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Selection of Solid Waste Dumping Site for Ludhiana City using Geoinformatics

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ABSTRACT
The Ludhiana city has been selected for identification of suitable sites for solid waste dumping/landfilling in the present study using CARTOSAT-I, IRS LISS-IV satellite data for the year 2008-09. Geographical Information Systems (GIS) based methodology was applied in order to identify and select potential suitable sites. The various parameters for the selection of suitable sites such as distance from built-up, forests/plantations, water bodies (river, canals and ponds), transportation along with wasteland, geology and ground water depth were examined. The respective thematic, buffer and classified maps were prepared. Analytical Hierarchy Process (AHP) model was incorporated in a GIS environment to obtain the weightages of different criteria and then they were overlaid according to their priority. The site suitability map for solid waste dumping/landfilling was prepared by considering proximity to the religious and recreational places, lithology, rivers and drains. Five suitable sites were identified out of which, three sites have been proposed and recommended as best suitable site viz. Alamgir, Narangwal and Assi Kalan villages covering an area of 100.78 ha, 50.89 ha and 25.69 ha respectively. Alamgir site situated 10 km away from the center of the city was found to be highly suitable for solid waste dumping for Ludhiana city which can accommodate huge amount of solid waste generated every day.

Keywords
AHP, Disposal site, GIS, Solid waste dumping, Suitable site

1. INTRODUCTION
An increase in urban population due to industrial growth and migration of people causes the increase in annual solid waste generation in many folds. The tremendous increase in per capita generation of municipal solid waste (MSW) results from improved lifestyle and social status of the populations in urban centers [1]. Management of solid waste is now a major global concern that is increasing day by day. Of the various techniques of solid waste management, land filling is the most popular and widely prevalent technique in India [2]. The processing and evaluation of spatial data with respect to various parameters governing the suitability of a site is required to select a solid waste landfill site [3]. In India, approximately 100,000 metric tons of solid waste generated everyday of which 90% is dumped in the open place. The MSW generated per day in India's major cities viz. Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Lucknow and Ahmedabad are 5000, 6050, 3500, 2500, 2000, 1800 to 2000, 1500 and 1280 tons respectively [4]. In Punjab, about 3034.65 tons per day of solid waste is being generated from municipal areas of the city. The MSW generated per day in Punjab's major cities viz. Patiala, Ludhiana, Jalandhar and Amritsar are 180, 850, 350 and Amritsar 450 tons respectively [5]. Out of total MSW generated, 71% is from the five corporations (Ludhiana, Amritsar, Jalandhar, Patiala and Bathinda) and out of this 31% from Ludhiana city only which is the largest volume in Punjab. The municipal corporation (MC) limit of Ludhiana city is spread over an area of 14100 ha. The population of the city within the municipal corporation is estimated about 34, 87,882 in 2011 [6]. There are three major designated municipal solid waste landfilling sites available at Ludhiana viz. Jainpur, Jamalpur and Noorpur Bet. Out of these, only Jamalpur site is being used. However, Jainpur site has been filled and Noorpur bet spread over 21 acres is just a long stretch near Satluj river and is not broad enough to accommodate the solid waste that may contaminate land and water. The huge amount of solid waste generation due to increasing population cannot be accommodated by single available site of dumping at Jamalpur. An alternate site for solid waste dumping/landfilling is therefore, urgently required for Ludhiana city, which must be environmentally suitable, economically viable and socially acceptable. Thus, finding a suitable site which is fit for both environment and health of people adds a significant point of view for this study. More efforts are needed to overcome the problem of land shortage for waste disposal and allocation of inappropriate landfill site in most of large urban areas. In most of the cases solid waste landfilling sites are selected randomly and waste is burned (with and without treatment) which impacts nature and human. To minimize these affects a solid waste dumping/landfilling site must be consider the processing and evaluation of many different criteria (spatial, economic and social) governing the suitability of site. Geographic information systems (GIS) and analytic hierarchy process (AHP) decision making procedures are required for appropriate site selection. GIS allows entering, storing, manipulating, analyzing and displaying large volumes of spatial data and facilitates spatial decision-making and planning processes[7]. In order to find a suitable landfill/dumping site, GIS can be integrated with Analytic hierarchy process (AHP) which is a powerful tool to identify the dumping/landfill site. The present study endeavors to identify suitable sites using remote sensing and GIS techniques for solid waste dumping around Ludhiana city of Punjab, India.

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2. DESCRIPTION OF STUDY AREA

The Ludhiana district is situated in central part of Punjab covering about 370600 ha geographical area having conspicuously flat terrain and the river Satluj flows along the northern side of the district.About 82 % of total geographical area of the district is under agriculture, which is the primary source of income for the inhabitants and the industry is secondary occupation for sizeable local and migrant population. The Ludhiana city was selected for the study which lies between latitude $30^{0}55'$N and longitude $75^{0}54'$E[8]. The location of the study area is generated by applying a 10 km buffer around the settlement boundary of Ludhiana city (Figure 1) which covers an area of 102842.33 ha within Ludhiana district. About 26% of the total geographic area of the city is under built-up and remaining represents other land use and land cover activities.

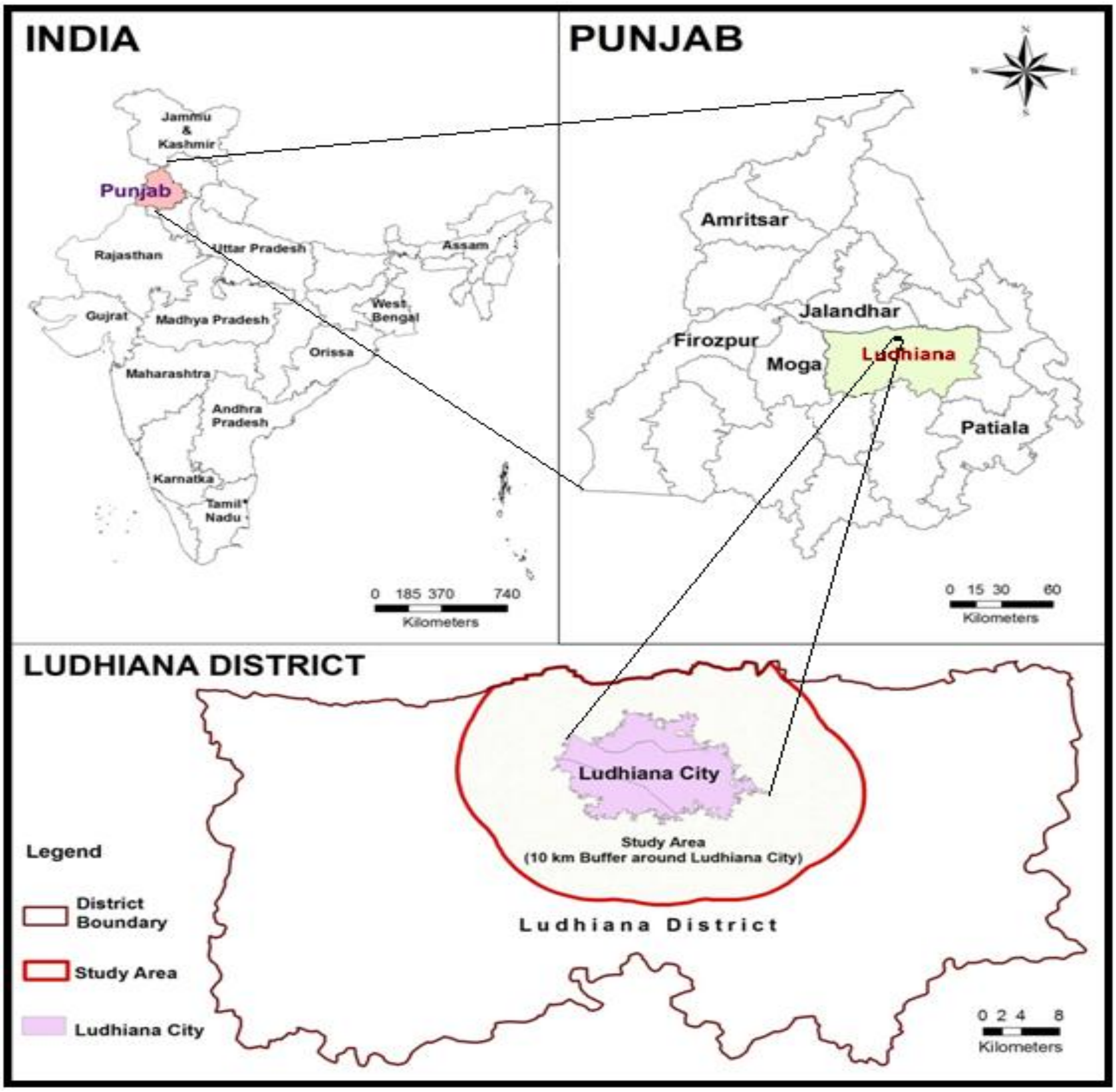

Fig 1: Map of study area map

The boundary of municipal corporation (MC) of Ludhiana city is extended to villages in the east are Bhamian Khurd, Bhamian Kalan, Mundian, Mangli, in West are Ayali, Tharike, in south are Gill, Dhandran and in north are Bahadur Ke and Nurwal covering an area of 14200 ha. The major part of the selected area (20 %) has been covered by built-up and the few area (0.99 %) is under wasteland. The other classes such as water bodies (river Satluj, canals and village ponds) and forest/plantation covers an area of 1640.22 ha (1.60%) and 3724.42 ha (3.62%) respectively.The Study area has a good network of roads connecting Ludhiana city to Khanna, Samlara, Phillaur, Moga and Malerkotla. There is a railway line from Ludhiana to Moga, Khanna, Phillur and dhuri. The national highway, state highway and district road have been categorized as major roads and some village roads are also mapped (Figure 2).

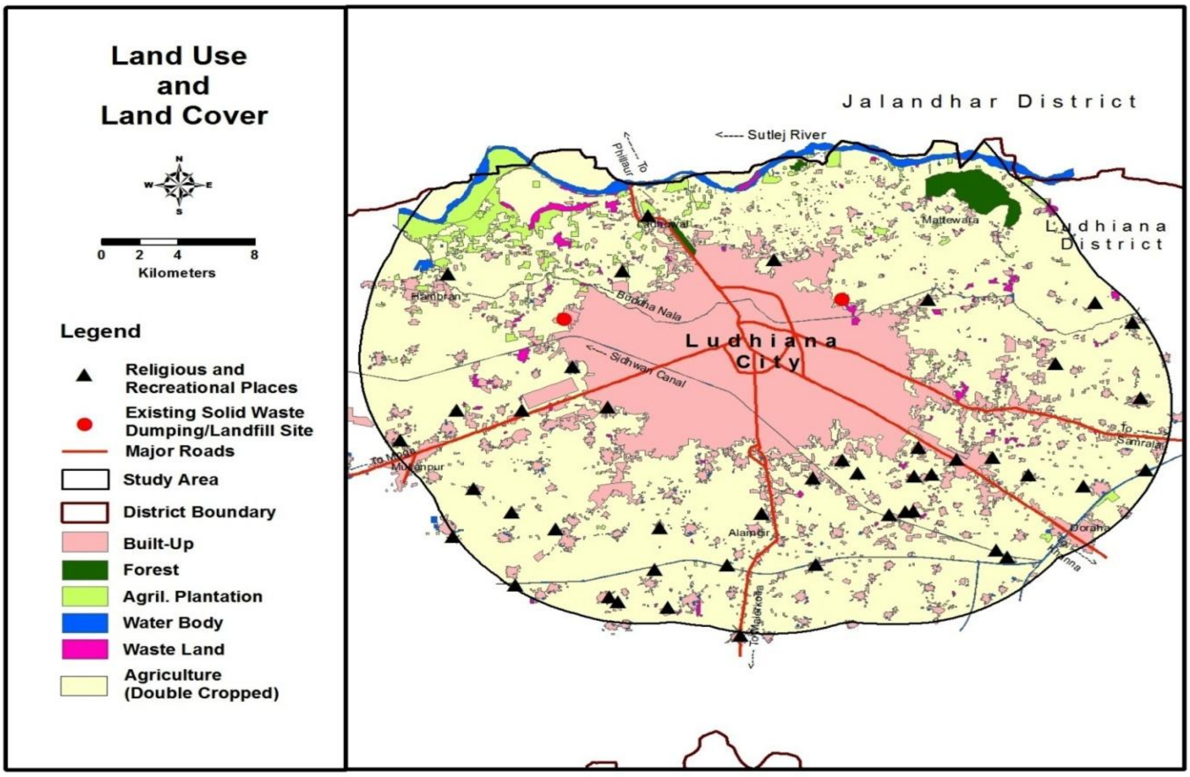

Fig 2: Land use and land cover map of study area

3. MATERIAL AND METHOD

The GIS-based solid waste dump/landfill site selection approach combines the spatial analysis tools to integrate and evaluate different datasets based on certain evaluation criteria. The IRS LISS-IV and CARTOSAT-1 merged digital satellite for the year 2008-2009 acquired from Punjab Remote Sensing Centre (PRSC), Ludhiana for built-up, water bodies, forests and plantations, wasteland, roads, railway network, current disposal sites and other land use activities etc. The spatial resolution of CARTOSAT-1 (PAN) and LISS-IV (Multispectral) merged image is 2.5 m. However, the LISS-IV has high resolution multi-spectral camera which operates in three spectral bands viz. 2(Green), 3(Red) and 4(Near InfraRed). Ground water table map of study area was generated using village wise water table data for the year 2012 (Post Monsoon) obtained from Department of Agriculture. Geological map of study area was obtained from Geological Survey of India [9]. The database regarding the categories and names of the features were added using the information in the Survey of India 1:50,000 topographical sheets.

The obtained data were visually interpreted on-screen, digitized and edited for topographical errors and converted into digital format in the ESRI ARC GIS 9.3 environment for the spatial analysis. The AHP model was applied on the selected criteria, and suitable weightages were allocated. All the layers were then converted into raster format and spatial analyst tool (weighted sum) was applied for finding out the suitable location for the dumping/ landfilling.

4. ANALYSIS

The analysis was carried out by using AHP model to compute eigen values and eigenvectors for assigning the weights to different criteria for selection of solid waste dumping/landfilling site based on the pair-wise comparisons [10]. A pair-wise comparison of the criterion was done to establish the relative importance of the criteria for identifying a suitable solid waste dumping/landfilling site (Table 1 and Table 2). Seven criteria have been selected for AHP model pertaining to distance from built-up, water bodies, forests/plantations, transportation network and nearness to waste land along with depth to water level and geology of the study area. The analysis from AHP model is presented in table 3, which indicates that the most important criteria are built-up, water bodies and depth to water level with priority percentages of 42.23%, 17.93% and 15.56% respectively. The forests/plantations (7.4%) and transportation (9.5%) are medium importance criteria. Geology and waste land with priority percentage of 5.23% and 2.15% respectively showed as the least important factors. The weights calculated for each criterion (n=7) are then used to derive a consistency ratio (CR) of the pair-wise comparisons which was computed from table 1 and table 2. The value of CR was found to be 0.18 which is slightly more than required value 0.10 but it is acceptable in range [11], [12]. The sum of AHP weights of all the parameters was found to be 1 (Table 3) which indicates that the weighted parameters are contributing for selection of solid waste dumping/landfilling site.

Table 1: Pair-wise comparison matrix of criteria

Criteria	BU	FP	WB	G	DWL	WL	T
BU	1	7	5	7	5	9	5
F/P	0.14	1	0.33	3	0.33	7	0.33
WB	0.20	3	1	5	3	5	3
G	0.14	0.33	0.20	1	0.14	7	0.33
DWL	0.20	3	0.33	7	1	7	3
WL	0.11	0.14	0.20	0.14	0.14	1	0.20
T	0.20	3	0.33	3	0.33	5	1
Sum Σ	**2.00**	**17.48**	**7.40**	**26.14**	**9.95**	**41.00**	**12.87**

Where,
BU=built-up; **F/P**=forest/plantation; **WB**=water bodies; **G**=geology; **DWL**=depth to water level; **WL**=waste land; **T**=transportation

Table 2: Pairwise comparison matrix of criteria by cross-analysis

Criteria	BU	FP	WB	G	DWL	WL	T	Weightage or Priority vector
BU	0.5013	0.4006	0.6758	0.2678	0.5025	0.2195	0.3886	**0.4223**
F/P	0.0712	0.0572	0.0450	0.1148	0.0335	0.1707	0.0259	**0.0740**
WB	0.1003	0.1717	0.1352	0.1913	0.3015	0.1220	0.2332	**0.1793**
G	0.0712	0.0191	0.0270	0.0383	0.0143	0.1707	0.0259	**0.0523**
DWL	0.1003	0.1717	0.0450	0.2678	0.1005	0.1707	0.2332	**0.1556**
WL	0.0556	0.0081	0.0270	0.0054	0.0143	0.0244	0.0155	**0.0215**
T	0.1003	0.1717	0.0450	0.1148	0.0335	0.1220	0.0777	**0.0950**

Principal Eigen Value **(λ_{max})= 8.4823**, Random index for 7 factors **(RI7)= 1.32**, Consistency Index **(CI) = 0.2470**, Consistency Ratio **(CR) = 0.1872**

Table 3: Final weightage of each criterion

Criteria	Weightage/Priority vector	Priority Percentage
Built-up	0.4223	42.23
Forest/Plantation	0.0740	7.40
Water Bodies	0.1793	17.93
Geology	0.0523	5.23
Depth to water level	0.1556	15.56
Waste land	0.0215	2.15
Transportation	0.0950	9.50
Total	1	100

The buffer analysis has been carried out on these layers and total of 10 buffers have been generated in GIS Environment. Each of the buffer is of 1km interval and reclassified with numerical weightages as 1, 2, 3, . . .10 with higher value to the buffer being more suitable for the selection of solid waste dumping/landfilling site and vice-versa. The digitized waste land area in the classified waste land layer was given numerical weight 9 remaining study area has given the weight 1 which indicates that the value 9 is suitable and 1 is unsuitable for the selection of solid waste dumping/landfilling site. The zone wise water table depth was demarcated, and higher value weightage was assigned to zone with maximum depth of water and vice-versa. The weightage values assigned for more than 20 m, 15-20 m and less than 15 m from ground surface are 8, 5 and 2 respectively. Each of the sites was also analyzed with litholog data for information about soil infiltration capacity which support in selection of suitable site. The layers were converted into raster format after reclassification. The weightage value of criteria obtained from AHP model was given input to the weighted sum tool and resultant weighted overlay analysis map was prepared (Figure 3). The resulting weighted overlay analysis map has further been re-classified into three classes of suitability viz. suitable, moderately suitable and highly suitable areas and the remaining part of the study area has been excluded as unsuitable for solid waste dump/landfill (Figure 4).

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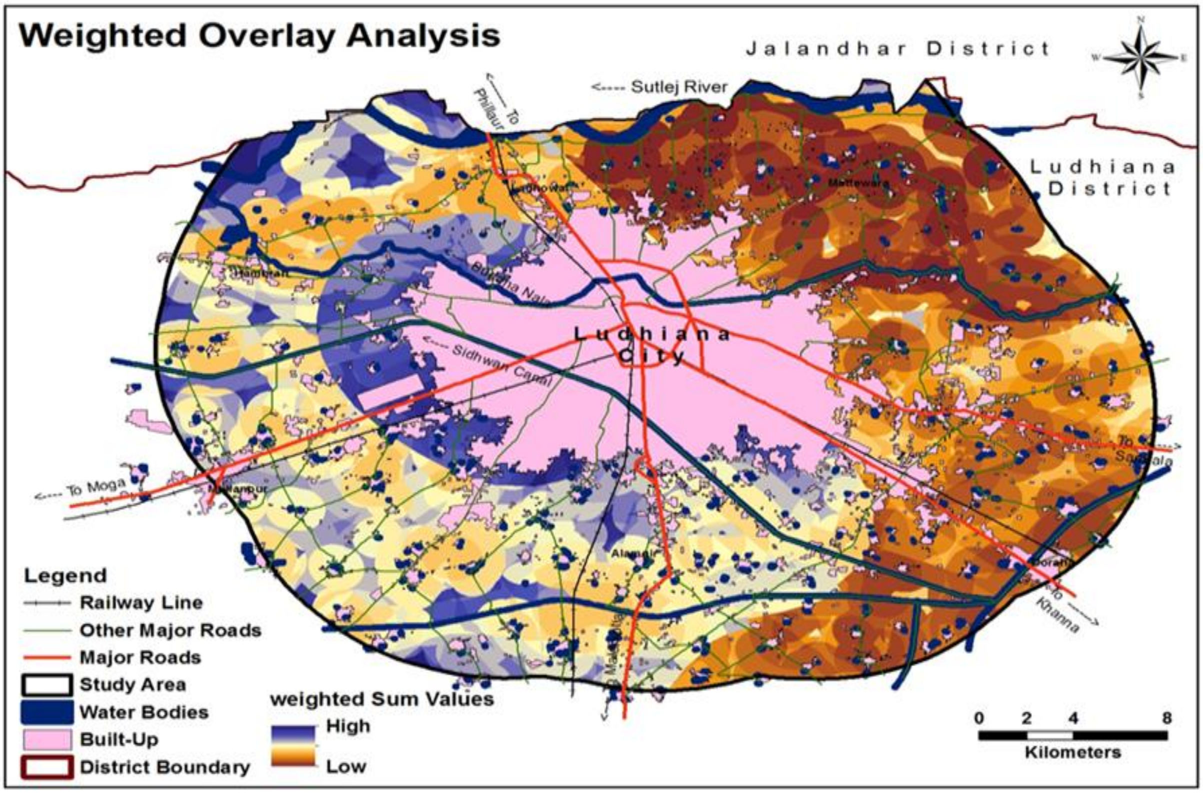

Fig 3: Weighted overlay analysis map for solid waste dumping/landfilling

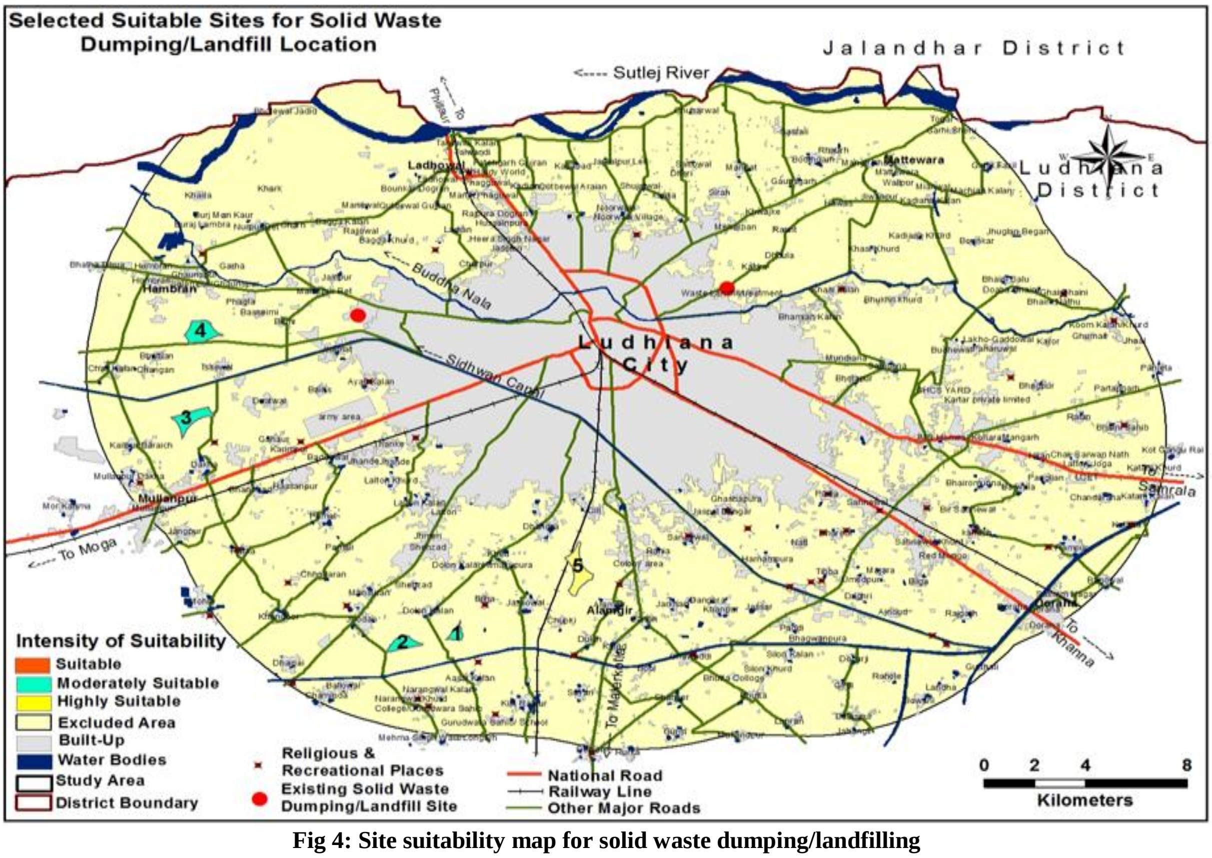

Fig 4: Site suitability map for solid waste dumping/landfilling

5. RESULTS AND DISCUSSION

Many suitable sites were found around the Ludhiana city by the weighted overlay analysis of criteria (Figure 4). As per municipal solid wastes management and handling rules [13], the solid waste dumping/landfilling site should be at a safe distance from the residential localities, water bodies (village ponds, canals, rivers and drains), forests and plantations and transportations (major roads). The waste disposal site should be in an area where ground water is at enough depth so that ground water quality is not affected. Figure 3 depict that the value ranging from high to low indicates the most and least suitable areas for locating solid waste dumping/landfilling sites. Probability of suitable sites seems to be more in western and southern sides of the study area. The suitable sites in the north western side of the Ludhiana city were excluded due to presence of Sutlej River. The remaining sites were found in the western, south western and southern sides of Ludhiana city. There was no such site found under suitable class. The sites found in moderately suitable class are near to Assi Kalan, Narangwal, Issewal and Dakha. The Alamgir village site was found under highly suitable class. Five suitable sites were selected after the ground truth, considering proximity to the religious and recreational place, river and drains. These sites are situated in Alamgir, Dakha, Issewal, Narangwal and Assi Kalan villages. Out of these, three sites were proposed for solid waste dumping/landfilling for Ludhiana city considering all the possible criteria viz. Alamgir, Narangwal and Assi Kalan. The Alamgir village site was found under highly suitable class having largest area of 100.78 ha with 10 m depth of clay layer from ground surface situated at 10 km from the center of city and 1 km away from historical religious place (Alamgir Gurudwara). The Narangwal (50.89 ha) and Assi Kalan village site (25.69 ha), both were found under moderately suitable class with clay layer at a depth of 10 m from ground surface situated at 18 km and 17 km from center of the city respectively.

6. CONCLUSION

Solid waste dumping/landfilling suitability map of the Ludhiana city was prepared after overlay operation of site selection criteria using remote sensing and GIS techniques. The site suitability map indicates that the most of dumping/landfilling sites were found in southern, western and south-western sides of Ludhiana city. There was no suitable site in eastern side of the city for solid waste disposal. Total five sites were identified for solid waste disposal viz. Alamgir (100.78 ha), Issewal (92.14 ha), Dakha (77.32 ha), Narangwal (50.89 ha) and Assi Kalan (25.69 ha)villages at 10 Km, 20 Km, 18 Km, 18 Km and 17 Km from center of the city respectively. Out of which, three sites were proposed and recommended for solid waste dumping/landfilling considering lithologs of locations which are situated in Alamgir, Narangwal and Assi Kalan villages. The Amalgir village site was found to be highly suitable having an area of 100.78 ha for solid waste dumping/landfilling in southern side of Ludhiana city situated at 10 km from the center of the city. The proposed site is environmentally suitable and broad enough to accommodate the huge amount of solid waste generated every day in Ludhiana city.

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