Journal of Geology and Mining Research Vol. 4(4), pp. 75-85, May 2012
Available online at http://www.academicjournals.org/JGMR
DOI: 10.5897/JGMR11.045
ISSN 2006-9766 ©2012 Academic Journals

Full Length Research Paper

Geological and environmental issues of the proposed link canal (Inchampalli to Nagarjunasagar) of Godavari to Krishna Rivers adopting remote sensing and geographical information system (GIS)

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Accepted 8 March, 2012

Extremely erratic rainfall, unevenly distributed and very heavy precipitation in short time resulting in flash floods and inundation in India became a usual phenomena in recent years. At every event, a huge quantity of water is being wasted into the sea as run-off quite frequently due to inadequate harvesting structures. This huge run-off / surplus water can be harvested through the proposed linking of river basins envisaged by National Water Development Agency (NWDA). Out of the total mega projects, the NWDA suggested three link canals from Godvari to Krishna basin, to harvest the surplus water as well as to transfer flood water from Godavari. The Godavari (Inchampalli) - Krishna (Nagarjunasagar) link canal and its possible impact on the socio-economic and infrastructural forms the present study. The link canal of length 299 km (including a tunnel of 9.150 km) is proposed in the upper reaches connecting Godavari and Krishna basins succeeded by two other links towards their downstream. It takes off from the foreshore of the Inchampalli reservoir and joins the existing Nagarjunasagar via Musi reservoir. IRS-1D, LISS-III data is analysed for morphological, geological and land use/land cover information. Geology, geomorphology and soil base maps were obtained and updated with remote sensing data and their aerial distribution in the study area was discussed. The study includes 10 km buffer area on either side of the alignment and the proposed canal command area (5157.48 Sq km) spread in Warangal and Nalgonda districts. The canal command area is occupied by dry land and wasteland classes. Pediplain weathered is the main landform that occupied major part of the study area. The study area in Warangal district is mostly occupied by unclassified crystalline rocks of Archean age. Fine to medium grained, granite gneisses and migmatities of older metamorphics from chainage 102 km to the end point of the canal. Deep loamy soil, deep clayey soil, deep clayey calcareous soil and gravelly clay soils are dominant in the canal study area. Clayey and loamy soils are suitable for wet / dry crops and gravely calcareous for plantations and dry crops. The study revealed that 23 villages are to be rehabilitated while executing the canal and about 816 villages would benefit from it by way of drinking water / groundwater in addition to crop requirements.

Key words: Link canal, donor basin, command area, geomorphology.

INTRODUCTION

Our planet is facing a water crisis in public health: more than a billion people in developing nations lack access to safe drinking water, and more than 2 billion lack proper sanitation. And in the near future, water shortages are likely to spread into other key sectors — notably agriculture and energy (Nature, 2008). The resulting pressures on water supplies are unrelenting. Global energy demand is projected to increase 57% by 2030, and water demand for food production might easily double.

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Unless policy-makers want water resources to be constantly squabbled and fought over, with farmers pitted against city dwellers, upstream users against downstream users, and region against region, every nation needs to think about water strategically. The Inchampalli - Nagarjunasagar link forms a part of the scheme of transfer of surplus waters of Mahanadi and Godavari rivers to the deficit basins of Krishna, Pennar, Cauvery and Vaighai in the south.

Linking of basins through canals is not a new concept, but has been in practice since times immemorial. Inter-basin water transfer was primarily envisaged by Rao (1973). The National Water Development Authority (NWDA-2003) after a thorough study indicated that Himalayan rivers, especially, Brahmaputra and Ganga have exceedingly surplus quantum of water, and hence, proposed transfer of water from these surplus basins to deficit basins in peninsular region (Vidyasagar, 2003; Reddy, 2003). The present Telugu Ganga project supplying Krishna river waters to Chennai city, Yeleru reservoir water in East Godavari district to Visakhapatnam Steel Plant, etc., have been successfully implemented. The Ganga-Brahmaputra-Meghua basins with an area of 33% in the total river basin area in the country, contribute 62% of water resources (Patel, 2003). These basins, rich in both groundwater and surface water resources are the potential water resource-donor basins to the water resource deficit basins. Shivaji (2003) strongly recommends that interlinking of river is inevitable to prevent the water and food famines by 2025. Kesava (2003) also appealed for a careful full-length study by engineers and scientists before implementing the river linking project. In the year 2009 the rainfall is quite erratic and recorded only 30% of annual rainfall in 280 districts in India. The agricultural drought is declared in 280 districts out of 593 in India in the year 2009. The recurrence of drought almost every year has resulted in severe scarcity of drinking and irrigation water leading to starvation, deaths and suicides of nearly 1500 farmers. The drought-affected area would be nearly 50% in the country every year. The situation demands an efficient and judicious management of available water resources for optimum utilization and their sustainability for the food and observed security of posterity. Rainfall and floods being natural phenomena, their occurrence cannot be changed, linking of frequently flood-prone high rainfall and surplus river basins with the seasonal rivers in the drought prone areas is to be considered from all aspects, hydrological, economic environmental, socioeconomic and political, predicting and weighing the individual and integrated impacts. The present study has to do with the peninsular links and its environmental impact on execution. It was found on the field that an increase in irrigated land after the linking of canals in local area increased the productivity of land in Tribal areas (Vasudeva, 2004). Jain et al. (2008) visualized this project and decided that, it will be the ambitious scheme in the history of India. Successful completion will rapidly wipe out many curses of poverty. The study so far conducted on the proposed links connecting Mahanadi with Andhra Pradesh and Tamilnadu shows the possibility of bringing nearly 7000 Sq km area of an un-irrigated, wasteland come under irrigation in Andhra Pradesh alone. Many earlier reviewers (Radhakrishna, 2003, 2004; Reddy, 2003; Ranjit, 2004; Rajamani, 2005; Govindaswamy, 2007) have discussed the pros and cons of linking of river basins in India. Even though the problem seems to raise many controversies, the country is now going ahead at intra-state level with projects like Buckingham canal in Taminadu and Eleru in Andhra Pradesh and inter-state project like Almatti and Telugu Ganga which are in successful operation adopting methods to reduce losses in social sector.

GEOGRAPHICAL LOCATION OF THE STUDY AREA

The link canal of length 299 km is taking off from the foreshore of the Inchampalli reservoir and out-falling into the existing Nagarjunasagar reservoir. The canal passes through Kharimnagar, Warangal and Khammam districts. The water received at the tail end of the link canal will be stored in the existing Nagarjunasagar reservoir on the Krishna River. The total study area is 8820.13 sq km and it is bounded by 79°5'55'' - 80°6'49'' E longitude and 16°33'17" - 18°51'1" N latitude. It covers 40 topographic maps surveyed in India (SOI) which are connected in a mosaic to study the area. Since most of the information used for impact assessment has some form of spatial content, we extensively use geographic information system (GIS) in this study.

From the topo-sheet mosaic prepared earlier, all settlements are extracted in GIS environment and district boundary, mandal boundary and villages of each mandal are integrated as shown in Figure 1.

The canal originates from Kudurapalli village of Mahadevpur mandal and passes through many mandals and villages of karimnagar district. After Karimnagar, it enters Warangal and Nalgonda districts, where the command area is located. It has a plain land occupying large numbers of villages. In Warangal district canal passes through many villages of different mandals. The village density is considered to be high in this part of the canal study area. The canal joins Nagarjunasagar in Peddavara mandal.

One kilometer buffer is created in Arc GIS on either side of canal alignment and it was found that 23 villages fall within the buffer area and these are to be rehabilitated during the construction of link canal.

Topography along the link canal

The link canal originates from Inchampalli reservoir and passes through Mahadevpur, Kataram and Mutharam

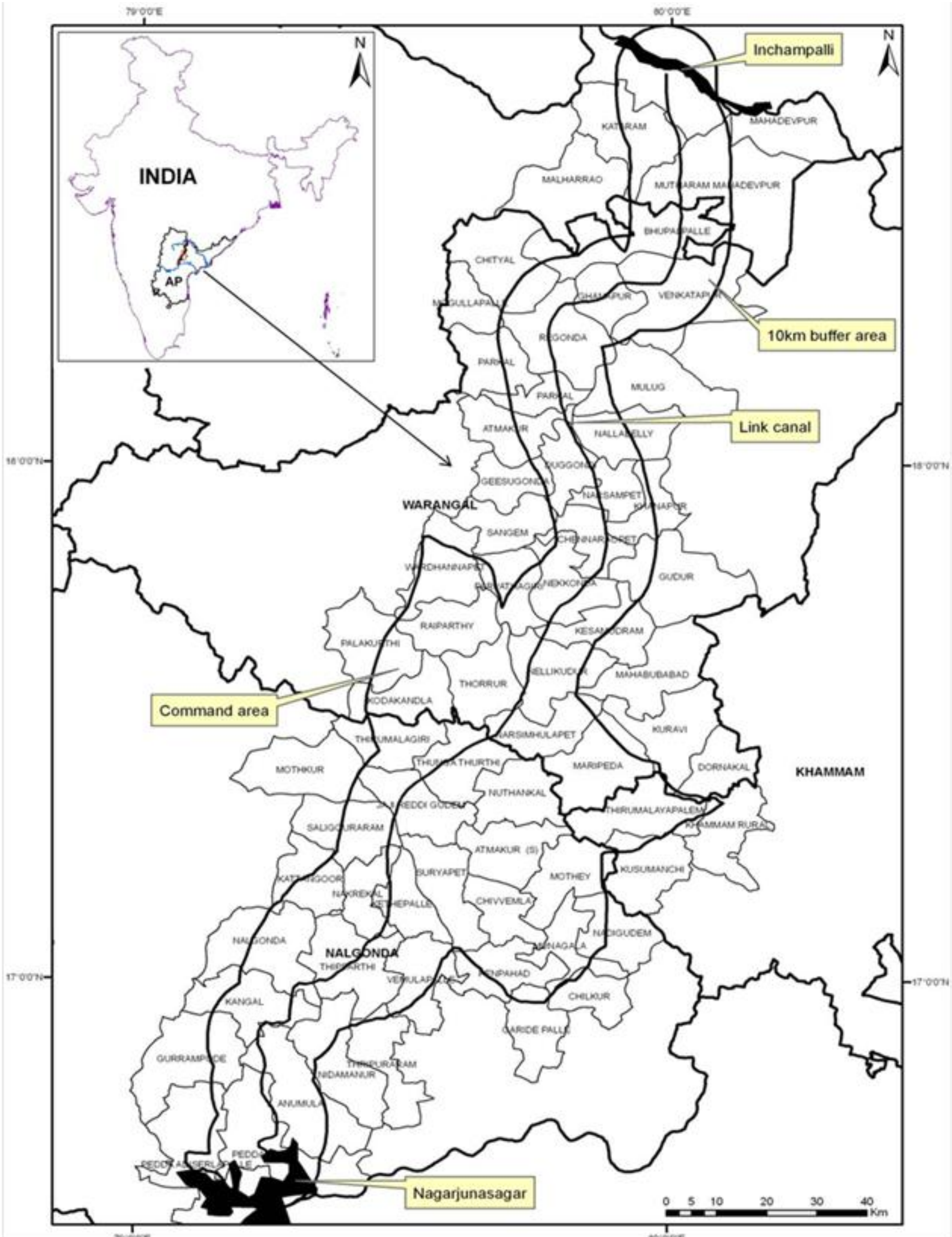

Figure 1. Location of the study area with district and mandals.

Mahadevpur mandals of undulating elevated terrain, which is characterized by wastelands. After Mutharam mandal, the link canal passes through Bupalapalli and Venkatapur mandals, where it is traversing through forest plantations and hilly region. Beyond Bupalpalli mandal the canal traverses the plain areas of Warangal district.

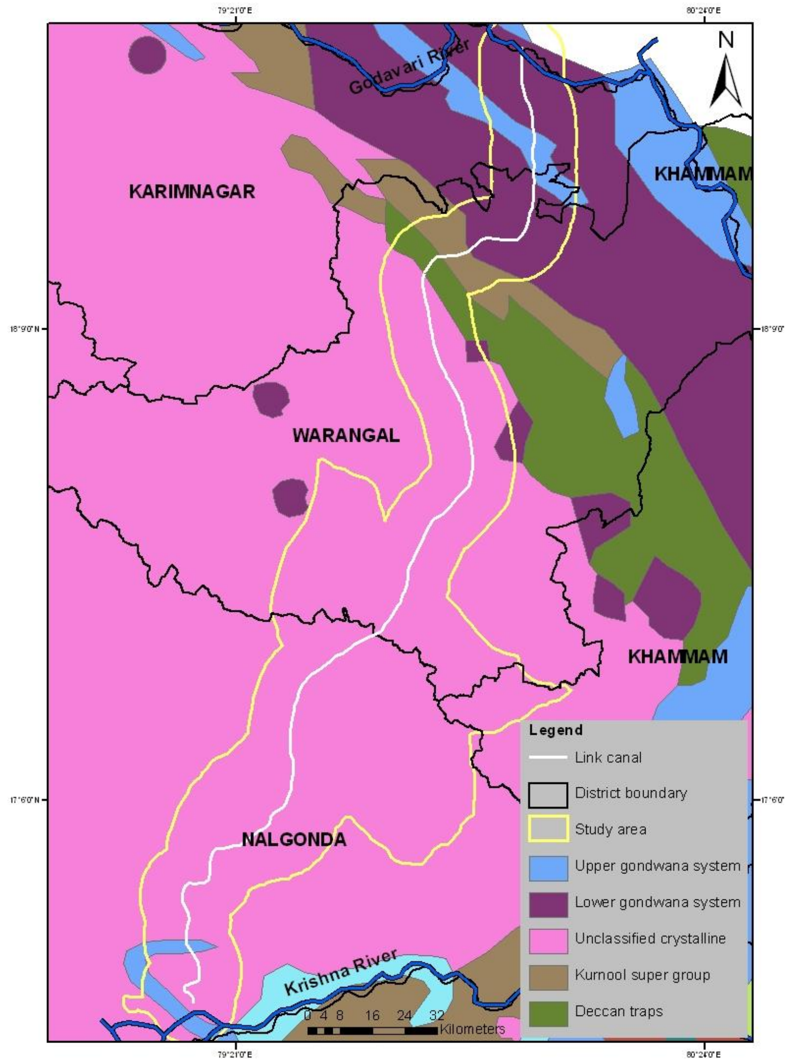

Figure 2. Geology map of the study area.

Beyond Jagireddigudem, the link crosses Musi River and it traverses through plain madals of Kaligowdaram, Kethepalli, etc. From Nalgonda district, the link passes through a chain of tanks and drainage system of various streams up to Kanakar mandal. Next to this mandal, the link crosses another river and through many tanks and natural drains of the area near Paddhahra mandal, and finally, joins Nagarjunasagar reservoir in Padhahar mandal.

MATERIALS AND METHODS

The method of the study consists of four main steps. In the first step, digital GIS database were generated on different thematic maps such as surface lineaments, drainage, point data, geology, geomorphology and soils. The second, third and fourth steps involve GIS integration of several data sets, and finally, they bring out the environmental impact in the study area. Geological setting, morphological features, various soils and land use land cover were studied to evaluate the environmental issues resulting from the alignment. Link canal alignment, study area buffer coverages were created in the Arc GIS. Each layer is taken in the Arc map and overlaid alignment, and study area, buffers and quantifications are made and discussed with illustrations. IRS-1D LISS-III data is analysed to evaluate the state of art land use / land cover pattern supported by ground truth.

MORPHOLOGICAL STUDY OF THE AREA

Geological setting

The study area of the link canal is a part of Eastern Ghats super group. Broadly, the Inchampalli – Nagarjunasagar link canal passes through three major geological domains, Gondwana super group, peninsular gneissic complex and medium grained granite gneisses (Figure 2). The study area in the Karimnagar district is occupied with lower Gondwana system of rocks and a small part by upper Gondwana. Gondwana super group of rocks comprises pebbly/ feldspathic sandstones, ferruginous sandstones, siltstones, shales and dolomitic limestones; and sandstones belonging to Penganga

Table 1. Aerial extent of various rocks in the study area.

Type of rock	Alignment length (km)	Area occupied (Sq km)
Upper Gondwana system	14.75	331.93
Lower Gondwana system	50.39	1023.97
Unclassified crystalline	216.76	6823.47
Kurnool super group	6.94	181.98
Deccan traps	6.31	171.70
Lower Gondwana system	-	29.29
Total	295.15	8562.34

group of rocks, collectively occupying the initial reach from chainage 0 to 55 km in Karimnagar district. The rock formations strike NE-SW in this part of the area. All the formations are cutting across the canal alignment.

The study area in Warangal district is mostly occupied by unclassified crystalline rocks of Archean age. A small area is occupied by Kurnool super group of rocks and Deccan traps. Grey to dark grey, coarse to very coarse-grained Granodiorite of Peninsular gneissic complex occurs between chainage 55 and 102 km. These rocks show similar trend as mentioned previously, but only seen in the northern part. The area in Nalgonda district is traversed by Archean group of unclassified crystalline rocks. Generally, fine to medium grained granite gneisses and migmatities which contain xenoliths of older metamorphics, from chainage 102 km to the end point of the canal 299 km. Rock exposures are seen only in very few locations. Dolerite, pegmatite and quartz intrusive bodies were observed only at a few places, mostly in this granitic suite of peninsular gneissic complex.

Rock types and their aerial distribution are given in the Table 1. Beyond 90 km there are no rock formations except scattered outcrops.

Surface morphology

The study area polygon is taken and canal alignment is overlaid on the digitized geomorphology map to demarcate various land forms pertaining to the study area (Figure 3).

The alignment length from 0 to 32 km is in Karimnagar district. The study area in this district is occupied by pediplain weathered and a small area by alluvial plain. The canal which is 32 to 142 km in length is covered in Warangal district where it passes through 4 types of landforms; pediplain weathered pediment inselberg complex, residual hill and flood plain. Out of the total 142 km in Warangal district, 109 km has weathered padiplain landform and the remaining part traverses through pediment inselberg and flood pains. In Nalgonda district, the canal covers 121 km and about 94 km is in weathered padiplain. Pediplain inselberg occurs here and there for a length of 12 km and Flood plain landform for a length of 15 km. The weathered pediplain is the dominant landform covering major areas (6458 sq km) in all the 3 districts of the study area and occurs at a distance of 235 km. Pediplain inselburg, flood plain and residual hills occupy 1277,358 and 266 Sq km respectively. District wise areal extent of all the above landforms and canal length in each are given in the Table 2.

Soils

In order to study soils along the alignment and the Command area, a soil map is geo-referenced with the help of topo-sheets in Arc GIS. After geo-referencing, all soil layers are digitized manually and coverages were created. The alignment and the study area boundaries are super-imposed on the digitized soil map to demarcate various soils along the alignment and their spread in the study area, (Table 3). The alignment traverses about 4 km in gravelly clay soils, 16 km clayey loamy soil and 7 km in loamy soils in Karimnagar district. The Command area along the alignment is mostly occupied with loamy soils, clayey soils and gravelly clay. In Warangal district, about 61 km of canal is in clayey soils, 43 km in calcareous soils and 32 km in loamy soils. About 123 km length of the canal is covered in Nalgonda district, where 70 km is through gravelly loam, 40 km in calcareous soil and 13 km in clayey soils. Gravelly loams are comparatively more permeable than clayey and calcareous soils, and hence, the length of the canal in the gravelly loam would be lined to minimize seepage losses (Figure 4).

SATELLITE DATA ANALYSIS

The relevant SOI topographical maps on 1:50,000 scale and the base maps surveyed in 1972 were used in geo-referencing the IRS-1D satellite data (Table 4). The IRS-1D digital data was geo-referenced to geographic latitude and longitudes, using ground control points derived from the SOI topo-sheets and the mosaics were created in ERDAS Imagine 9.1. The study area buffer, the alignment and the command area are overlaid on the LISS-III mosaic data of two scenes which covers the study area (Figure 5).

The satellite image of the area and forest boundary AOI, extracted from topographic maps, is overlaid and the status of the forest is examined. The image shows that there is hardly any forest seen from the image, though there was forest marked in SOI maps. Most of this area is noted as deforested. Through, the canal alignment passes through the reserved forest area, yet there would be hardly any forest loss, but 30 sq km of this area would be disturbed while the canal construction.

Land use land cover

Studies on land use/land cover changes using satellite data, have gained lot of importance within the last two decades. Many investigations were done with remote sensing and GIS inputs for studying various land features (Civco, 1993; Rao et al., 1996, Murthy and Venkateswara,

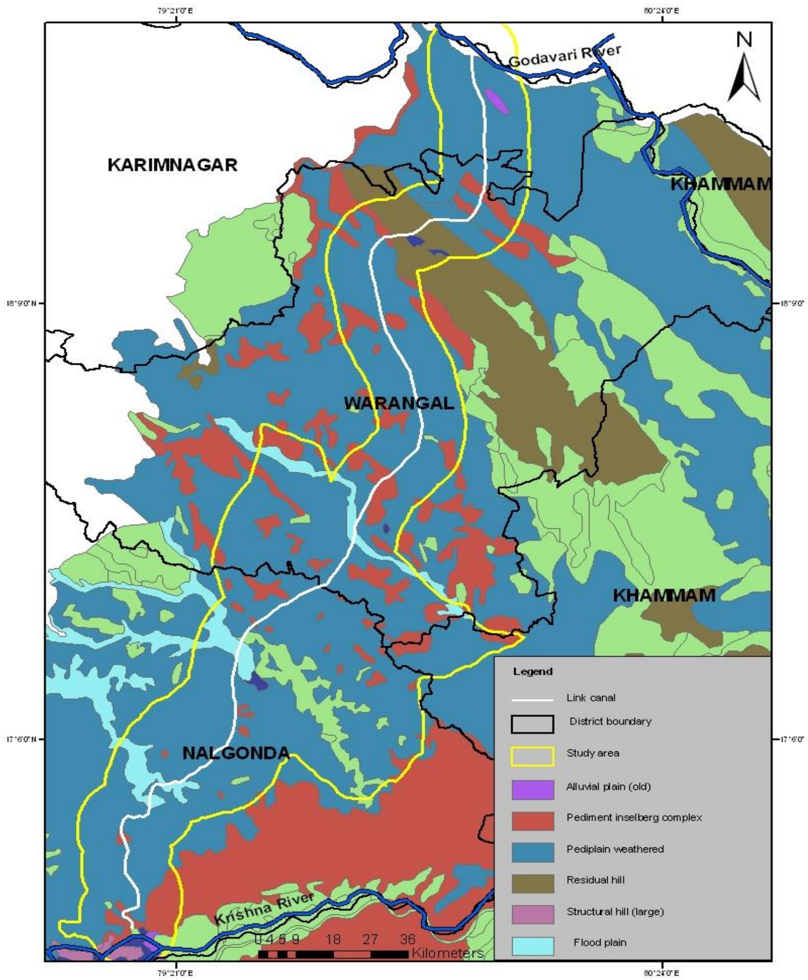

Figure 3. Geomorphology of the study area.

Table 2. Aerial extent of various landforms in the study area.

District	Landform name	Alignment (km)	Area (sq km)
	Pediplain weatherd	31.64	582.83
Karimnagar	Pediment inselberg complex		2.52
	Alluvial plain (old)		15.80
		31.64	601.15
	Pediment inselberg complex	15.33	643.47
	Flood plain	5.44	129.70
Warangal	Structural hill (large)		2.58
	Pediplain weathered	109.34	2684.81
	Residual hill	12.06	273.53
		142.17	3734.09
	Structural hill (large)		4.69
	Pediplain weathered	94.39	3154.96
Nalgonda	Pediment inselbeg complex	12.37	615.04
	Alluvial plain (old)		53.27
	Flood plain	14.47	234.38
		121.23	4062.34

Table 3. Occurrence of soils in the alignment and aerial extent.

District	Soil name	Length (km)	Area (sq km)
Karimnagar	Moderately deep gravelly clay soil	5.25	65.99
	Deep calcareous soil	2.16	27.48
	Deep clayey soil	10.68	154.58
	Very shallow loamy soil	8.00	120.85
	Deep loamy soil	5.16	258.21
		(31.25)	(646.82)
Warangal	Deep clayey soil	59.20	1142.55
	Very deep clayey soil	1.62	64.15
	Very shallow loamy soil	3.25	125.59
	Deep clayey calcareous soil	29.25	561.67
	Gravelly clay soil	3.98	47.69
	Deep loamy soil	22.81	361.09
	Moderately deep gravelly loam soil	9.41	764.25
	Very deep clay calcareous soil	12.68	268.19
		(142.20)	(3482.93)
Nalgonda	Moderately deep gravelly loam soil	42.22	1251.97
	Deep clayey calcareous soil	9.08	944.76
	Moderately deep gravelly clay soil	3.24	137.94
	Gravelly loam soil	8.70	278.88
	Deep clayey soil	11.65	426.01
	Moderately deep clayey soil	17.78	218.40
	Gravelly clayey soil	15.63	449.11
	Deep loamy soil	11.03	511.88
	Deep calcareous soil	4.04	84.49
		(123.37)	(4461.19)

1997; Weicheng et al., 2002). Radiometric correction is applied to images to remove noise present in the image. A 3*3 Median filter is applied to all bands of IRS-1D, LISS-III satellite images and maintain the output values which are not affected by the actual values of outlier cells within the filter window. The median filter is particularly good for removing isolated random noise. The study area is classified into 8 land use / land cover classes; water bodies, cropland, gullied land, scrub land, settlements, sand, forest and others. The study area AOI is overlaid on the classified map and discussed below (Figure 5).

First 20 km of the link passes through forest and hilly area. From 22 to 31 km the study area consists of stony waste / wasteland on either side of the canal. From 31 to 57 km length, it goes through hilly area of Venkatapur and Ghanapur mandal. The canal passes through mostly waste land and irrigated area with a length of 16 km, where the area on either side of the canal water would be useful for land development. From 80 to 175 km length, the area on either side is characterized by wastelands and irrigated lands. The canal water would be utilized extensively throughout this area for the purpose of second crop and drinking water needs of the surrounding villages. After 175 km about 60 km length, the Command area is spread on either side of the canal in Warangal and Nalgonda districts. The command area mostly comes under the class of dry land and wasteland category and this area would be developed due to the link canal. The canal crosses the Musi River and passes through irrigated lands of river for a length of 30 km. From 265 km, the canal passes through wasteland, dry land and partly irrigated lands till it joins Nagarjunasagar reservoir. All this land can be developed with the canal water. Besides this, the right hand side of the area and beyond is classified under waste lands and they may be brought into irrigation under the canal water in future. The crop land is only 27%, but gullied land and scrub land amounts to 44% of the study area (Table 5 and Figure 6). Hence a huge extent of land will be developed by the canal in addition to drinking water needs of the population in the area.

Surface lineaments extraction

The satellite images due to its many capabilities such as the synoptic aerial coverage, multi spectral captivity of

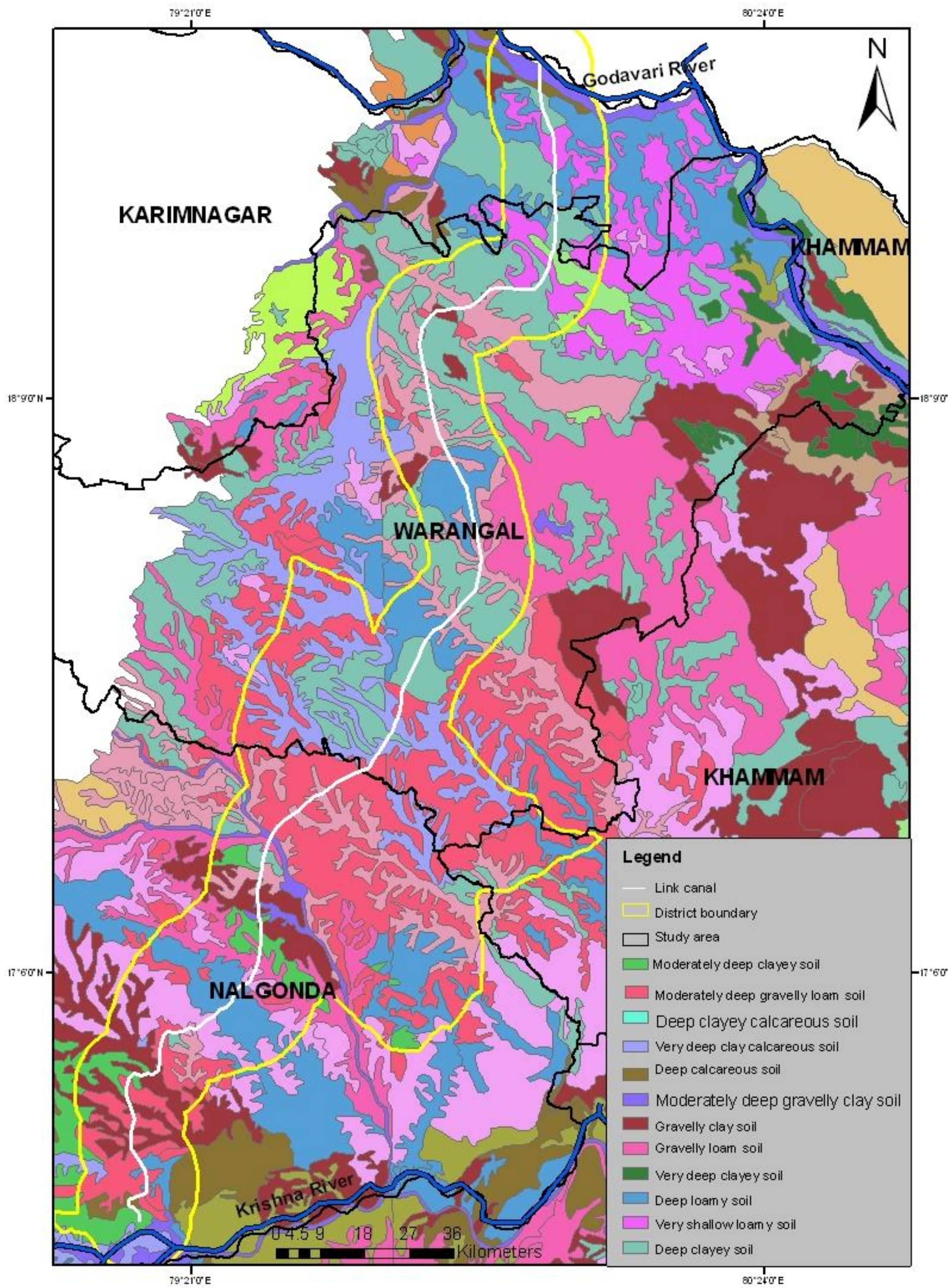

Figure 4. Soil map of the study area.

Table 4. Satellite, sensor and image particulars.

Date	Satellite/sensor	Path/row	Spatial resolution/radiometric
23-Jan-2010	IRS-1D/ LISS-III	Path: 101 Row: 059	23 m/8 bit
12-Mar-2010	IRS-1D/ LISS-III	Path: 101 Row: 060	23 m/8 bit

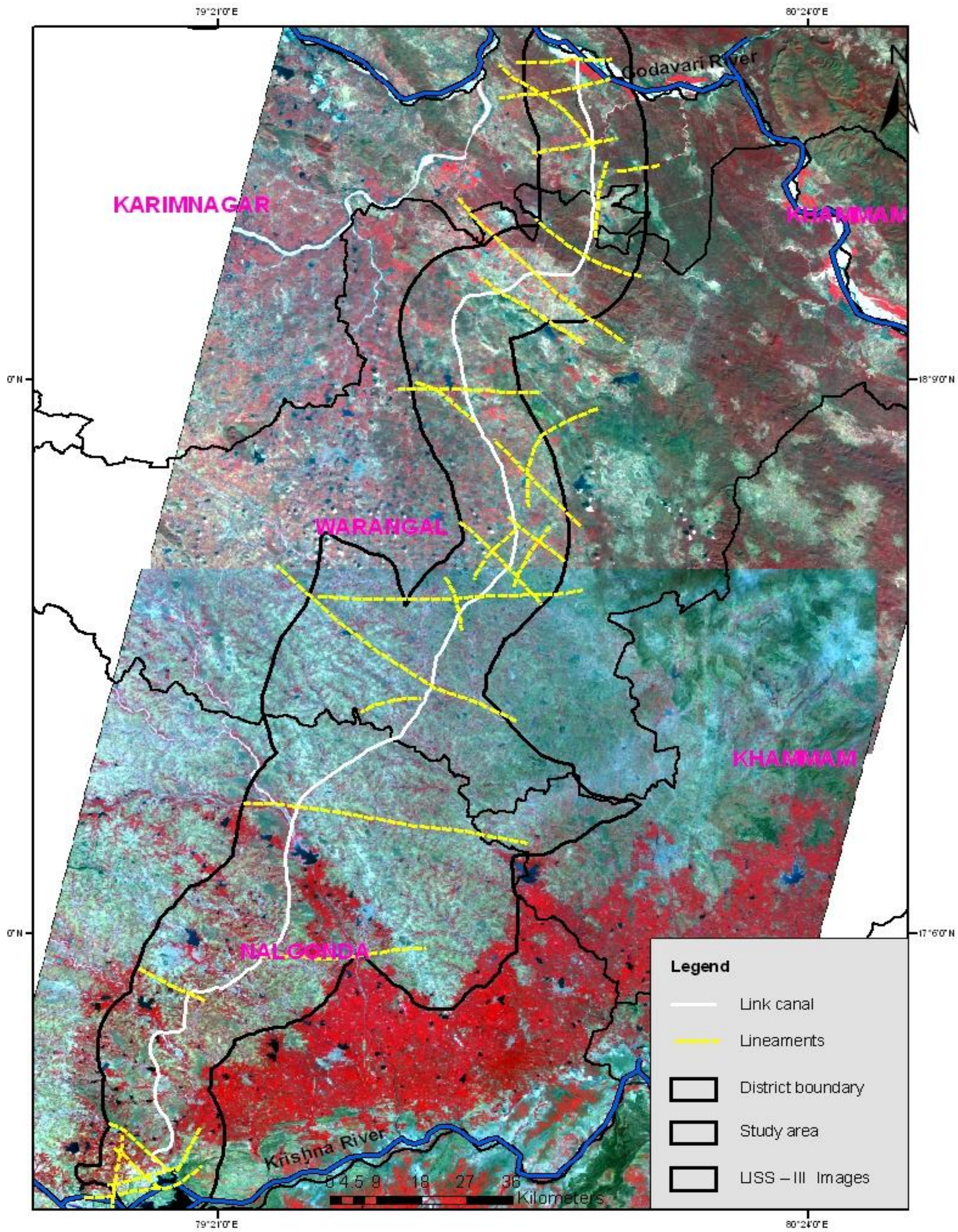

Figure 5. IRS-1D, LISS-III image and lineaments.

Table 5. Land use and land cover.

S/N	Class name	Area (sq km)	Percentage
1	Water bodies	208.39	2.36
2	Crop land	2405.00	27.26
3	Gullied land	2174.00	24.64
4	Scrub land	1739.78	19.73
5	Settlements	639.51	7.25
6	Sand	421.83	4.78
7	Forest	1070.00	12.14
8	Others	161.62	1.84
Total		8820.13	100.00

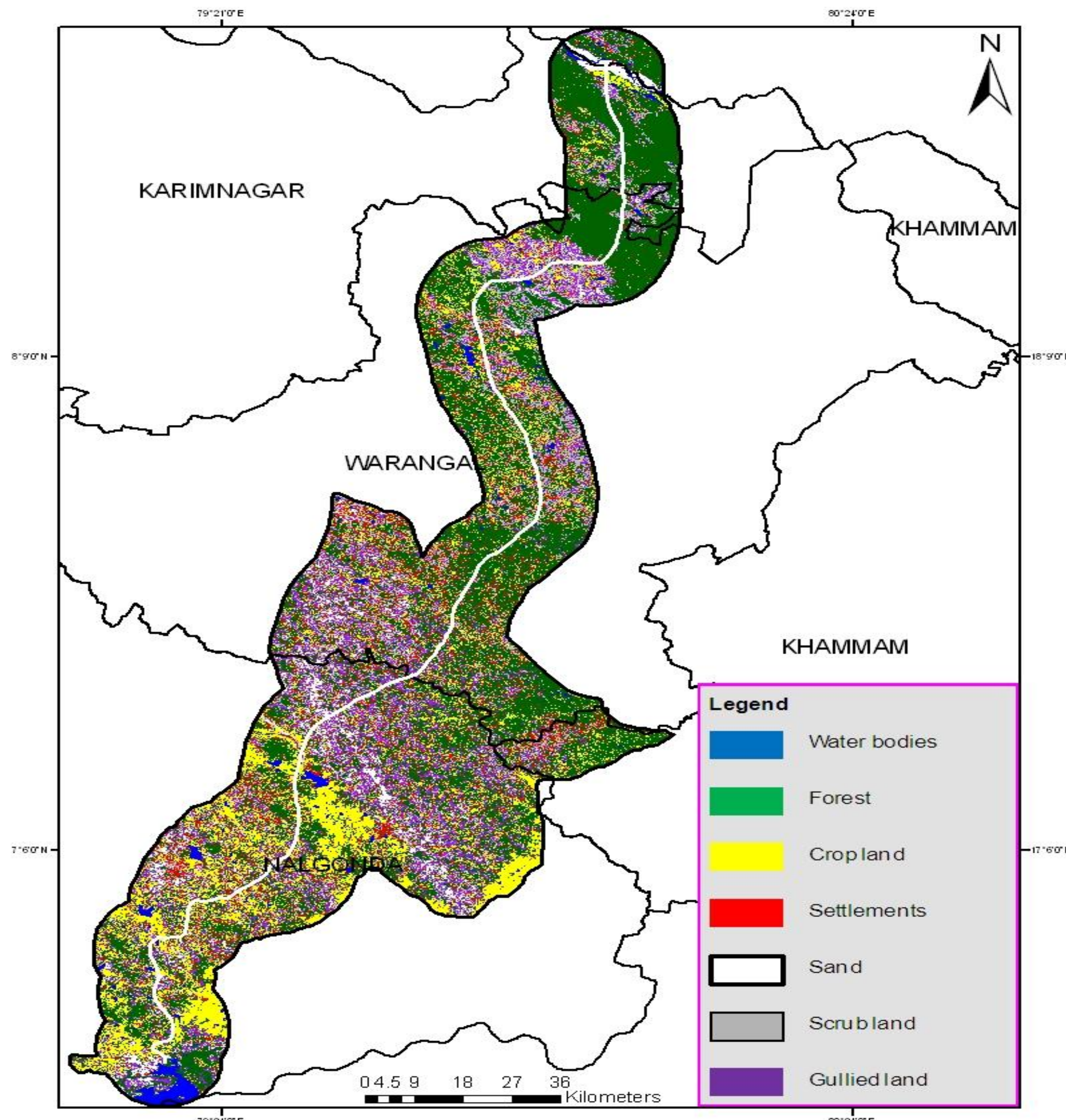

Figure 6. Land use land cover.

data, temporal resolution, etc., produce better information than conventional aerial photographs (Lillesand and Kiefer, 1999), so the same was selected for the task of extracting surface lineaments. With the help of image interpretation keys and elements, lineaments are interpreted for the entire study area. As the digital image enhancement techniques can contribute significantly in extracting lineaments, the same has been attempted using the software ERDAS 9.1. Geological lineaments / faults zones are identified and drawn through screen digitization of image mosaic. 5 lineaments were demarcated in the study area in Karimnagar district and 3 of them are cut across the canal alignment. In Warangal district study area, 13 lineaments are identified and 9 of them are intersecting canal alignment at different locations as shown in the Figure 5. Most of the lineaments are parallel to regional strike. Study area in Nalgonda district has indicated 6 lineaments and 4 of them cut across the canal alignment. The locations of lineament crossings with the alignment are weak zones where necessary precautions are to be taken for seepage losses of water in the canal.

ENVIRONMENTAL IMPACT

The proposed reservoir at Inchampalli would submerge areas in all the three states of Maharashtra, Chhattisgarh and Andhra Pradesh. The total submergence area in these three states is about 94620 ha. The submergence area consists of 31.9% of forest, 38.3% of cultivable lands, 23.3% of open water bodies, 5.8% of shrubs, fallows and rock out crops and 0.7% of other varieties (NWDA-2003).

To estimates forest loss due to the alignment of the canal in the study area, an attempt was made by considering a width of 0.5 km on earthier side of the canal. The maximum loss of forest area was about 30 sq km reserved forest area in Mutharam Mahadevpur, Bhupalpalle and Venkatapur mandals.

There are 5 Tribal villages in the forest area. The canal would meet drinking water needs of Tribal's and forest plantations in this area. From 57 to 175 km length, the canal would supply water for the land on either side of the canal where lands were rain-fed and drinking water needs of 380 villages. The proposed Command area 5157.48 sq km was classified as wasteland class which could come under irrigation by the canal water.

Out of the total study area 8820 sq km, only 27% is under single crop rain-fed land and about 45% is classified as gullied land and scrub land which accounts for 3913.78 sq km. The canal supplies water to this area and is brought under irrigation if the canal could be implemented. About 217 km length of canal is through crystalline rocks where precautions could to be taken to line the canal to arrest possible seepage losses.

Loamy soil and clayey soil occupied 532 sq km in study area of Karimnagar district. Loamy soil and clayey soil occupied the maximum area of 1514 sq km and 1325 sq km with calcareous soil and the remaining area was occupied by gravelly loam in Warangal district. The areal extent of gravelly loam soil (2117 sq km), calcareous soil (715 sq km) and clayey soil (630 sq km) were present in the study area of Nalgonda district.

CONCLUSIONS

Vast area of the present study was classified as gullied land and scrub land which accounts for 3913.78 sq km. It could be brought under irrigation. The major part of the study area (6823 sq km) is occupied by unclassified crystalline rocks and 1024 sq km by lower Gondwana system of rocks. Major part of the hilly area is in Kharimnagr district and a part in Warangal. Pediplain weathered landform occupied 6458 sq km area and the remaining was covered by inselberg complex, residual hills and flood plains. The initial reach of 78 km was through protected forest area, where 30 sq km would be affected during the canal construction. The reserved forest cover was 1070 sq km where most of the areas were deforested which could be indirectly supported by canal water for afforestation. Fluoride content in the ground water is a formidable problem in Nalgonda district where the canal water could route out this problem. Groundwater would be recharged in due course in the canal surroundings and all 816 villages would benefit from protected water supply permanently besides land irrigation in the study area.

ACKNOWLEDGMENTS

The first author acknowledges MoEF for awarding research Project on River linking in Peninsular India. He also extends his thanks to AICTE for awarding Emeritus Fellowship for the period 2010 to 2012.

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