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# Application of GIS in Environmental Assessment (EA) of Highway Projects

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***ABSTRACT***
The paper describes the GIS methods used as a tool for collecting primary data as a part of baseline environmental studies for preparation of environmental impact assessment report of highway projects and its findings. GIS techniques can be an integral part Environmental Impact Assessment Process and can be used effectively to record the environmental settings, land use, sensitive receptions. It can also be used for study of population ecology, air pollution including quantum assessment through dispersion modeling, demography etc. and to analyze the extent of proposed impacts due to the project.

## I. INTRODUCTION

GIS methods used as a tool for environmental assessment of improvement of an existing State Highway (SH-57) in the State of Karnataka. The project road starts at Bagalkote and ends at Honnali, which forms an important connectivity between four districts namely Bagalkote, Gadag, Haveri & Davanagere. The project road connects several important tourist destinations such as Badami caves, Itagi, Pattadakal Temples etc. Hence, improvement of the existing state highway would facilitate connectivity to major towns for business, medical requirement, educational facilities, employment opportunities, market for finished goods, boost economy due to increased number of tourists and also would ensure safer movement of goods and people. The project road has been designed for minimum speed of 80 km per hour in rural areas and minimum speed of 50 to 60 km per hour in settlement areas.

The environmental studies due to the project was carried out within existing policy, legal and administrative framework considering the applicable environmental legislation, regulations & guidelines of MOEF&CC, Government of India as well as multilateral funding agencies. GIS techniques have been used in identifying sensitive receptors, forest and eco-sensitive areas, preparation of land use and land cover maps, mapping of green tunnels and giant trees.

## II. SCOPE OF GIS USE IN EA

The GIS techniques were used in the environmental studies for preparation of EA Report at both field levels for data collection as well as report preparation. The scope of using GIS is as under:

- To identify and map Environmental features including sensitive receptors within 50 m on either side of project road
- To identify and map the forest areas within 15 km radius of the road
- To mark the locations of green tunnel and giant trees along the road
- To prepare land use map covering 15 km radius of the road

Apart from the mapping requirements, GIS can be used effectively as a decision making tool for selection of alignment so that important existing features such as green tunnels, giant trees, water bodies, sensitive receptors, cultural and heritage properties could be saved from being impacted.

## III. STUDY AREA

Bagalkote is the district town of Bagalkote district of north Karnataka. The Project road starts in Bagalkote town near Bagalkote railway Station from the junction of local city road with the approach road to ROB and ends at the bus terminus of Honali town. It passes Gadag, a district town en-route where a bypass has been proposed to avoid congested urban stretch.
Total length of the project road is about 240 km. The location of the road is shown in **Figure 1.**

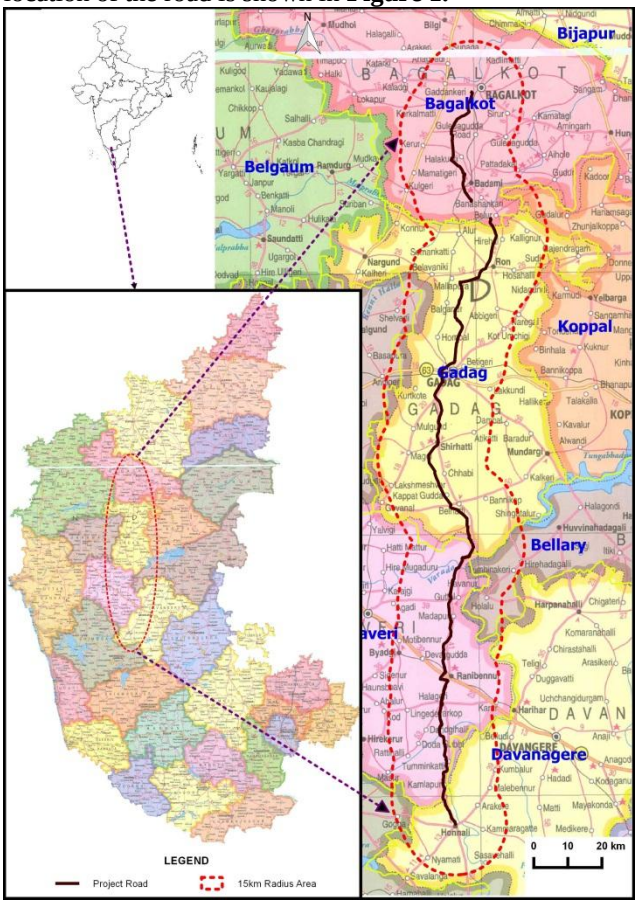


**Figure 1: Map Showing Location of Project Road**

## IV. METHODOLOGY

**Task 01 Reconnaissance Survey**:

A reconnaissance study has been made for identification of Valued Environment Components (VECs) on proposed project road. Location of protected areas (National Parks, Wildlife Sanctuaries, Biosphere Reserves, Reserved / Protected Forest, Important Bird Areas, World heritage Sites, Archeological Monuments etc.); surface water bodies; environmentally sensitive receptors (educational institutions, religious structures, medical facilities etc.); cultural and heritage properties along the alignment has been identified using the data from secondary sources.

**Task 02 Primary Data Collection**:
Primary survey at field was carried out to verify the secondary data as well as to collect primary information like location of sensitive receptors & CPRs, green tunnels and giant trees, forest areas adjacent to the road, which is not available in the secondary data.

**Task 03 Data Analysis & Validation**:
All collected Data were geo-referenced and mapped using multiple mapping tools ArcGIS, ERDAS Imagine and QGIS). The complied data were verified for discrepancies as per the requirement. Based on the distances of each feature from the proposed right of way, the affected status of the each structure was determined based on which suitable mitigations measures were formulated in EMP/RAP.

## V. RESULTS AND DISCUSSIONS

**Archaeological Sites**
Badami Cave Temples, a complex of four Hindu, Jain and possibly Buddhist caves of 6th Century, is located within a distance of 260m from the road at the outskirts of Badami town on the left side of the road. It is an archeologically protected site and considered as an example of Indian rock-cut architecture, especially Badami Chalukya Architecture. The temple, being located at sufficient distance from the project road remains un-impacted due to project activities. However, the project is expected to increase tourist footfalls due to improved connectivity.

**Forests**
The protected areas and forests in the study area have been identified and marked in map using GIS techniques and ground truth verification. It has been found that the road does not traverse through any National Parks, Wildlife Sanctuaries or Biosphere Reserves. Ranebennur Black Buck Sanctuary is located within the study area (15 km) but not adjacent to the road. The shortest distance from this sanctuary to the road is found to be 2.3 km. However, it passes through Reserved and Protected Forests for 7.928 km stretch as per existing alignment.

Based on the findings, efforts were made to reduce impact on forests by shifting the road alignment to the maximum possible extent towards the non-forest areas. As all the forest areas within 15 km radius of the road has been mapped through GIS, it helped to fix alternative alignment avoiding forest areas without compromising on safety features. This exercise yielded final alignment having a forested stretch of 5.701 km, thereby reducing road length through forest by 28% in comparison to the existing road. However, acquisition of forest land could not be completely avoided due to connectivity issues, geometric constraints and to avoid resettlement issues arising out of acquisition of fertile agricultural or residential private land.

The forests stretches along the project are presented in Table 1. Forest location map being large due to long project route, a sample map showing few forest locations is shown in **Figure 2.**

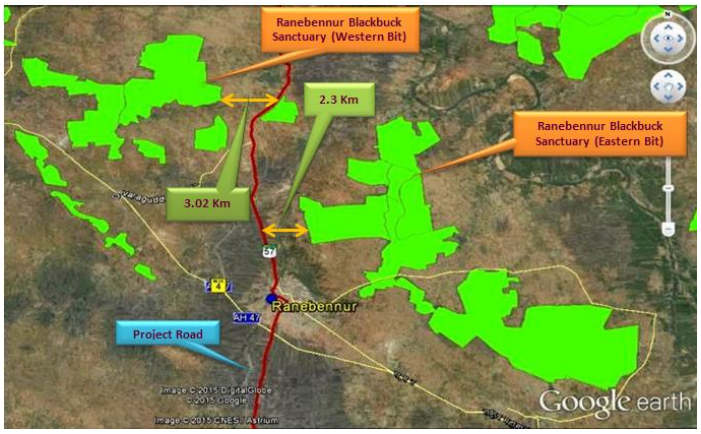


**Figure 2: Map Showing Forest Location along Project Road**

**Table 1 Location of Forest along Project Road**

| SN | Existing Ch. Km | | Length (Km) | Side | Forest Type |
|---|---|---|---|---|---|
| | From | To | | | |
| 1. | 06+470 | 06+760 | 0.290 | RHS | RF |
| 2. | 14+240 | 14+420 | 0.180 | LHS | RF |
| 3. | 27+965 | 28+600 | 0.635 | RHS | RF |
| 4. | 30+900 | 32+000 | 0.100 | LHS | RF |
| 5. | 35+400 | 36+100 | 0.700 | LHS | RF |
| 6. | 47+000 | 47+500 | 0.500 | LHS | RF |
| 7. | 142+140 | 142+990 | 0.850 | Both | RF |
| 8. | 154+160 | 154+230 | 0.070 | LHS | RF |
| 9. | 154+970 | 155+185 | 0.215 | LHS | RF |
| 10. | 155+185 | 155+223 | 0.038 | Both | RF |
| 11. | 157+500 | 157+820 | 0.320 | RHS | RF |
| 12. | 162+935 | 163+535 | 0.600 | RHS | RF |
| 13. | 163+535 | 164+035 | 0.500 | Both | RF |
| 14. | 202+775 | 204+775 | 2.000 | LHS | RF |
| 15. | 21+000 | 21+100 | 0.100 | Both | RF |
| 16. | 22+100 | 22+300 | 0.200 | RHS | RF |
| 17. | 27+025 | 27+200 | 0.175 | RHS | PF |
| 18. | 27+200 | 27+575 | 0.375 | RHS | PF |
| 19. | 27+575 | 27+655 | 0.080 | RHS | PF |
| | **Total** | | **7.928** | | |

Note: RF Reserved Forest; PF – Protected Forest

Source: Joint Field Survey with Forest Department

**Green Tunnels**

Green tunnels are formed along the road at some locations. These tunnels provide shade, reduce heat effect, reduce glaring of road and provide overall cooling. Location of green tunnel have been identified and marked on map using GIS Techniques. Species observed in the green tunnel mainly includes Ficus benghalensis (Banyan), Tamarindus indica (Tamarind), Delonix regia (Gulmohar) Ficus religiosa, (Pipal), Azadirachta indica (Neem), etc. The location of green tunnel is given in **Table 2** and also marked in map in **Figure 3**.

**Figure 3: Map Showing Green Tunnels Location of Project Road**

**Table 2 Location of Roadside Green Tunnels**

| SN | Start Point GPS | End Point GPS | Length (m) |
|---|---|---|---|
| 1. | 15°59'16.58"N 75°39'37.02"E | 15°59'14.63"N 75°39'38.75"E | 750 |
| 2. | 15°59'9.07"N 75°39'50.10"E | 15°59'7.05"N 75°39'55.70"E | 200 |
| 3. | **15°54'34.11"N 75°41'11.91"E** | **15°53'40.32"N 75°41'57.29"E** | **2,100** |
| 4. | 15°46'56.17"N 75°45'35.01"E | 15°46'50.84"N 75°45'32.66"E | 200 |
| 5. | 15°22'56.21"N 75°35'54.06"E | 15°22'52.40"N 75°35'51.20"E | 145 |
| 6. | 14°44'51.01"N 75°38'21.25"E | 14°44'44.74"N 75°38'20.80"E | 195 |
| 7. | 14°44'40.24"N 75°38'19.69"E | 14°44'36.46"N 75°38'18.93"E | 115 |
| 8. | 14°44'20.18"N 75°38'17.95"E | 14°44'15.02"N 75°38'18.00"E | 160 |
| 9. | 14°44'7.09"N 75°38'13.86"E | 14°44'3.79"N 75°38'11.51"E | 130 |
| | | **Total Length (km)** | **3,995** |

Source: Field Survey

Efforts were made to save green tunnel by restricting the widening within the existing ROW or choosing eccentric widening instead of concentric one. The GIS maps of green tunnels were used extensively to find out the alignment alternatives. As the width of the tunnel was also marked, it helped to decide upon the best possible construction width so that impact on matured trees (more than 100 years old in some cases) could be minimized. **Green tunnel has been saved at Badami** (2.1 km) by modifying engineering design, where widening has been proposed on right side to save approx. 100 matured trees of the left side.

**Giant Trees:**

Field survey was conducted to identify the location of giant trees. 191 giant trees are found along the project road, out of which 96 trees are on the left side and 95 trees are on the right side. Majority of the giant trees have been saved by slightly modifying the construction width.

**Sensitive Receptors & CPRs**

Sensitive Receptors includes educational institutes including student hostels, medical facilities for both human and livestock, places of religious importance etc. while bus shelters, overhead water tanks, water supply tanks (ground level), public amenities like petrol pumps, banks, various Govt. offices etc. have been categorized as Common Property Resources (CPR). All the existing sensitive receptors have been geo-referenced and marked in a map. The project being a long linear one, a sample map these features both affected and unaffected in presented in **Figure 4**.

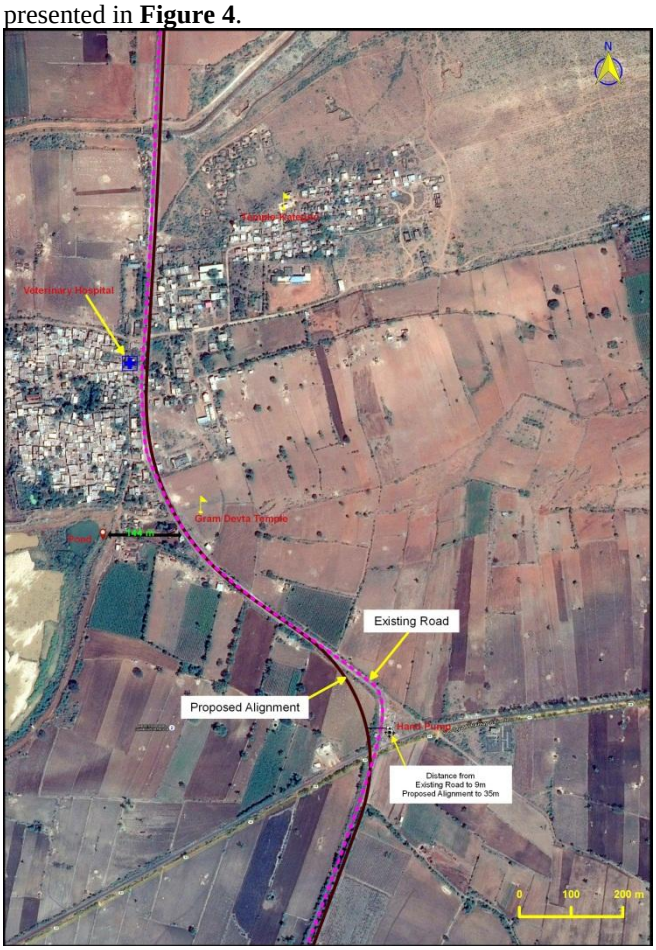


**Figure 4: Map Showing Sensitive receptors & CPRs**

The distances of the individual receptors with respect to proposed centerline were calculated through GIS and their respective affected status was determined. This technique

is particularly useful in decision making during the planning stage when alignment gets finalized. Analysis of affected status of receptors as per different distant category is summarized in Table 3.

**Table 3: Summary of Affected Sensitive Receptors**

| Distance Category* | Not Affected | Affected | Partially Affected | Grand Total |
|---|---|---|---|---|
| A (0-5) | 9 | 39 | 0 | 48 |
| B (6-10) | 139 | 101 | 2 | 242 |
| C (11-15) | 173 | 6 | 3 | 182 |
| D (16-20) | 119 | 1 | 0 | 120 |
| E (21-25) | 62 | 0 | 0 | 62 |
| F (26-30) | 48 | 0 | 0 | 48 |
| G (>30) | 209 | 0 | 0 | 209 |
| **Grand Total** | **759** | **147** | **5** | **911** |

* Figures in parenthesis indicates distance of receptor from the proposed centerline of the road

**The data was further classified in GIS and the type-wise impact in each sub-category of receptors were assessed, which is summarized Table 4 to 7.** This information is particularly crucial for impact prediction and formulation of mitigation measures in environmental studies and resettlement action plan.

**Table 4: Impact on Educational Institutions**

| Particulars | Not Affected | Affected | Partially Affected | Total |
|---|---|---|---|---|
| College | 11 | 0 | 0 | 11 |
| Hostel | 2 | 0 | 0 | 2 |
| ICDS[1] | 8 | 0 | 0 | 8 |
| ITI | 4 | 0 | 0 | 4 |
| Med College[2] | 1 | 0 | 1 | 2 |
| School | 87 | 0 | 1 | 88 |
| **Total** | **113** | **0** | **2** | **115** |

1Integrated Child Development Service center (Anganwadi)
2 Medical College

It can be seen from Table 3 that most of the affected features are located within 6-10 meters range of the existing centerline. 83.6% of the fully affected features belong to CPR and public utilities such as hand pumps, tube wells, bus shelters, water supply tanks etc. which can be relocated with minimum cost and efforts. The GIS enabled mapping system helped to select the alignment in such a way that the educational & medical facilities, places of religious importance as well as water bodies (having high ecological significance and water storage and recharge potential as the project is located in semi-arid area) are saved from being impacted.

**Table 5: Impact on Medical Facilities**

| Particulars | Not Affected | Affected | Partially Affected | Total |
|---|---|---|---|---|
| Water Body | 47 | 0 | 1 | 48 |

It evident from Table 5 & 6, only one water body will be partially impacted out of a total of 47 while boundary wall of 1 primary health center will be required to be shifted for the proposed project.

Table 6: Impact on Medical Facilities

| Particulars | Not Affected | Affected | Partially Affected | Total |
|---|---|---|---|---|
| Hospital | 15 | 0 | 0 | 15 |
| PHC[3] | 8 | 0 | 1 | 9 |
| Veterinary Hospital | 5 | 0 | 0 | 5 |
| **Total** | **28** | **0** | **1** | **29** |

3Primary Health Center

**Table 7: Impact on Religious Places**

| Particulars | Not Affected | Affected | Partially Affected | Total |
|---|---|---|---|---|
| Church | 3 | 0 | 0 | 3 |
| Idgah | 3 | 0 | 0 | 3 |
| Mazar | 5 | 1 | 0 | 6 |
| Mosque | 10 | 0 | 0 | 10 |
| Temple | 158 | 23 | 1 | 182 |
| **Total** | **179** | **24** | **1** | **204** |

3Primary Health Center

The 24 affected religious places are small roadside worship platforms. All built up religious places have been saved from being impacted.

**Table 8: Impact on Common Property Resources**

| Particulars | Not Affected | Affected | Partially Affected | Total |
|---|---|---|---|---|
| Bore well | 129 | 40 | 0 | 169 |
| Bus Shelter | 35 | 31 | 0 | 66 |
| Bus Terminus | 2 | 0 | 0 | 2 |
| Milk CS[4] | 3 | 0 | 0 | 3 |
| Funeral Place | 2 | 2 | 0 | 4 |
| Govt. Office | 21 | 0 | 0 | 21 |
| Hand Pump | 27 | 19 | 0 | 46 |
| Library | 1 | 0 | 0 | 1 |
| Memorial[5] | 4 | 0 | 0 | 4 |
| Museum | 1 | 0 | 0 | 1 |
| Overhead Tank | 36 | 1 | 0 | 37 |
| Petrol Pump | 32 | 0 | 0 | 32 |
| Sports Facility | 3 | 0 | 0 | 3 |
| Water Tank[6] | 76 | 29 | 0 | 105 |
| Well | 17 | 1 | 0 | 18 |
| WTP[7] | 1 | 0 | 0 | 1 |
| **Total** | **390** | **123** | **0** | **513** |

4 Milk Collection Center
5 Memorial includes statutes, busts and mausoleums

6 Water Supply Tank with Tap at ground level
7 Water treatment plant

**Land Use**

The land use map covering 15 km on either side of the road was prepared using both satellite images and Survey of India Sheets in 1:50000 scale as per the requirement of EA report. The map data has been processed and analyzed using Image-processing software Erdas Imagine and ArcGIS supported with ground truth verification. Land use wise area coverage was also calculated by image classification.

Agriculture is the main land use. Commercial activities were only noted when alignment passes through settlements however no major industries are noted along project road. The project road passes through various small and big settlements such as Bagalkote, Badami, Ron, Gadag, Guttal, Ranebennur, Halageri, Hallur and Honnali.

**Land Use within road corridor**

The land use pattern within 50m on either side of the project road is agricultural (82.5%) followed by residential cum commercial area (14.8%) and forest (2.7%). Within ROW the land use is mainly open land with trees by the side of the earthen shoulder.

**Land Use within the Study Area**

The land use classification within **15 km** area on either side of the road is summarized in **Table 8** and major land use types are graphically presented in **Figure 5**. Majority of the land is under agrarian use (80.3), followed by forest (11.1%) and built up area (2.2%).

**Table 9 Land Use Classification Statistics**

| Land use Classes | Sq. km | Percentage |
|---|---|---|
| Agriculture | 6875.29 | 80.3 |
| Barren Rocky | 48.61 | 0.6 |
| Water Body/River/Canal | 49.27 | 0.6 |
| Built-up Area | 186.57 | 2.2 |
| Forest | 950.63 | 11.1 |
| Vegetation | 456.46 | 5.3 |
| **Total** | **8566.83** | **100.0** |

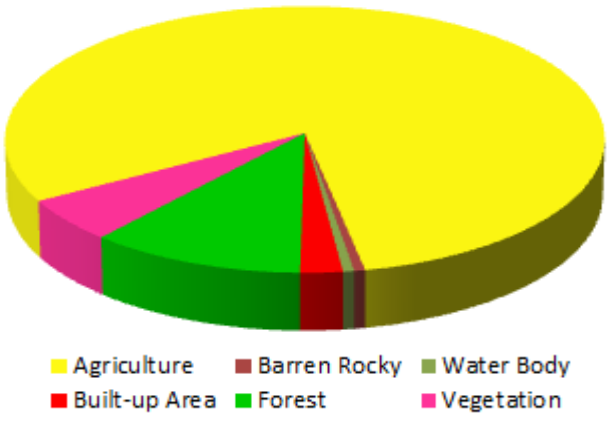


**Figure 5: Land use map of study area**

Being a long linear project having 240km length, the prepared Land use map has multiple sheets of A0 size. A compressed version of the map prepared in 1:500000 scale is presented in **Figure 6.**

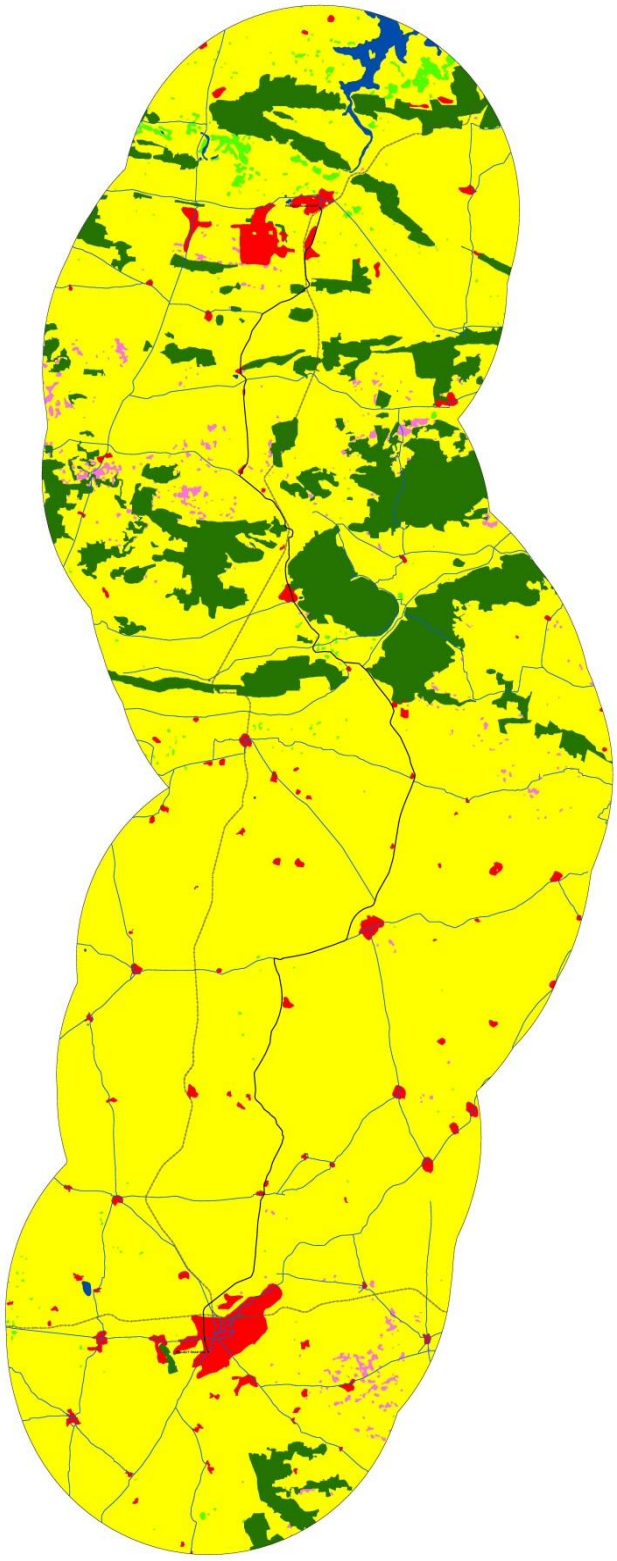

**Figure 6: Land use map of study area**

## VI. CONCLUSION

GIS techniques can be used effectively in the surveying and mapping of environmental features. The analyzed data provides a valuable input to the impact assessment process for quick estimation of impacts and also help to choose suitable road alignment so that impact can be minimized.

The use of GIS technique is cost effective and quick. It can yields accurate results subject to dedicated data validation. GIS applications can also be used to depict findings of dispersion models, which is extensively used for quantification of predicted impacts on air, water and noise levels. Similarly, demographic profile of the study area can also be mapped and analyzed to avoid major resettlement impacts

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