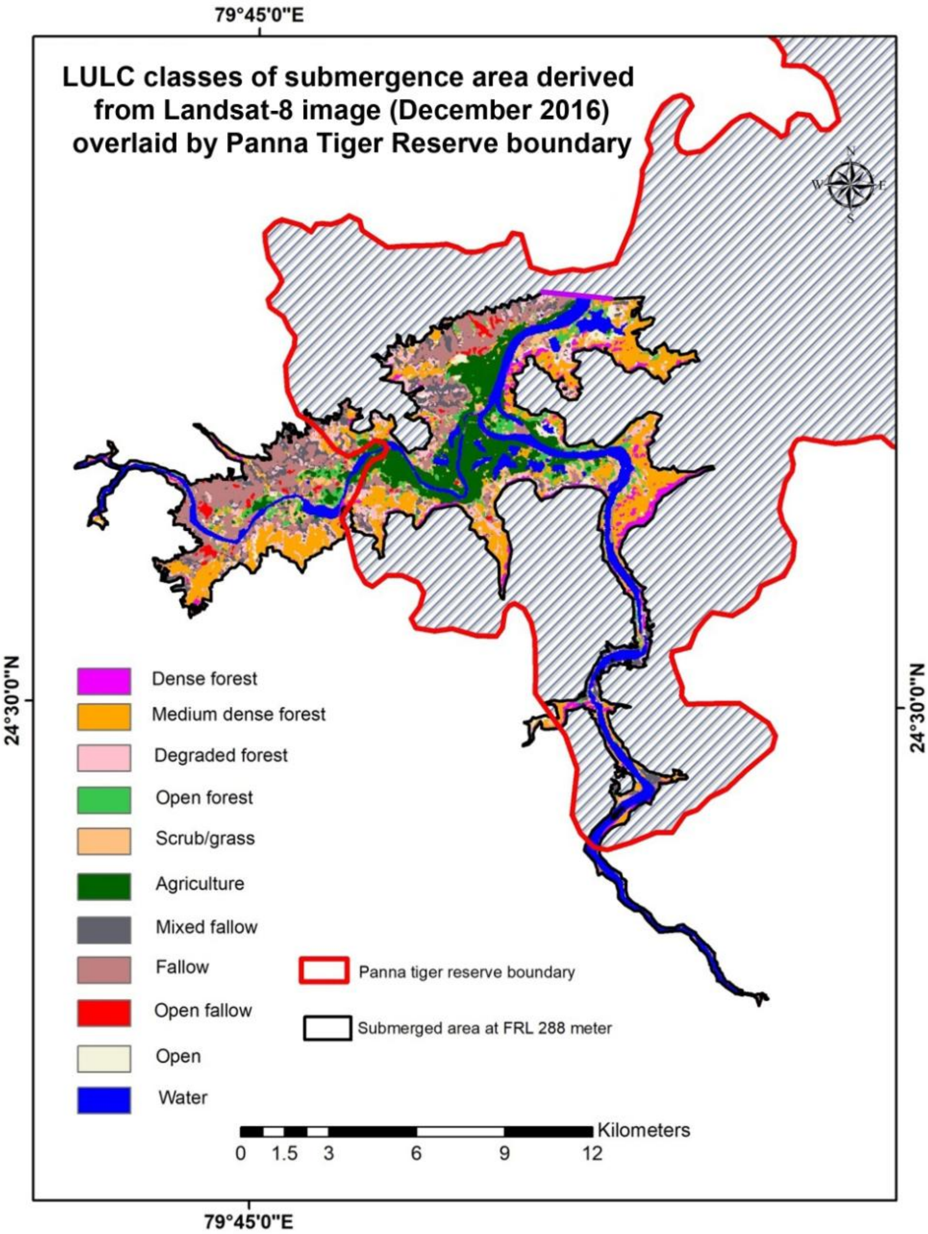

Fig. 6. LULC of submergence area in Panna Tiger Reserve

Table 6. The surface area and volume of water at different FRL levels: based on ASTER DEM and Landsat data

Height	Area (in ha)	Volume (MCM)
278 m	8002.1	2317.8
283 m	8600.0	2731.8
288 m	9057.1	3165.4
289 m	9357.0	3266.4
293 m	9969.5	3650.2

The LULC were categorized into eleven classes (as analyzed in the present case). Dense forests are around the borders of the polygon followed by medium dense forest. The central part of the polygon is an agriculture area where plots of various geometrical shapes are seen (verified from high resolution data of Google Earth).

Total submergence at proposed FRL of 288 m is 9057.06 ha as per our assessment, 57 ha above the submergence area assessed by EIA. This is not an insignificant difference.

More obvious is the difference between the area of PTR facing submergence as given in the EIA and as per our assessment. Our assessment says that the total area of PTR to face submergence at proposed FRL of 288 m is 6440.67 ha, whereas the EIA gives only one figure for this submergence of 4141 ha.

The submergence at FRL 289 m is further 300 ha (including the additional 173 ha of PTR), this area is likely to face submergence, since the EIA does not make any assessment of backwater impact, and also assumes that the Full Reservoir Level is the same as the Maximum Water Level (water level at dam site when the river is in the 1-in-100 year flood).

The streams seem to dry up in the post monsoon season after a period of a few months, but water flows through them in the monsoon and the dry river bed is full of water. (VENHF analysis shows the area under water in the submergence area as 1442.61 ha at 288FRL whereas the EIA/EMP report shows the water area to be 1571 ha).

The selection of satellite data must ensure that it is of winter months. The study area is dominated by dry deciduous species which shed their leaves with the onset of summer; hence the landscape appears barren (without vegetation during those months). In the winter season (November to February), such species have good crown cover which assists in the interpretation of forest area.

Scrub/grasslands are also a part of forest. They have scarce vegetation and less shade but have shrubs and trees with short height. They form an integral part of forests and are a home for many animal species. They cannot be ignored as they have an ecological significance.

In the study area fallow land was quite prominent. At places, they appear as shining white, termed as open fallow. Fallow mixed was found where the fallow land was mixed with other land use categories.

The gross storage capacity we have assessed is 3165.4 MCM, which is much higher than the storage capacity at FRL 288 assessed in the EIA, at 2853 MCM.

In fact, the gross storage capacity at FRL 283 m as per our assessment is 2732 MCM, which is just 4% below the current proposed gross storage capacity. So this 5 m reduction in FRL should be possible without any major impact on the storage capacity. This 5 m reduction in the current proposed FRL is what both the Forest Advisory Committee and National Board of Wildlife had suggested, but was rejected by MoWR without any independent assessment. This reduction can help save about 457 ha of total land from submergence and at least 270 ha of PTR land.

Conclusion

Geospatial technology when used properly would definitely help in studying and efficiently analyzing the impacts on the environment. The present study has aimed to address the issue of submergence in relation to the proposed Daudhan Dam in the Ken Betwa River Link Proposal. Landsat data analysis and the generation of various thematic layers have been helpful for the visualization of the study area. High resolution satellite data & fine resolution DEM would give a more detailed view. It would guide the policy makers in taking an appropriate decision which would mitigate the negative impacts and help to minimize them. When incorporated in decision making processes it would benefit the people at large by arriving at an informed and optimum decision. Regular monitoring and assessment is required before the final decision is taken. The time period that the plan was conceived and the actual execution period has been too long, in the mean time a lot of land use and land cover change has taken place.

Acknowledgements:

The authors are grateful to USGS portal for providing the LANDSAT data and the ASTER DEM for the analysis.

References

Anderson J.R., Hardy E.E., Roach J.T., Witman R.E. 1976. A land use land cover classification system for use with remote sensor data. *US Geol. Surv. Prof. Paper,* 964.

Cihlar J., Xiao Q., Chen J., Beaubien J., Fung K. And Latifovic R. 1998. Classification by progressive generalization: a new automated methodology for remote sensing multispectral data. *Int. J. Remote Sens.,* 19: 2685–2704.

Chigbu N., Onukaogu D. 2013. Role of Geospatial Technology in Environmental Sustainability in Nigeria-An Overview. An overview. In: *FIG working week 2013. Environment for sustainability.* Abuja, Nigeria.

Chowdary V.M., Desai V.R., Gupta M., Jeyaram A., Murthy YVNK. 2012. Runoff Simulation Using Distributed Hydrological Modeling Approach, Remote Sensing and GIS Techniques: A Case Study from an Indian Agricultural Watershed. *ISPRS-Int. Archiv. Photogram., Remote Sens. Spatial Inform. Sci.,* 1: 203–207.

Indian Water Resources Society (IWRS) 1996. Theme Paper on Inter-basin Transfers of Water for National Development: Problems and Perspectives. IWRS.

EIA/EMP Report. *Ken-Betwa Link project Environmental Impact Assessment and Environmental Management Plan, Final EIA and EMP report.* National Water Development Agency, (Ministry of Water Resources, River Development and Ganga Rejuvenation, Government of India). May 2015.

Krueger K., Segovia F., Toubia M. 2007. Assessment of the India River linking plan: A closer look at the Ken-Betwa pilot link. Univ. Michigan.

Lakra W.S., Sarkar U.K., Dubey V.K., Sani R., Pandey A. 2011. River inter linking in India: status, issues, prospects and implications on aquatic ecosystems and freshwater fish diversity. *Rev. Fish Biol. Fish.,* 21, 3: 463–479. DOI:10.1007/s11160-011-9199-5.

Lillisand T.M., Kiefer R.W. 2004. *Remote Sensing and image interpretation.* John Wiley, New York.

Mehmood K., Patel A., Singh V., Prajapati S., Kalubarme MH., Prakash I., Gupta KP. 2014. Submergence Analysis Using Geo-Informatics Technology for Proposed Dam Reservoirs of Par-Tapi-Narmada River Link Project, Gujarat State. *India Int. J. Geosci.,* 5: 622–633.

[i] The reason why areas were assessed at FRLs of 278 m, 283 m and 289 m is because there were proposals to reduce the dam height by 10 m and 5 m by NBWL and FAC. Similarly, earlier version of the project documents had mentioned MWL (Max Water Level, likely to be achieved when the river is in the 1-in-100 year flood) of 289 m. Additional assessment of 293 m was done for computation of possible back water impacts, which the EIA has not assessed.