Rapid Environmental Impact Assessment (EIA) using Remote Sensing and Geographic Information Systems (GIS) – A case study of River Ib Barrage, Odisha

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Rapid environmental impact assessment using remote sensing and geographic information systems: A case study of river Ib Barrage, Odisha

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Abstract: A barrage project has been proposed by Odisha State government across river Ib, downstream of the confluence of rivers Basundhara and Ib, near village Deogaon of Jharsuguda district, Odisha, India. The major objectives of the proposed project are to provide water for irrigation for approximately 800 ha, drinking water to three urban bodies, i.e., Jharsuguda, Brajrajnagar and Belpahar, and water for various industries in Jharsuguda and its periphery.

Like all water resources projects, this project also has wide-ranging impacts on the environment. The government-sponsored Environmental Impact Assessment (EIA) based on conventional ground-based methods is still in progress since 2005. The objective of this study was to conduct a rapid EIA using remote sensing and geographic information system (GIS) to demonstrate the utility of these tools in providing high-quality survey results which is not possible with conventional ground-based methods. Satellite data have been used as input parameters for demarcation of water spread and computation of barrage storage capacity, and land-use/land-cover assessment for various heights of the barrage.

The total annual water demand estimated for fulfilling the project objectives is 94.8 million m^3/y, while water availability in the river Ib catchment area is estimated to be 50 million m^3/y. Three design alternatives were evaluated and included barrage heights of 4, 5 and 6 m. The storage capacity of the barrage with a height of 6 m is close to 14 million m^3 and can satisfy only a fraction of the total annual water demand, i.e., none of the alternatives evaluated is capable of satisfying the total annual water demand of the area. A barrage height of 4.5 m was chosen after comparing the impacts for each alternative. The results of this study highlight the accuracy and effectiveness with which RS and GIS can be used to conduct a rapid EIA. Further, it is clear that alternatives to the proposed project need to be examined in greater detail with similar tools.

Keywords: Ib Barrage project, Environmental Impact Assessment (EIA), Remote Sensing, Geographical Information System.

1.Introduction

MAll water resources projects tend to have wide-ranging impacts on the environment and most require environmental clearance from State or Central governments and financial agencies. Any environmental impact assessment (EIA) requires collection of large amounts of baseline data that can then be used to predict future impacts of the proposed project and to evaluate different design alternatives. Conventional ground-based surveys and methodologies result in inordinate delays in getting environmental clearances and often, lead to political interference and social disturbance. Remote sensing and geographical information systems (GIS) are tools that are available for the collection of baseline data that are both, coincident and synoptic, i.e., these tools provide simultaneous coverage of large areas at the same time. They can be used to conduct rapid EIAs in a timely and cost-effective manner while providing high-quality data that can be used for formulating and implementing appropriate environmental management plans.

Remote sensing and GIS

Remote sensing (RS), according to Campbell (1987), is the science of deriving information about the earth's resources from images acquired from a distance. It relies upon measurement of electromagnetic energy, reflected or emitted from features of interest. RS data are usually obtained from sensors on-board remote platforms such as satellites and aircrafts.

Remote sensing data can be used to identify and isolate regional to sub-regional objects/factors of significance for an EIA in a timely and cost-effective manner. For example, satellite images integrated with GIS can provide accurate land use/land cover information for large areas and over varying periods of time. Depending on the remote sensing sensors used, map-like images can be generated that integrate information regarding various aspects of the environment, including land use, vegetation cover, water temperature, and air pollution.

Major advantages of remote sensing surveys compared to ground-based surveys are:

- It facilitates the study of various features of the earth surface in their spatial relation to each other and helps to delineate required features and phenomena.
- It makes it possible to gather information about inaccessible areas where it is not possible to gather

information through ground surveys.

- These techniques save cost, time and effort as information about large areas can be gathered quickly and repetitively unlike even the most extensive ground surveys.
- Remote sensing data are useful to all earth science-based disciplines such as geology, fisheries, forestry, land use, environmental science, agriculture, water resources, meteorology, etc.

RS data have been used as input parameters for various models such as ArcGIS and ERDAS IMAGINE software for demarcation of water spread and computation of storage capacity (Xia et al., 1983, Vibulsreth et al., 1988, Manavalan et al., 1993, Raichur et al., 1993) and land-use/land-cover assessment (Apan, 1996).

GIS and Environmental Impacts Assessments

GIS is a rapidly developing tool with a range of applications. GIS is defined as a computer database system capable of assembling, storing, manipulating, and displaying geographically referenced information. The power of GIS lies in its tremendous clarity of presentation and analysis. It has the ability to take scattered, confusing data and to represent its spatial relationships in such a way that researchers can realize new levels of understanding.

RS and GIS together provide a systematic, integrated approach for the collection of baseline environmental information which lies at the heart of a good EIA. Other advantages of this approach include data accessibility, compatibility and comparability with other practitioners, low cost analytical tools for diverse applications, easy to update, and produce high quality documents like photos, and maps. GIS tools provide valuable information to complement traditional ground-based environmental assessment and monitoring sources by allowing digital-image processing, spatial analysis and field validation.

The proposed project

River Ib is a major, rain-fed tributary of River Mahanadi. It has its source in the state of Chhattisgarh and a total length of 251 km. The upper portion of the river lies in Chhattisgarh and Jharkhand and lower portion in Odisha. Most of this river flows through the state of Odisha.

A barrage project was proposed in 2005 on River Ib in the Jharsuguda district by the Government of Odisha. The barrage site is located across river Ib, downstream of the confluence of Rivers Basundhara and Ib, near village Deogaon of Jharsuguda district in the state of Odisha. The major objectives of the proposed project are to provide water for irrigation for approximately 800 ha, drinking water to three urban bodies, i.e., Jharsuguda, Brajrajnagar and Belpahar, and water for various industries in Jharsuguda and its periphery. The Govt. of Odisha commissioned an EIA for this project in 2005 which is still in progress. An interim state government report serves as the only source of data regarding the proposed project (Ib Investigation Division, Sundargarh, Odisha, 2007).

The main objective of this study was to conduct a rapid Environmental Impact Assessment for the proposed River Ib barrage project based on remote sensing data and GIS. Assessment of various design alternatives for the barrage project is required as part of any EIA. Since one of the important design parameters for the proposed project is the height of the barrage, the environmental impacts of varying the height of the barrage were assessed using Micro Digital Elevation Model (Micro-DEM) model. Major categories of impacts evaluated were changes in land use/ land cover, area and nature of submerged land, storage capacity of the barrage, and water supply for the command area.

2. Methodology

The objective of this study was to conduct an EIA for a small water resources project based on RS and GIS data. A brief description of the general procedure for conducting an EIA is provided here.

The EIA process and use of RS and GIS

Generally, the stages of an EIA process depend upon the requirements of the country or donor agency. However, almost all EIA processes have a common structure and maintaining this structure is a basic standard of good practice. An EIA consists of eight steps with each step equally important in determining the overall outcomes of the project. Typically, the EIA process begins with screening to ensure that time and resources are directed only at those proposals that affect the environment and ends with some form of follow-up on the implementation of decisions and actions taken as a result of an EIA report. The eight steps of the EIA process are described in brief below:

1. **Screening:** Step one of an EIA, where it is determined whether the proposed project requires an EIA and if it does, then the level of assessment required.
2. **Scoping:** Step two of an EIA is scoping where key issues and impacts are identified for further investigation. This stage also defines the boundary and time limits of the study.
3. **Impact analysis:** Step three of an EIA is impact analysis where likely environmental and social impacts of the proposed project are identified and their significance evaluated. Design alternatives are proposed and compared for their impacts so that the best alternative can be implemented. In general, the alternative with least cost and highest benefit is chosen.
4. **Mitigation:** Step four of an EIA is impact mitigation where actions to reduce or avoid potential adverse environmental consequences of development activities of the chosen design alternative are recommended.

5. **Reporting:** Step five of an EIA is reporting where the results of an EIA are presented in the form of a report to the decision-making body and other interested parties.

6. **Review of EIA:** Step six of an EIA is review where the adequacy and effectiveness of the EIA report is examined and information necessary for decision-making is provided.

7. **Decision-making:** Step seven of an EIA is decision-making where the decision to reject, approve or modify the proposed project is made.

8. **Post-monitoring:** The last step in the EIA process is post-monitoring which is carried out once the project is commissioned. Project impacts are checked to ensure that they do not exceed legal standards and implementation of mitigation measures is in the manner described in the EIA report.

For obvious reasons, the scope of the rapid EIA described in this paper is limited to steps 1 to 5.

Data collection and analysis

An EIA requires comprehensive baseline data for the area that is likely to be impacted. All data regarding the study area were obtained from Ib Investigation Division, Sundargarh, Department of Water Resources, Govt. of Odisha, unless stated otherwise. Remote Sensing data were collected from various sources on the Internet, and Census of India data from the Registrar General of India.

Population data used in this study are based on Census of India 2001 (Registrar General of India, 2001).

Geomorphological data: Elevation data were required for watershed delineation, marking river cross–sections, submerged areas, etc. These data can be freely downloaded from the Internet in the form of Digital Elevation Model (DEM) from http://srtm.csi.cgiar.org/. The downloaded DEM file of the study area was processed in Arc-GIS and Soil and Water Assessment Tool (SWAT) was used to delineate the basin boundary, sub-basins or watersheds and drainage networks.

To extract geomorphologic input parameters of the basin, SRTM (Shuttle Radar Topography Mission) data of 90 m x 90 m resolution was used. SRTM data sets provide terrain information which can be used for handling regional environmental problems, and can be applied in river network and terrain analyses.

Land-use\ land-cover data for the study area were available in the form of Landsat Enhanced Thematic Mapper (ETM) images which can be freely downloaded from Global Land Cover Facility (GLCF: http://www.glcf.umd.edu/index.shtml). The land use/ land cover map of the entire study area and catchment area were derived from Landsat ETM images using ERDAS IMAGINE software.

Hydrological data: Rainfall and temperature data were collected from India Meterological Department (IMD) website for Jharsuguda. Evaporation data for the region are available in CWC reports (2006).

Yield data: CWC has collected flow data at Sundargarh (north of Jharsuguda on the River Ib) for the period 1987-88 to 2007-08 (CWC, 2009). Department of Water Resources (DOWR), Government of Odisha is also gauging the flow in river Ib near village Deogaon, Jharsuguda and data have been collected for the period 1985 to 2010 (Ib Investigation Division, 2007).

Calculation of submerged area and storage volume: Digital Elevation Model of the study area was used in MicroDEM and ArcGIS software for different heights of the barrage. Model outputs allow calculation of storage volume and submerged area and corresponding changes in land use/land cover.

3. Description of study area

Ib River basin

River Ib is the third largest tributary of River Mahanadi. It rises in the hills near Pandrapat at an elevation of 762 m in Raigarh district of Chhattisgarh. The total river length is 251 km and some of Ib's major tributaries are Bandajore, Ichhanalla, Sapai, Basundhara and Bheden. Ib River falls into Hirakud reservoir from the left bank of River Mahanadi.

The upper portion of River Ib lies in Chhatisgarh and Jharkhand and the lower portion lies in Odisha. The sub-basin in Odisha lies between 83°33'38" E to 84°47'29" E longitudes and 21°25'54" N to 22°31'46" N latitudes. The total catchment area of River Ib was found to be 8492 km^2 and is shown in Figure 1.

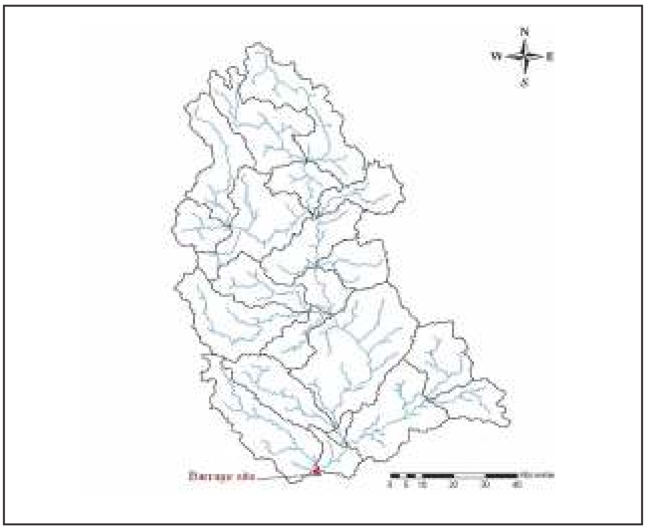

Figure 1: Ib river basin with its sub-basins and flow lines

Topography: The topography of the project site is almost plain with gently sloping, slanting hills, dwarf hills and small hillocks. In fact, several seasonal streams such as Saraswati nalla, Ichha nalla, Bheden, Basundhara, Sapai nallas fall into river Ib, upstream of the proposed project site. In general, there is always some flow in river Ib throughout the year. However, flow during the summer months can go down to zero during drought years. Standing water remains available in several deep gorge portions in river Ib.

The maximum elevation at the upstream end and minimum elevation at the downstream end of the basin were found to be 1157 m and 157 m, respectively as shown in Figure 2.

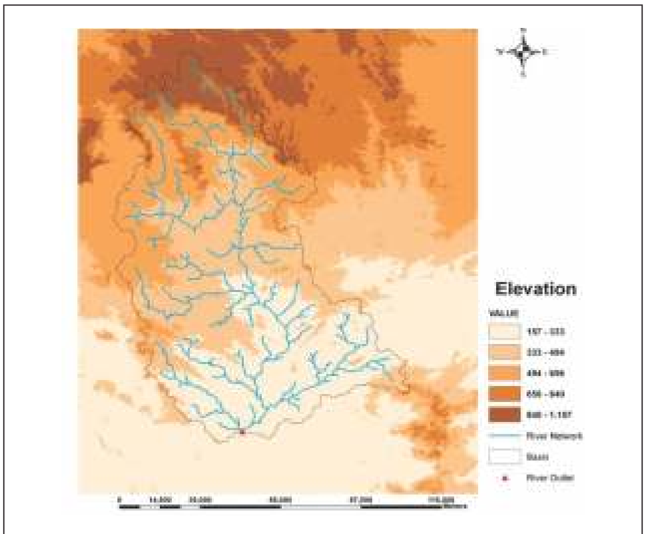

Figure 2: Elevation contours of catchment area

Land use/ land cover classification

The land use and land cover statistics of the entire study area were derived from Landsat ETM remote sensing images and show that almost 46.5% of the catchment area, i.e., the study area, is occupied by cultivated land (Figure 3). Cropping activity is seen throughout the year on these lands. There are two main cropping seasons in this region: Kharif from June to September/October and Rabi from October to February.

Vegetation (forests, trees and shrubs) covers 46% of the total catchment area. Settlement area covers about 5% of the study area. In the catchment area, most of the land is agricultural land and vegetation covers 395000 ha and 390100 ha, respectively as shown in Figure 4. Water bodies are areas of impounded water and generally include the river bed with water coverage. Barren lands include the dry river bed, i.e., sand, and degraded land which can be brought under vegetation cover with some effort.

Soil: Broadly, the soil of the basin area is classified as transported soil and residual soil on the basis of its formation. Transported soil is an admixture of eroded materials and is heterogeneous in nature. Different agents of erosion mainly wear out residual soils. The primary factors responsible for soil pattern in the area appear to be parent materials, relief and climate. Influence of biotic factors is secondary. The topsoil is mainly lateritic alluvial soil with an admixture of stone.

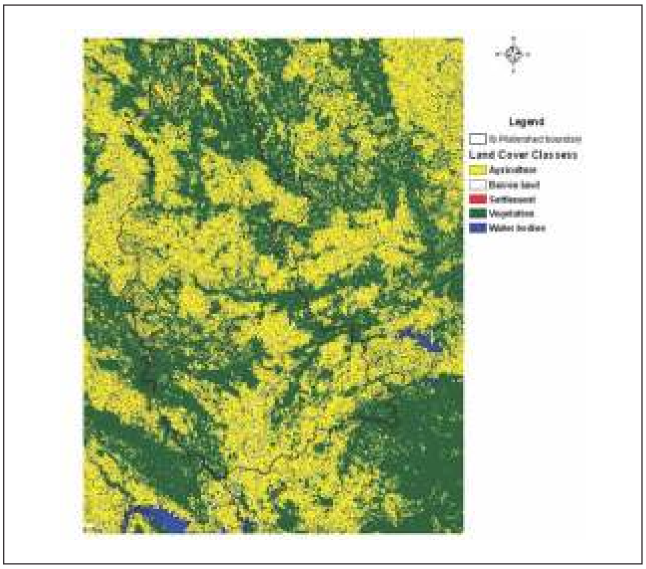

Figure 3: Land use/ land cover classification of study area

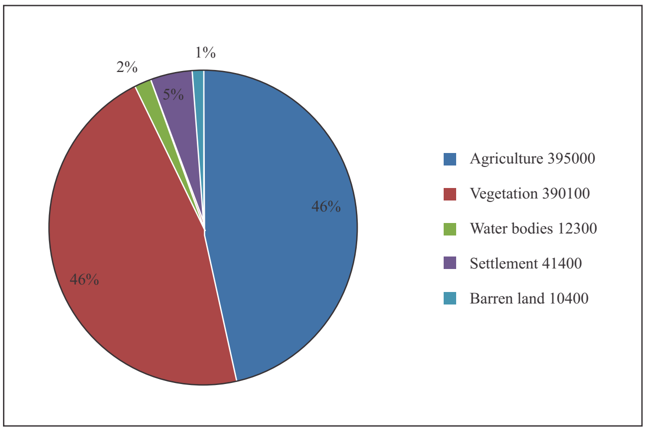

Figure 4: Land use/ land cover in the catchment area in hectares

Climate: The climate is characterized as tropical with hot summers and mild winters. Rainfall occurs mainly during the monsoon stretching between mid-June to September. The climate of the entire basin is 'tropical monsoon type' with four distinct seasons: Summer from March to May, Monsoon from June to September, Post-monsoon from October to November, and Winter from December to February.

Rainfall: The distribution of rainfall is not uniform throughout the year. Most of the precipitation falls in the 3 months of monsoon while the remaining 9 months are relatively dry. The annual average rainfall based on India Meteorological Department data for Jharsuguda from 1984 to 2000 was 1345 mm/year (IMD, 2012).

Temperature: The area lies in the tropical climate zone. The average maximum temperature in summer ranges from 33 ºC to 44 ºC and in winter, the average minimum temperature ranges from 9.3 ºC to 13.5 ºC (IMD, 2012).

Evaporation: The average annual rate of evaporation in this region is 144.4 mm/month amounting to 1733 mm/year (CWC, 2006).

Figure 5 shows rainfall and evaporation data along with water yields per month. The water yield is calculated based on 'rainfall minus evaporation' (USGS, 2012) and does not include transpiration and infiltration losses. These data demonstrate that there is a net water deficit throughout the year except during the 3-month monsoon season if groundwater and stream flow inputs are not included. Further, it is important to note that the monsoon surplus is subject to severe evaporation losses during the remaining part of the year. This is a very serious problem for water resource projects where water storage and supply are the main objectives (CWC, 2006).

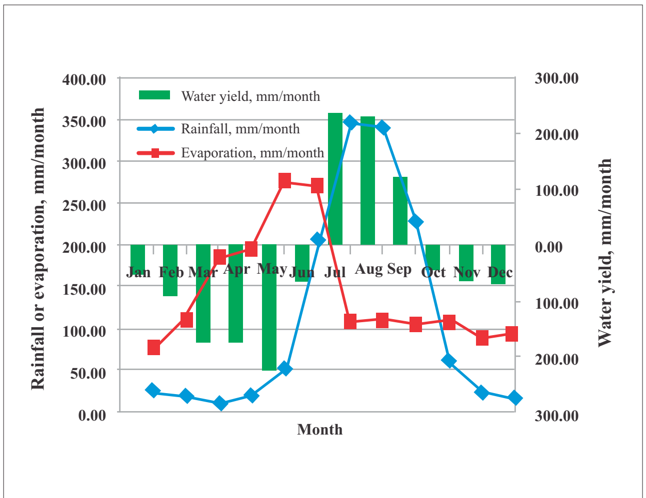

Figure 5: Water yield, rainfall and evaporation data for Jharsuguda (averaged from 1984 to 2000). Based on IMD data, 2012

Based on Figure 5, it is clear that water from precipitation and surface runoff will reach the stream only during the monsoon months. No runoff is likely to make it to the streams and rivers during the rest of the year due to high evaporation and infiltration losses. If precipitation for the 3 monsoon months is assumed to be available for augmenting stream flow then the total amount of precipitation available is 915 mm (monsoon period only). Deducting evaporation losses during this period results in a net water yield of 593 mm/y at the end of the monsoon period. If runoff efficiency during the monsoon period is assumed to be 1 % for large catchment areas (FAO, 2012), then the water flowing from the catchment area of 8492 km^2 to river Ib is estimated to be 50 x 10^6 m^3/y. This is subject to further evaporation and infiltration losses during the remaining part of the year and are not accounted for here.

Flow conditions and water availability: Pertinent data for Sundargarh for a reporting period from 1976 to 2007 show that minimum water levels and discharge in river Ib were 214 m (above MSL) and 0 cumecs, respectively (CWC, 2009). Maximum water levels and the corresponding discharge during the same period were 222.6 m (above MSL) and 6341 cumecs, respectively. Maximum observed discharge at the site was 10404 cumecs. Further, the annual 100% dependable flow is 0 MCM/y while the 90% and 10% annual dependable flows are 1808 and 4320 MCM/y (CWC, 2009) which amounts to 57 cumecs and 137 cumecs (1 cumec = 35.31 cusec).

Flood data: The maximum flood discharge of the project site is calculated using Dickens formula assuming the value of Dicken's constant as 20. For a catchment area of 8492 km^2, the flood discharge comes to 17,692.42 cusecs or 501 cumecs.

Population and water demand

Urban water demand: Quantum of drinking water required for the three urban areas of Jharsuguda, Brajrajnagar, and Belpahar can be assessed for a population projected up to year 2031. Population of three Urban Local Bodies (ULBs) as per 2001 Census is 1,85,885. The projected population of the three urban areas is computed using the Geometrical increase method assuming a 3% annual growth rate for urban areas.

$$P_n = (1+r/100)^n \times P_0$$

where, P_n = Future population at the end of 'n' years,

P_0 = Population of the base year

r = Annual average growth rate, n = number of years

Substituting these values in the above equation results in population estimates (rounded off) for subsequent decades:

P11 = 2,50,000

P21 = 3,36,000

P31 = 4,51,000

Indian standards (IS1172:1993) require that a minimum of 135 Litres per Capita per Day (LPCD) is to be provided in urban areas. Based on this water requirement and for the population in 2031, the total annual water demand is estimated to be 22.2 million m^3/y.

Industrial water demand: Besides the above urban water demand, demand from one large industry in this area - Mahanadi Coal India Limited (MCL) has been taken into consideration in computing total domestic water demand (Table 1).

Irrigation water demand: Annual irrigation requirement for 800 ha command area is estimated to be about 6900 ha-m (69 x 106 m^3/y) assuming rice as the maximum water requiring crop with 90 % and 40 % cropping intensity in Kharif and Rabi season. Therefore, the total annual water demand in the study area is estimated to be 94.8 million m^3/year.

Table 1: Domestic, industrial and irrigation water demand in the command area

Sl. No.	Water requirement	Quantum of water in 10^6 m^3/y
1	Urban Local Bodies of Jharsuguda, Brajrajnagar, Belpahar	22.2
2	Mahanadi Coal Limited, Ib valley area	3.6
3	Irrigation requirement for two crops/year	69
Total		**94.8**

4. Impact assessment

Screening: Indian regulations (MoEF, 2012) do not require an EIA for a project of this magnitude. However, the State Government and financial (lending) agencies often require an EIA prior to giving environmental clearance to projects that have wide-ranging environmental and socio-political impacts.

Scoping: Major issues in the proposed project are water availability, submergence of land and its associated impacts on land use/ land cover, and rehabilitation of displaced people. Since all these issues are related to the height of the barrage, 3 design alternatives were evaluated as part of this EIA.

Impact analysis: The proposed height of the barrage is 5 m and other design alternatives were evaluated for their impact on key environmental issues like land use/cover, submergence of land, and displacement of people.

Description of project alternatives

In this study, project alternatives were evaluated in terms of various heights of the barrage as the location is ideal for building a barrage (below the confluence of Basundhara and Ib River to acquire maximum river flow). Five different barrage heights (pond water level) were assumed for calculating the area submerged and storage volume; these heights were 2, 3, 4, 5 and 6 m at 197, 198, 199, 200 and 201 m elevation, respectively above M.S.L. The average river bed level is estimated to be 195 m above M.S.L.

The storage volume was calculated along with the submerged land area for the different barrage heights on the river Ib using Micro-DEM model and the results are shown in Figure 6. A linear relationship was found between barrage height and submerged land and storage volume of the barrage. While increasing the height of the barrage will result in higher storage volume, it will also lead to greater submergence of useful land areas including agricultural lands, settlements, and forest areas which is a major adverse impact of any water resource project. Losses of water bodies and barren land are not considered significant adverse impacts here.

Almost all the submerged areas lie within the river banks for barrage heights of 2 m and 3 m. However, storage volumes associated with these heights are 153.6 and 345.6 ha-m, respectively and will not satisfy the total annual water demand. Therefore, only the remaining three options were considered as project alternatives for this rapid EIA. Barrage height of 4 m at 199 m elevation was named Alternative 1, 5 m barrage height at 200 m elevation and 6 m barrage height at 201 m elevation were named Alternative 2 and Alternative 3, respectively.

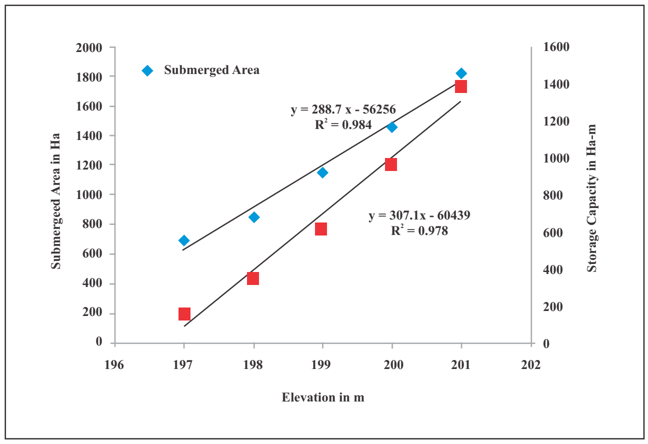

Figure 6: Calculated storage volume and the submerged land area at different barrage heights

Alternative 1: For alternative 1, i.e., at 4 m barrage height (199 m elev.), different classes of land use/ land cover under submergence and their percentages are shown in Table 2. Useful land, i.e., agriculture fields of 528.5 ha, 63.09 ha of vegetation cover including trees, shrubs and forests and 36.63 ha of settlement areas will be submerged. Water bodies of 120.06 ha area lie mostly within the river stream or bed and comprise 11% of the total submerged land, while barren land

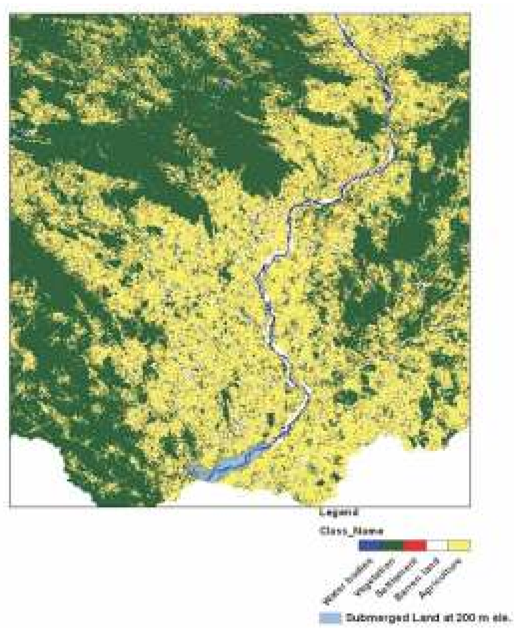

Figure 7: Submergence at 200 m elevation (5 m barrage height) over study area

Table 2: Distribution of submerged areas by land use for different barrage heights

Elevation (m)	198		199		200		201	
Agriculture	311.13	36.66	528.53	46.91	786.83	54.12	956.25	52.44
Vegetation	29.7	3.50	63.09	5.60	85.33	5.87	148.68	8.15
Settlement	18.9	2.23	36.63	3.25	46.26	3.18	69.57	3.82
Total useful land	**359.73**	**42.38**	**628.25**	**55.76**	**918.42**	**63.17**	**1174.50**	**64.41**
Water bodies	115.83	13.65	120.06	10.66	130.68	8.99	168.75	9.25
Barren land	373.23	43.97	378.43	33.59	404.82	27.84	480.15	26.33
Grand total	**848.79**		**1126.74**		**1453.92**		**1823.40**	

of about 378.43 ha area will be fully submerged. Barren land constitutes 33% of the total submerged land. At this height, storage capacity of the reservoir is estimated to be about 614 ha-m, which is only 6.5% of the total annual water demand.

Alternative 2: At 5 m barrage height (200 m elev.) storage capacity of the reservoir is about 960 ha-m and is approximately 10% of the total annual water demand. More land area is submerged at 5 m height of barrage and the distribution is shown in Table 2. Submerged agricultural fields will be 786.83 ha, vegetation cover will be 85.33 ha, and about 36.63 ha of settlement areas are coming under submergence. Water bodies of 130.68 ha which lie mostly within the stream bed and about 404.82 ha of barren land are going to be submerged. The submerged area is shown in blue at the bottom of Figure 7 for a barrage height of 5 m.

Alternative 3: At 6 m height of barrage, storage capacity of the reservoir is about 1382 ha-m, which can satisfy about 14.6% of the total annual water demand. However, it involves submergence of much more land compared to the other alternatives. 956 ha of agricultural land, 148.68 ha of vegetation (trees and shrubs), settlement areas of 69.57 ha and 480.15 ha barren lands and 168.75 ha water bodies will be submerged (Table 2).

Design alternative chosen

Water availability and area submerged: The best alternative was chosen based on its ability to fulfill water demand with the least adverse impacts on the environment. The most significant adverse impact is loss of useful land due to submergence. As storage volume increases, there is a proportionate increase in loss of useful land as shown in Figure 8.

For alternatives 2 and 3 with barrage heights of 200 and 201 m, respectively, the areas of submerged useful lands are 1174.5 ha and 918.4 ha, respectively. These areas are higher than the land area that is to be irrigated, i.e., 800 ha and therefore, not justifiable options. Alternative 1 will result in the submergence of 628 ha of useful land and will satisfy only 6.5% of the total annual water demand. Based on the model simulations, a more reasonable alternative to the proposed height of 200 m is a barrage height of 199.5 m which will satisfy about 8.25% of the total annual water demand, and lead to the submergence of approximately 770 ha of useful land. Both, Government land as well as private land will be submerged. Loss of useful land and revenue from it is highest at a height of 201 m. It was estimated that a total of 12 villages will be affected fully or partially for a barrage height of 200 m and will have to be rehabilitated.

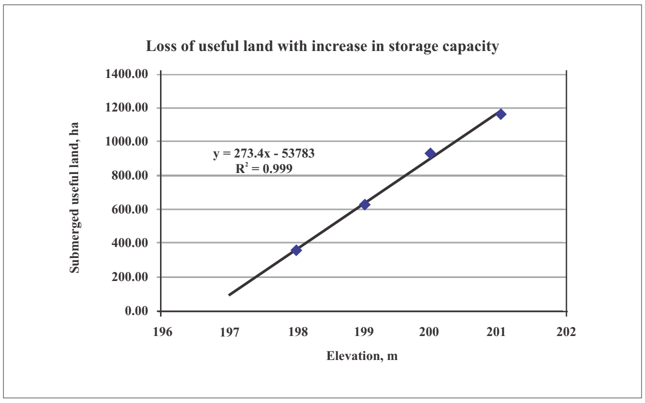

Figure 8: Useful land submerged with increase in height of barrage

Impact on flora and fauna: Agricultural land and some vegetated areas can be observed on both sides of the river bank. However, no dense forests are observable in the RS images. Further, no major wildlife species are reported in the project area. So the area proposed to be acquired for this project does not represent a good habitat for wildlife. No sanctuary is likely to be acquired as a result of reservoir submergence and other project-related impacts.

Cost-benefit analysis

Cost of constructing the project: The cost of the project is computed based on expenditure incurred on Naraj barrage project which has a length of 900 m and 32 m height across river Kathajori in Odisha. This project was completed in

2001. Approximate expenditure for civil works only was 1490 crores and the project estimate was prepared on the basis of "Guidelines for preparation of cost estimates for River Valley projects" published by Central Water Commission, New Delhi (WAPCOS, 2012). Assuming price escalation as 10%, expenditure for present barrage of 630 m length and 5 m height is estimated as approximately 180 crores.

Benefits from the project: The benefits of this project can be realized in many ways. For example, benefits in terms of increased production of paddy, selling at a rate 20,000 rupees per metric ton (MT), benefits from meeting industrial water supply which fetches higher revenue, and benefits from satisfying urban domestic water supply requirements. The rice yield per hectare is estimated to be 1.4 MT/ha-season in Odisha and additional rice production by irrigating 800 ha is calculated to be 1120 MT/season. Since irrigation will allow two paddy crops per year, the total additional rice production is estimated to be 2240 MT/y which at a minimum selling price of ₹ 20,000 amounts to ₹ 4.48 Crores/y. If the design period of the barrage is 50 years, the total benefit from irrigation alone amounts to ₹ 224 crores. Additional benefits will accrue from industrial production which cannot be quantified at this time. Further, essential requirements of water for domestic use in urban areas cannot be quantified in financial terms.

5. Mitigation measures

Mitigation measures can be proposed to address some of the major adverse impacts of the proposed project.

1. Submergence of land: Some loss of agricultural and vegetated land is likely if the proposed project is implemented. Reforestation programs in the areas away from the submerged land should be undertaken to maintain forest cover. Farmers losing agricultural land will have to be compensated by land-for-land or cash compensation.

2. Rehabilitation of displaced people: Based on the ownership and use of land (residential or agricultural) being acquired, appropriate compensatory measures can be recommended. Guidelines issued by the Central or State Governments from time to time should be followed while undertaking rehabilitation and resettlement measures. Appropriate cash compensation or land-for-land alternatives need to be examined in detail with adequate social surveys for mitigation of this problem.

3. Only partial fulfillment of water demand: The largest fraction of the total annual water demand arises from irrigation followed by the urban demand for water.

    a. Irrigation requirements can be reduced by planting less water-intensive crops instead of rice.

    b. Urban water demand can be reduced by implementing water conservation policies and/or augmenting water requirements by developing groundwater sources.

    c. Evaporation and infiltration losses throughout the year result in a very high net water deficit in the catchment area especially in the non-monsoon periods. Alternatives to the proposed project that will minimize evaporation and infiltration losses need to be examined in greater detail and include:

        i. Building a network of numerous large underground tanks within the catchment area for intercepting rainwater for irrigation and drinking water requirements.

        ii. Examine the presence of traditional ponds and tanks in the catchment area which have served as long-term water supply sources and may need repair or augmentation for their continuance.

6. Conclusions

A barrage was proposed by Govt. of Odisha across the river Ib in 2005. One of the major design parameters is height of the barrage which determines the area submerged as well as the storage capacity of the barrage. RS and GIS were used along with a Micro-Digital Elevation Model (DEM) to calculate storage capacity and area of submergence for different heights of the barrage. Three alternatives for design height (4 m, 5 m and 6 m) of the barrage were evaluated.

As barrage height increases, so does storage volume resulting in a proportionate increase in loss of useful land due to submergence. None of the three barrage heights (4, 5 and 6 m) examined is capable of satisfying the total annual water demand of 94.5 million m^3/y in the study area. A height of 4 m, leads to submergence of 628 ha and satisfies only 6.5% of the annual water demand. Heights of 5 and 6 m will satisfy 10 and 14.6% of the annual water demand, respectively. However, these alternatives are not justifiable since the area submerged (useful land lost) is greater than the area to be irrigated. Based on simulations, a more reasonable alternative to the proposed height of 5 m is a barrage height of 4.5 m which will satisfy about 8.25% of the total annual water demand, and lead to the submergence of approximately 770 ha of useful land. These results highlight the rapidity, accuracy and effectiveness with which RS and GIS can be used to conduct a rapid EIA. Various mitigation measures have been suggested for the proposed project. However, our results indicate that alternatives to this project for satisfying the year-long water demand need to be examined in greater detail. Tank and pond irrigation which are traditional practices need to be continued with some modifications where necessary. Since evaporation losses in this region are excessive and result in a net annual water deficit, building a network of numerous large underground tanks may be a viable and more effective option for meeting the growing water demand of this region and should be examined in greater detail.

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