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SPACE BASED INPUTS FOR HEALTH SERVICE DEVELOPMENT PLANNING IN RURAL AREAS USING GIS

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Abstract. The use of Geospatial Techniques for quick decision making is the demand of the time. Geospatial techniques play a very important role to help decision makers, stakeholders and citizens for planning at various levels of governance. Geospatial technology is fast and accurate enough to make analysis and derive the useful results to help the decision makers in planning process. This has augmented the need for development of a model utilising the geospatial datasets to automatize the process which can aid in quick decision making for effective planning and development at village level. The objective of this research work is to build a spatial model for identifying suitable sites for hospital in rural areas. A pilot study has been carried out which aims to identify and prioritize the potential sites for hospitals/Clinic utilizing the 1:10 k scale database with the help of Geographic Information System (GIS) in Hisar, Harayana, India. This study identifies the following factors as indicators of suitability for landscape: road connectivity, demography and location of existing facilities. The evaluating process for suitable hospital/clinic sites have been carried out based on five chosen criteria including land use/cover type, road network and settlement location, proximity to existing facilities and population. The outcome of the model has been further used as input to Location- allocation tool in GIS to select the suitable location for medical and health facilities. The adopted methodology identifies the 10 new suitable sites for medical and health facilities by putting all the criteria with the actual resources of the region. The proposed approach can be effectively utilized by the Government for Health Service Development Planning in Rural areas where medical and health facilities are poor.

Keywords: digital empowerment, remote sensing, site suitability, decentralized planning, panchayat, medical facilities.

Introduction

In many parts of the world, rapid population growth, urbanization, and industrialization have increased the need of a decision support system to do effective planning and development in timely manner. In India, various health related schemes are being run by centre/states to improve the medical infrastructure and facilities/services at the grassroots level. One of the very important centrally sponsored schemes is National Rural Health Mission (NRHM). The NHRM (2005-12) seeks to provide effective healthcare to rural population throughout the country with special focus on 18 states in the country, which have weak public health indicators and/or weak infrastructure. Following are the visions of the scheme (NRHM 2006).

- To increase public spending on health from 0.9% GDP to 2–3% of GDP, with improved arrangement for community financing and risk pooling.
- Effective integration of health concerns through decentralized management at district, with determinants of health like sanitation and hygiene, nutrition, safe drinking water, gender and social concerns.
- To improve access to rural people, especially poor women and children to equitable, affordable, accountable and effective primary health care.

A generic Public Health Delivery System envisioned under NRHM from the Village to the Block Level is summarised in Table 1.

Narayana and Kurup (2000) have highlighted some issues due to decentralization of the health care sector in Kerala. They discussed the three basic problems of decentralising the health care sector, namely

Table 1. Generic Public Health Delivery System envisioned under NRHM

S. No.	Level of facility	No. of villages	Population
1	Block Level Hospital	100	100,000
2	Cluster of GPs (PHC Level)	30–40	30000–40000
3	Gram Panchayat Sub Health Centre Level)	5–6	5000–6000
4	Village Level (Asha, AWW, VH& SC)	01	1000

spill over effect, role and relevance of a pre existing body Hospital Development Committee (HDC), and the level of minimum health care service to be provided by the health care institutions. In the state, health care services are fairly widespread as the distribution of Primary Health Centers (PHC) with at least one PHC per village panchayat.

The problem of finding the suitable location of the facilities to be deployed or constructed in an area has augmented the need for development of an automatic system to solve the problem effectively. Research for development of the algorithms in this regard has been carried out since more than two decades. Some of the literature related to location-allocation algorithms can be found at Scott 1970, Hodgson 1990. Shams-ur and David (2000) have presented a review on the use of location-allocation models in health service development planning in context of developing nations. They examined the suitability of location-allocation methods for designing health care systems and their relevance to overall development problems.

Forzieri *et al.* (2008) proposed an approach for pre-selection of suitable sites for surface and groundwater small dams using the spatial methods. A total of 17 suitable sites were proposed as per the selection criteria. Singh *et al.* (2009) conducted a case study in Soankhad Watershed, Punjab in which they suggested a method for selection of suitable sites for Water Harvesting Structures using Remote Sensing and Geographical Information System (RS&GIS). IRS-1C, P6 satellite imagery was used as base for the analysis. A total of 14 check dams and 6 percolation tanks at appropriate sites were proposed. Nas *et al.* (2010) have proposed an approach for selection of MSW landfill site for Konya, Turkey using multi-criteria evaluation. They used eight input map layers to identify appropriate landfill areas in the selected region with the help of GIS. They emphasised on further field research to obtain the final MSW landfill site.

1. Background

The location-allocation model in ArcGIS starts by generating an origin-destination matrix of shortest-path costs between all the facilities and demand point locations along the network. Then Hillsman editing is used to construct the modified cost matrix. The model generates a set of semi-randomized solutions. Vertex substitution heuristic is adopted to refine the generated solutions to produce the group of better solutions with the help of Metaheuristic. Metaheuristic returns the best solution if no additional improvement in the previous group of better solution. The combination of all solutions yields near-optimal solution. The mathematical formulation of the algorithms can be found at (Carey *et al.* 1981; Densham, Rushton 1992).

1.1. Origin-Destination Matrix

Origin–Destination (OD) matrices, which specify the travel demands between the origin and destination nodes in the network. Mathematical modeling of traffic requires a lot of data and other information about the road network and the travel demand. There are three types of traffic models for the generation of OD matrix viz. macroscopic, microscopic and mesoscopic (Peterson 2007).

1.2. Location-Allocation Problem Types

The network analyst module in ArcGIS v10.0.2 list out several methods such as finding shortest route, location – allocation etc. The location – allocation approach offers the following solutions for a particular problem (ESRI 2016).

Minimize Impedance: This approach locates the facilities such that the sum of all weighted costs between demand points and solution facilities is minimized. Traditionally, it was used for locating the warehouses to reduce the overall transportation costs of delivering goods to outlets. This problem type reduces the overall distance the one needs to travel to reach the chosen facilities.

Maximize Coverage: This problem type is frequently used to locate the emergency services locations such as fire stations, police stations, and ERS centers, which often required to arrive at all demand points within a specified response time.

Maximize Capacitated Coverage: In this problem type, facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cutoff; additionally, the weighted demand allocated to a facility can't exceed the facility's capacity. Maximize Capacitated Coverage selects facilities in such a way so that all or the greatest amount of demand can be served without exceeding the capacity of any facility. Maximize Capacitated Coverage works same as the Minimize Impedance or Maximize Coverage problem type with the added constraint of capacity.

Minimize Facilities: Minimize Facilities problem type is the same as Maximize Coverage but with the exception of the number of facilities to locate, which in this case is determined by the solver. The minimize facilities problem type may also be used to cover all the demand points in place of maximize coverage (e. g. emergency response) if the cost of building facilities is not a limiting factor.

Maximize Attendance: In the method a facility is selected by allocating the as much as possible demand weight to a facility with the assumption that the demand weight decreases in proportion with the distance between the facility and the demand point.

Maximize Market Share: This problem type is used to maximize the allocated demand in the presence of competitors. The total market share is calculated by adding all demand weights for valid demand points.

Target Market Share: This problem type selects the minimum number of facilities required to capture a specific percentage of the total market share in the presence of competitors.

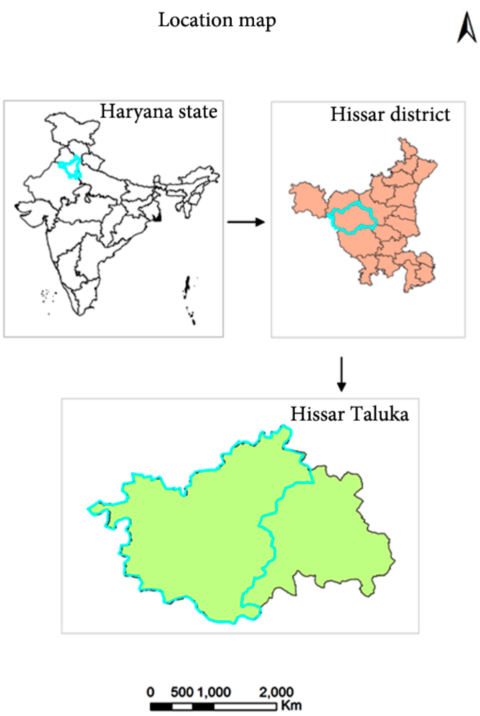

Fig. 1. Study area

2. Study area

The study has been carried out in some selected panchayats of Hisar block of Haryana state. The administrative area of the region selected for study covers 1226 km^2 and the total population is 310 398. The population information has been collected from the census 2011 document. The study area covers 79 panchayats consisting of 80 villages. The co-ordinates of the centroid of the study region are 75.5342° E and 29.2169° N. The Study area is shown in Figure 1.

3. Data resources

In this study, 2.5 m fused product (Cartosat-1 + LISS-IV) has been used for analysis. The thematic datasets (LULC, Roads, Drainage and Rail) generated at 1:10000 scale are also used (Fig. 2). The satellite imagery has been categorized in 30 landuse/cover classes. The settlement location in each village has been obtained from the landuse/cover of the study area. The administrative boundaries of the village are generated by dissolving the cadastral boundaries and panchayat boundaries are obtained by dissolving the village boundaries. To carryout suitability analysis using multi-criteria evaluation with the available datasets, a vector-based GIS software package ArcGIS 10.0.2 and its extensions were used. In order to use GIS for selection of suitable medical facilities, the available information for the study area was digitized and stored in the information system.

4. Methodology

Methodology for the proposed research work has been summarised in Figure 3.

The various thematic datasets viz. landuse/cover, road network, drainage and rail are delineated from the 2.5 m spatial resolution IRS imagery (fused product of (orthorectified Cartosat-1+LISS- IV)). The details of the population and household information in each village have been taken from the Govt. of India, census 2011 (GOI 2016) the same has been summarized in Figure 4.

4.1. Decision rules for identification of candidate sites

The following decision rules have been applied to derive some parameters for obtaining the candidate site locations which are further used in the location-allocation model in GIS:

- The land use may be barren land, scrub land or salt affected land.

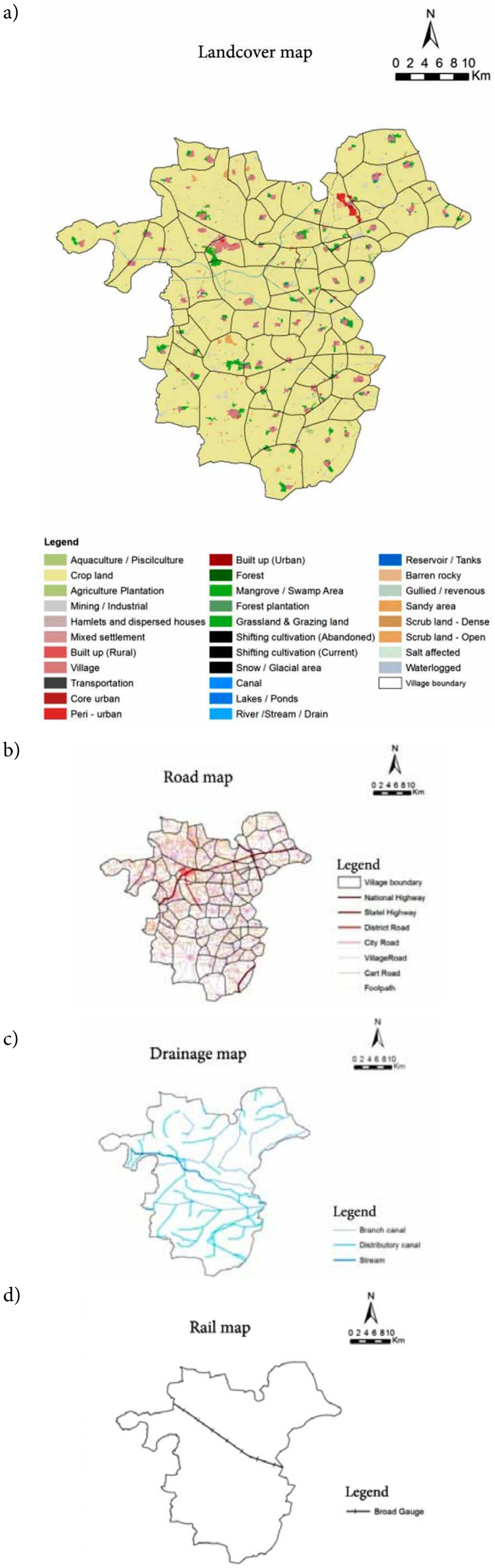

Fig. 2. Thematic maps: a) Landcover, b) Road, c) Drainage, d) Rail

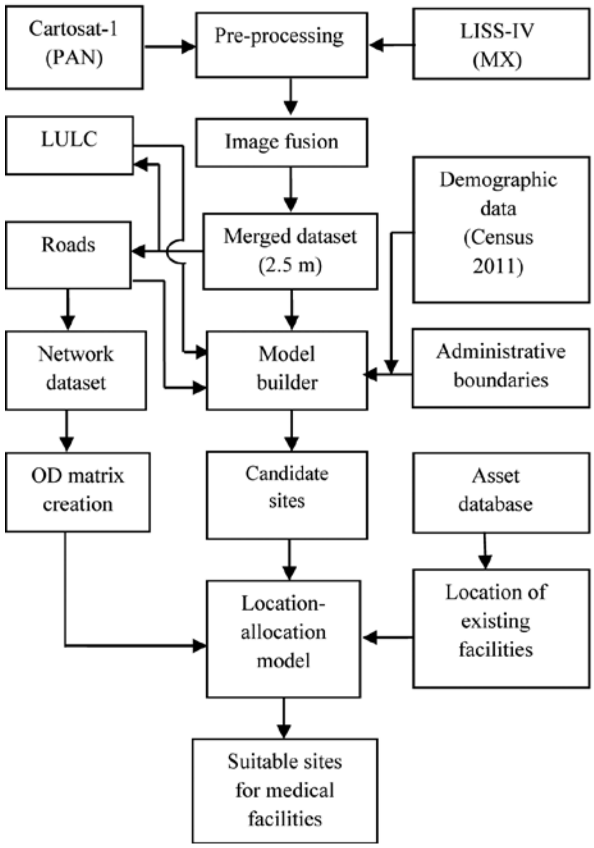

Fig. 3. Methodology

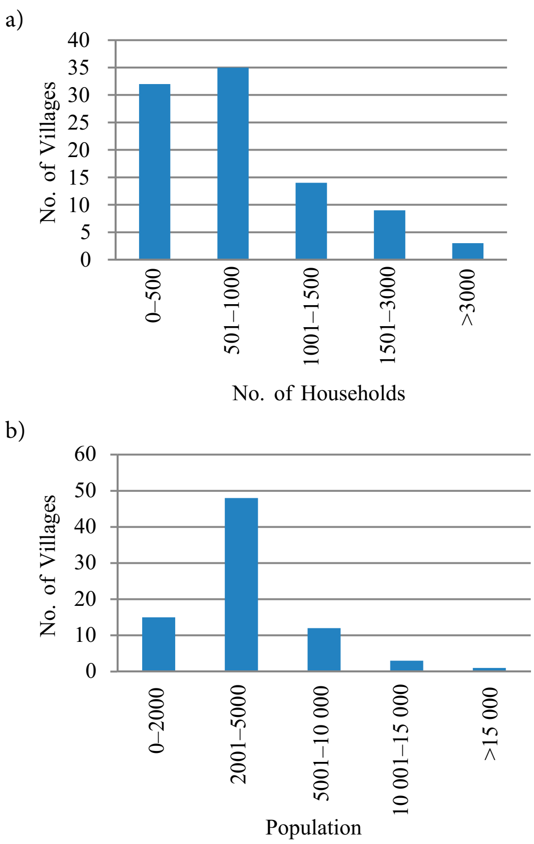

Fig. 4. Plot of Demographic Information: a) No. of Households vs. No. of villages, b) Population vs. No. of villages

- Settlement should be connected to the proposed sites through pucca road (village road) network.
- Village population should be in the range of 4000–10000 and No. of households in the village should lie between 1000–1500.
- The candidate facility site should be restricted to fall in a locality where the same facility already exists and distance from the settlement should be minimum.

The population and household information of the all 79 panchayats is summarized in the Table 2.

Table 2. The details of different group of population as per the Census 2011

S. No.	Total	Population
1	No. of Households	53967
2	Total Population	310398
3	Male Population	165727
4	Female population	144671
5	No. of Literate	155795
6	No. of illiterate	154603
7	Working population	138481
8	Working male population	85023
9	Working female population	53458

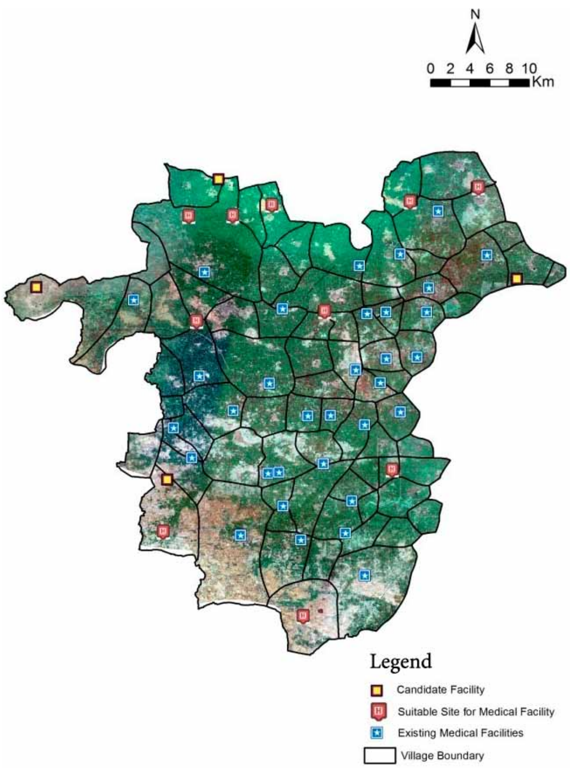

Fig. 5. Location of the proposed sites for medical facilities overlaid on satellite imagery

5. Results and discussion

A total of 79 village panchayats are covered in the study region. The average population of each village panchayat is 4000. It can be inferred from the Generic Public Health Delivery System envisioned by NRHM (Table 1) that the each village may have at least one medical facility within its vicinity. Now the question is at which location the medical facility required to be constructed while taking the locations of existing medical facility into consideration. The idea is to give less weightage to the village locations where the medical facilities are already available. The next required information is the type of land on which the medical facility has to be constructed. The information on type of land cover has been extracted from the Landuse/cover layer generated at 1:10,000 scale. The average geographical area of each village is 15.5 km^2. To make the proposed sites reachable from the settlement locations, the road information and its connectivity with different habitation is also required which has been extracted from road layer of the study region. A total of 33 medical facilities were already present in the different villages. This information has been gathered by collecting the geo-locations of the available medical facilities and capturing the photograph of the respective facilities. The details of the different facilities have been provided in Table 3. The analysis has been conducted using Location -allocation method in ArcGIS which requires several spatial layers as input such as required facilities, candidate facilities and demand points. The spatial layer for candidate facilities has been created by building a model in GIS. The model output a total of 14 locations as the candidate facilities in the study region by applying all the decision rules to the input thematic datasets. The location-allocation model identifies the 10 suitable sites out of 14 candidate sites for the medical and health facilities. The suitable locations for the medical and health facilities resulted from the analyses have been shown in Figure 5.

Table 3. Details of the different facilities

Type of facility	No. of existing facilities	No. of candidate facilities	No. of proposed sites
Hospital/Clinic	33	14	10

The validation of the proposed location is based on the information extracted from the recently generated thematic datasets from the ortho-rectified high resolution satellite imagery.

Conclusions

In this paper, an approach to indentify the suitable sites for the medical facilities such as hospital/clinic has been proposed. A group of villages which lack the medical facilities in the region are chosen as the area to carry out the pilot study. Various thematic layers such as Landuse/cover, drainage, rail, road and assets locations along with the non-spatial datasets (demographic as per the census 2011) have been used for the analyses. The adopted approach has been found very promising in identifying the suitable sites for medical and health facilities. The huge thematic datasets for entire country generated under the project Space Based Information Support for Decentralized Planning (SIS-DP) at 1:10000 scale is available, the same may be used to carry out the analysis in a bigger way to assist the decision makers in quick and accurate decision making in planning and developmental activities at all three levels of Governance viz. District, Block and Village-Panchayat. The proposed approach can be effectively utilized by the Government for Health Service Development Planning in Rural areas where medical and health facilities are poor.

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