Proceedings of the Pakistan Academy of Sciences:
B. Life and Environmental Sciences 53 (4): 309–321 (2016)
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ISSN: 2518-4261 (print), ISSN 2518-427X (online)

Pakistan Academy of Sciences

Research Article

Identification of Suitable Sites for Solid Waste Disposal using GIS Multi-criteria Analysis in Peshawar, Pakistan

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Abstract: In this paper an effort has been made to identify suitable sites for safe disposal of municipal and other solid waste generated in Peshawar City District. Using GIS and Remote Sensing for identification of landfill site is more economical and effective than traditional techniques. Selection of suitable site depends on a number of factors to ensure environment friendly disposal of solid waste. For analysis and identification of suitable site for safe disposal in Peshawar city district, SPOT satellite image of 2010 and Topographic sheets have been used as a base map. Primary and secondary data were collected from various sources. Using multi-criteria analysis in ArcGIS 9.3, surfaces were generated for all the selected parameters by applying spatial analysis tools. Weighted parametric values were assigned to all the layers using some of the Environmental Protection Agency standards parameters for selection of landfill site. The sites were selected having minimum environmental consequences. Based on the selected parameters including distances from residential areas, airport, water bodies, distance to spine roads, water table, land values, slope stability and land use pattern were used. As a result, the entire Peshawar city district was divided into three regions of least suitable, moderately suitable and most suitable landfill sites. The most suitable sites were located largely in southern parts of the city district where weight according to site suitability was the highest.

Keywords: Accessibility, suitability, land use pattern, land values, EPA parameters, GIS, landfill site

1. INTRODUCTION

Solid waste is any discarded and other abandoned materials. They are found in different states like solid, liquid, semi-solid as well as gaseous material, emitting from industrial, commercial, mining and municipal uses [1]. Globally, the increasing urbanization has multiplied the quantity of solid waste generation in cities. In developing countries, it is common for municipalities to spend over 20 percent of the city recurrent budget on solid waste collection and disposal [2]. However, almost half of the total generated waste remains uncollected in developing world [3]. It has estimated that 30% of total urban dwellers are un-served in terms of waste collection [2]. Batool and Chaudhary [4] discerned that in cities of the developing countries open dumping and burning is a norm.

Pakistan, like other developing countries, is also facing serious environmental problems. Disposal of waste is problematic in almost all major cities of Pakistan due to lack of strategic guidelines, consistent use of orthodox procedure of waste disposal, inefficient use of resources and improper control on dumping procedures [5]. Peshawar is the capital city of Khyber Pakhtunkhwa province and sixth largest city of the country [6] and is densely populated generating large amount of waste and there is no hygienic and environment friendly method for its disposal. Different types of waste generated in Peshawar city are hospital waste, industrial waste, municipal waste etc. Peshawar went through a very big and prompt structural change in terms of spatial growth after the migration of Afghan refugees since early 1980s and their settlement

Received, November 2015; Accepted, December 2016
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until now [7]. This also contributed to increase in generation of solid waste in the city. According to one estimate by Environmental Protection Agency (EPA), about 600-700 tones/ day of solid waste are generated in Peshawar city [8]. It makes a per capita about 0.3 to 0.4 kg per day. Bulk of this waste is generated in rural areas where it is used as manure in agricultural fields. As most of the people in Peshawar belong to low and middle income, therefore, waste generation rate varies in various parts of the city [9]. Many irrigation channels pass through Peshawar and houses are being built along these channels on either of the banks. People dispose their household waste into those irrigation waters, which is influencing water quality as well as causing overflows because of blockage of culverts in the course of these channels.

The overall goal of urban solid waste management is to collect, treat and dispose of solid wastes generated by all urban population groups in an environment friendlier, general public acceptable and cost effective manner [10-11]. Most government agencies do not have the necessary mechanisms neither have capability to effectively engage all parameters for safe and efficient disposal of their municipal waste [12-13]. Although in Peshawar, recently efforts are done for improving collection process of solid waste but disposal is still a big issue. Inefficiently disposed municipal waste is a potent threat to human health and the environment spreading infectious diseases. Due lack of adequate disposal sites, much of the wastes find its way on open spaces, roads sides, agricultural lands, ponds, rivers and flood plains causing significant environmental damages.

It is imperative to note that there is a big gap in Pakistan between solid waste generation and the amount reaching final disposal sites. At present solid waste in Pakistan is not collected, transported and disposed of properly; therefore, environmental and sanitary conditions have degraded over the years. Waste generated per capita increases with increase in per capita income [14-15]. Quantity of solid wastes also varies with seasons of year. Uncontrolled urbanization also leads to increase the generation of solid waste [16].

This study underscores the significance of using modern techniques like GIS and Remote Sensing to identify suitable sites to minimize the environmental problems resulting from solid waste disposal practices. It takes into consideration some of those important parameters as indicated by EPA of Pakistan. Weights were assigned based on importance of the parameters used. In this research weight is used in terms of a value given to an assessment that shows its significance in relation to other factors under consideration [17]. Simple additive weighting method was used for analysis also called as weighted linear combination or scoring technique. This method is straightforward and most frequently used multi-attribute decision method [18-21] successfully applied analytic hierarchy process (AHP) in Oklahoma for landfill location. Erkut and Moran. Erkut and Moran [22] used the same AHP for siting landfill in Alberta, Canada. Lober in 1995 included social criteria in the suitability analysis for recycling site [23]. He combined the social criteria with environmental one to achieve a more sustainable and acceptable location. Omua et al. [24] used the GIS multi-criteria analysis for siting of optimum site for municipal wastes in Kenya using various environmental criteria. Yesilnacar [25] applied the same technique in Turkey.

This paper also combines the environmental and social criteria for selection of suitable landfill site in one of the fastest growing city of Pakistan. This technique is based on the average weights for the criteria used. Assessment score is considered for each option by multiplying the value assigned to the choices of that attribute with the weights of relative importance given by decision maker. Finally, products for all criteria were summed up. For example agriculture land was given less weight than barren land. Areas having high land values were given low weight than areas having low land values so as cost of purchasing land may be minimized. Similarly, a buffer was created around residential area and water bodies so that landfill site may not be located near them. Moreover, a five kilometer buffer was generated around airport where the land fill site should not be located. Percolation from landfill site is a common phenomenon therefore; area with high water table was given low weights. Steep slopes and very gentle slopes were also given low weights so that the site may be more stable.

Most of the attributes concerned with the development of suitable landfill sites are spatial in nature that has provoked the prevalence of geographical approaches that permit for the combination of numerous attributes using GIS [23, 10, 26-30].

2. MATERIAL AND METHODS

This study is based on the collection of primary and secondary data. The procedure for data collection is as follows:

- SPOT Satellite image 2.5m of 2010 obtained from SUPARCO Regional Office, Peshawar for the city was the main source of data for the study. Topographic sheets of 1:50,000 Scale obtained from Survey of Pakistan for the district Peshawar, were used as a base map [31].
- First of all the topographic sheets and satellite image were Georeferenced using tie points. Lambert Conformal Conic coordinate system was retained in this process. The other layers like rivers, major roads, contours were digitized from the topographic maps. For this purpose, topographic sheets of scale 1:50,000 were used [31].
- Ground water table data was obtained from Public Health Engineering Office as well as from the field. Data for ground water table was converted into surfaces using IDW interpolation technique. Literature about the solid waste was collected from different books, articles and journals.
- The collected data was then analyzed using different software. ERDAS IMAGINE was mainly used for image enhancement and image classification, but Arc GIS 9.3 was the major software used for analysis.
- Then the satellite image was classified for different land uses to get the land use layer. These layers were interpolated in the Arc Map followed by reclassification of the interpolated surfaces. New numerical values were given to different classes for analysis.
- Finally, all these raster surfaces were combined in the weighted overlay analysis tool. Then this combined weighted map was reclassified for the identification of final map. Areas with lowest weights were assigned as least suitable while areas with highest weights were assigned as the most suitable location with minimum environmental consequences.

Pakistan Environmental Protection Agency (EPA) has established following guidelines for selection of solid waste disposal sites. Some of these criteria were incorporated in this study [9].

- Adequate land area and volume to provide the landfill capacity to meet projected needs for at least twenty five years, so that costly investments in access roads, drainage, fencing and weighing stations are justifiable.
- The land should not be in areas where adequate buffer zones are not available or in areas immediately upwind of a residential area in the prevailing wind direction(s).
- Areas characterized by steep gradients, where stability of slopes could be/are problematic.
- The seasonally high table level (i.e. 10 year high) of the groundwater should be below the proposed base of any excavation or site preparation to enable landfill development.
- No environmentally significant wetlands of important biodiversity or reproductive value, sensitive ecological and/or historical areas should be present within the potential area of the landfill development.
- There should be no private or public irrigation, or livestock water supply wells down-gradient of the landfill boundaries because they are at risk from contamination alternative water supply sources are readily and economically available.
- No residential development should be adjacent to the perimeter of the site boundary. The waste disposal site should be at least outside a radius of one thousand meters away from a residential or commercial area and water sources.
- A buffer zone of no-development shall be maintained around landfill site and shall be incorporated in the concerned municipality's

land-use plans.

- Landfill site shall be away from airports.

Due to shortage of time and resources, present study is limited to only few of these criteria like distance from water bodies, distance from airport, water table, slope were taken into consideration. The remaining criteria may be taken into consideration in future studies. This paper will in long run help local planning authorities to select proper disposal sites using modern techniques like GIS/RS.

3. RESULTS AND DISCUSSION

The analysis was based mainly on the parameters taken from guidelines of Environmental Protection Agency (EPA) of Pakistan. The selection of suitable sites required different information about the geographical conditions of Peshawar city district.

Parameters necessary for the process of selection of suitable disposal sites are described with Figures below.

3.1 Land Use Pattern

Central part of the district mainly consists of built up area with little or no agriculture land (Fig. 1a). The southern part of the district, which constitutes Town IV, mainly consists of agricultural land with some patches of rocky area. This category could be best land for solid waste disposal but they are located too far away from the central city where most of the solid waste is generated. Agricultural land though not preferred could not be avoided because most dominant land use in Peshawar city district was agricultural land. As per requirement, built up area was to be avoided from the selection of site for solid waste disposal. According to criteria the landfill site should be at least 1000 meters away from the built environment. By reclassification of Euclidean distance area within 1000 meters was given 0 value while outside was given higher value (Fig. 1b). This buffer zone sets the limit for the built up area where no such site can be developed. This is an important condition to avoid health risk for the surrounding population.

It is clear from the Fig. 2a that most of the district consists of agricultural land particularly in the north and eastern part of the district with almost no barren or unused land area. The dominant land use is agriculture interrupted in some places by built up area and rivers. The western part of the city is dominated by range land and built up area, where Hayatabad Township and recently designed Regi Model Town are located.

Different land uses were given values for the final selection of the site. The land use which was most suitable was given high value and the one which was least suitable was given low value. As such barren rock area was given a value of 3, barren land was given value of 4 and agriculture was given the value of 2 and so on (Fig. 2b). Built up area and water bodies were given 0 value as they should in no way be considered for solid waste disposal site. Agriculture land could be used as a second option after barren land and range land. In Peshawar barren land are very limited or located in inaccessible areas so the site could be located on agriculture land.

3.2 Land Values

Land values play a very important part in selection of suitable site for waste disposal. Landfill sites should be located in such areas where the land values are comparatively lower. Average market values were collected for all parts of the district. Fig. 3 shows locations of all settlements about which land values were collected and incorporated in this study. Land values for these locations were interpolated using spatial analysis tool (Fig. 3b). Land values were very high for central locations while they were low for the surrounding areas (Fig. 4a). To avoid high land values areas, 0 value was given to areas having highest land values, while areas with lowest land values were given a value of 6 in the reclassified weighted map (Fig. 4b).

3.4 Transport Network

Transport network plays a very important role in selection of site for solid waste disposal. It determines a link between the areas where waste is generated to the site at which it is deposited. Transport network also determines the cost of transporting the waste from origin to destination. Suitable site should not be located too far away from the major roads so that there is no extra cost of

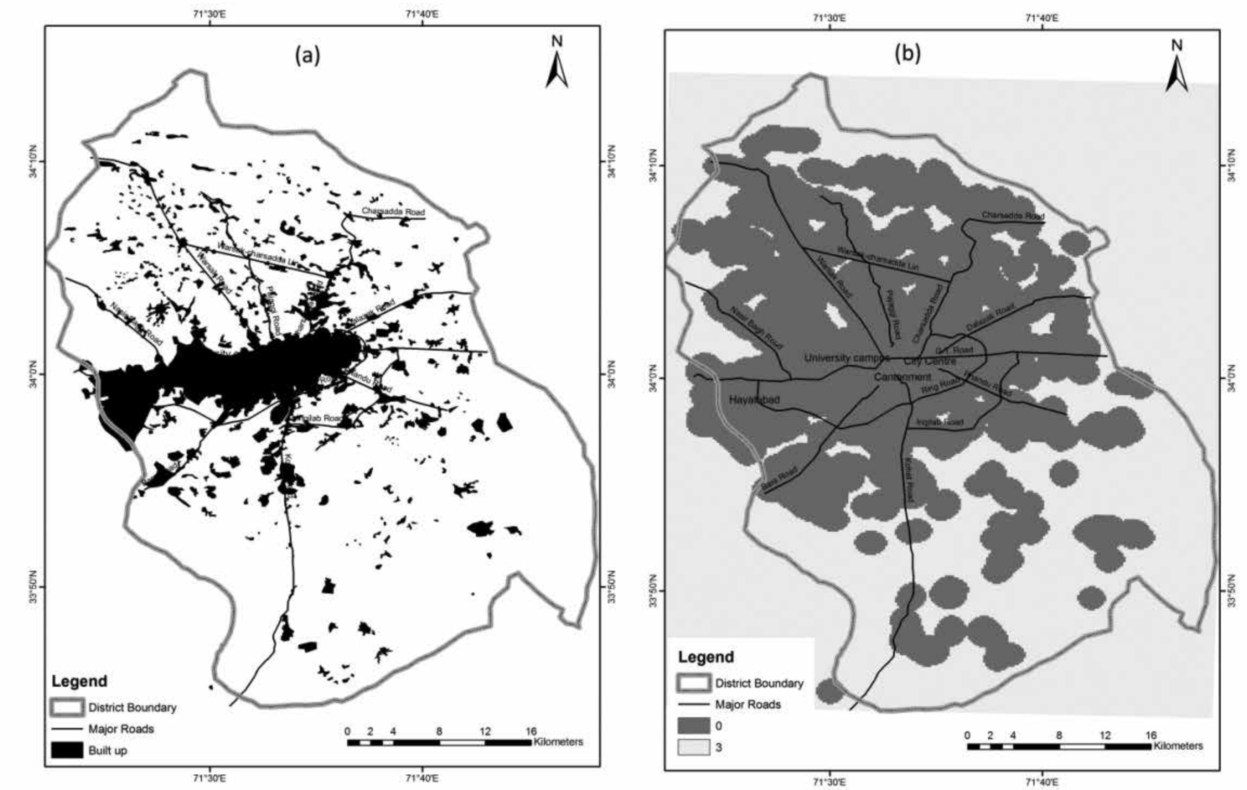

Fig. 1..**(a)** Built up 2010 after SPOT Image 2.5 m, 2010; **(b)** Weighted built up.

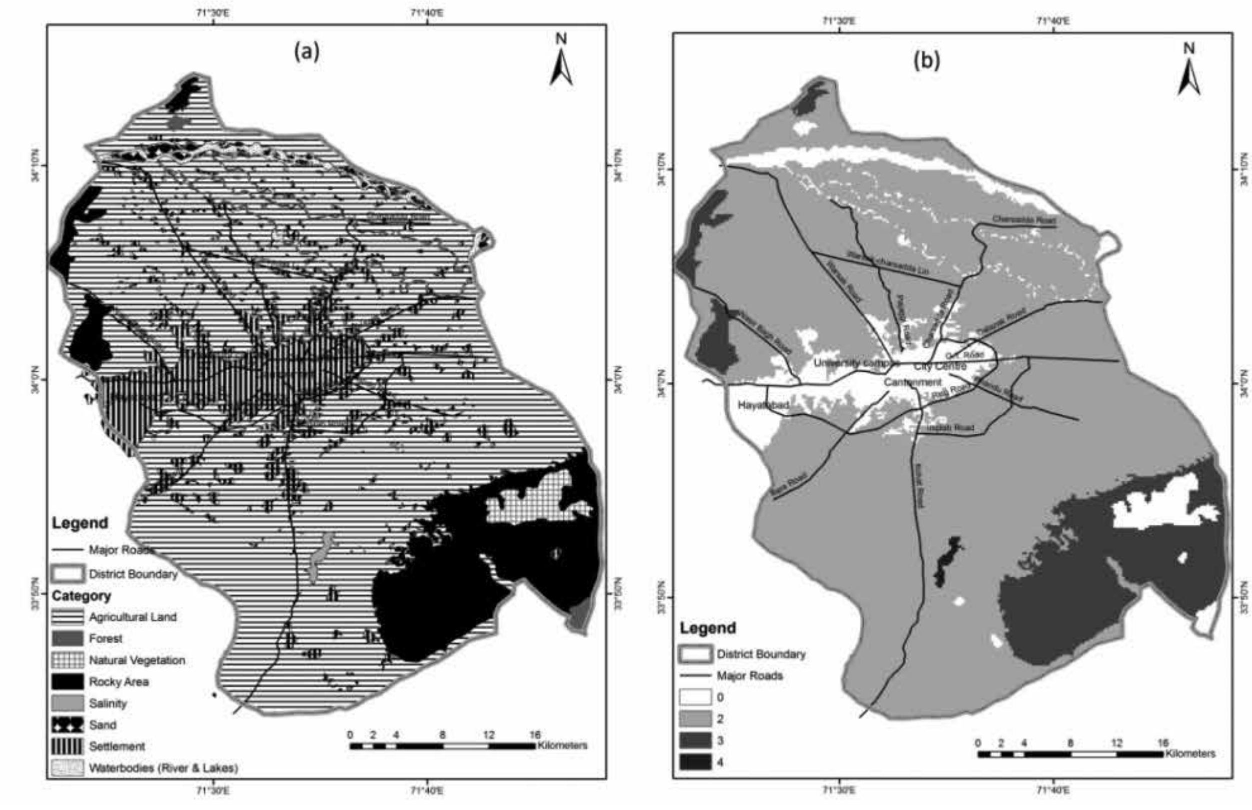

Fig. 2. (a) General Land use Pattern after SPOT Image 2.5 m, 20100; **(b)** Weighted Land use.

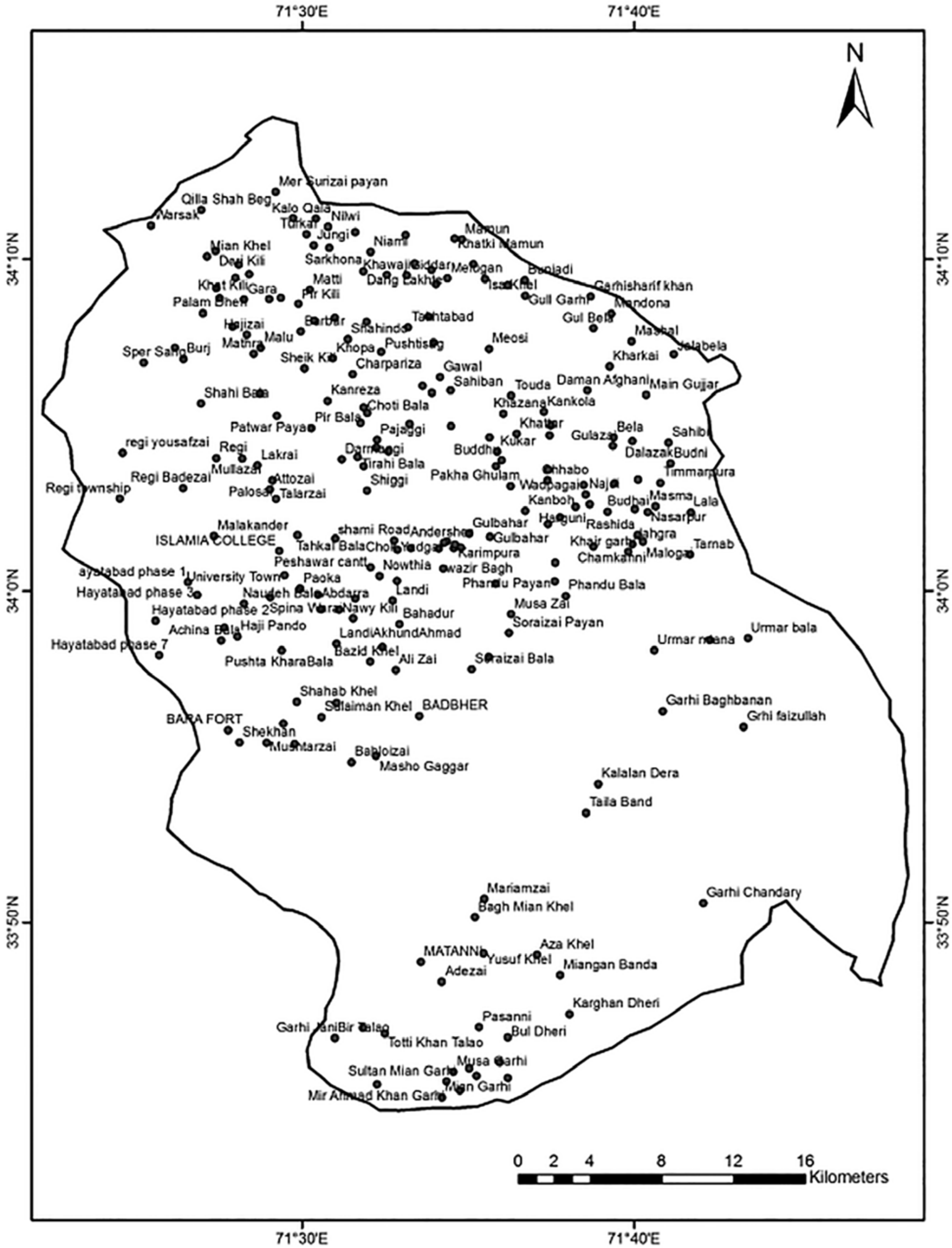

Fig. 3. Land values Sites (Source: Field Survey, 2010).

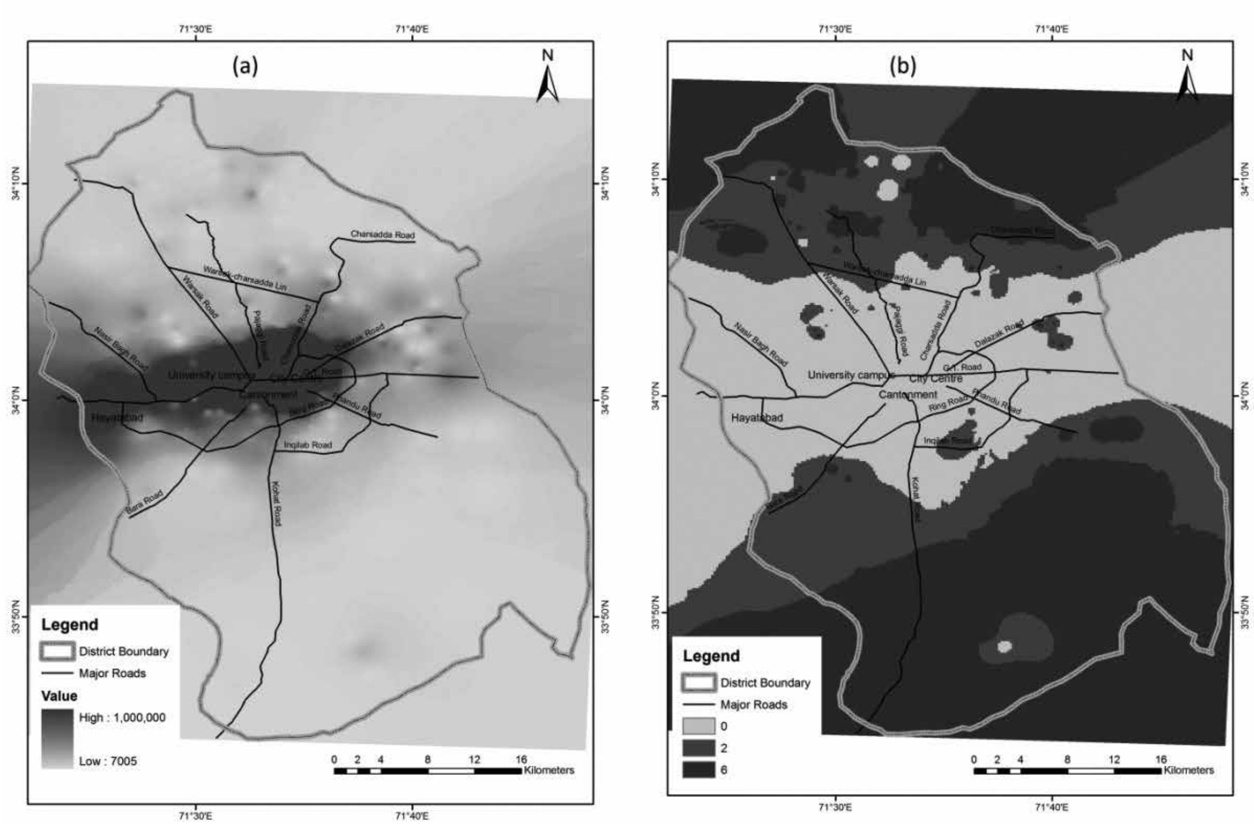

Fig. 4. (a) Land values, 2010; **(b)** Weighted land values.

transportation. For this purpose major roads were shown on the map so that a buffer of 5000 meters of the major road can be created where the site should be located. Distance of 5 km is considered as sufficient distance where the site could be located. Aesthetically, the landfill site should not be located very close to the roads so as to avoid inconvenience and pollution for the road users. For this purpose Euclidian distance tool in spatial analysis was used. In the reclassified weighted map, areas with 2000 meters were given a 0 value while areas located between 2000-5000 meters were given the highest value of 5 (Fig. 5b). Transport network criteria was not included in the original criteria defined by EPA but in this research it was incorporated to minimize the extra transport cost and to make the selection more economical.

3.5 Hydrological Network

For selection of site for solid waste disposal special care should be made for rivers and water bodies. As the criteria states that the selected area should not be in close proximity to significant surface water bodies, e.g., watercourses or dams. For this purpose all the important rivers and water bodies drawn as a separate layer (Fig. 6a). Locating solid waste disposal site near them will adversely affect their water quality. To achieve this objective and to avoid the adverse effects all the water bodies were restricted. A zone of 1000 meters created around all water bodies, was given 0 value in the reclassified map, while area outside was given a value of 5 (Fig. 6b). The existing dumping sites of the city district government in most cases are the rivers and streams like Budni River in the north and Bara River near Hazarkhwani in the south. That has made these rivers very polluted and unable to use for drinking purpose.

3.6 Slope

The map shows that in Peshawar overall slope is reasonable (Fig. 7a). However, in the extreme south the slope is much steep so this area near the hills should be avoided. In north of the central city in vicinity of rivers the slope is very gentle. So both areas should be avoided from selection in terms of slopes. South of the G.T road the slopes are in general optimum for landfill site (Fig. 7a).

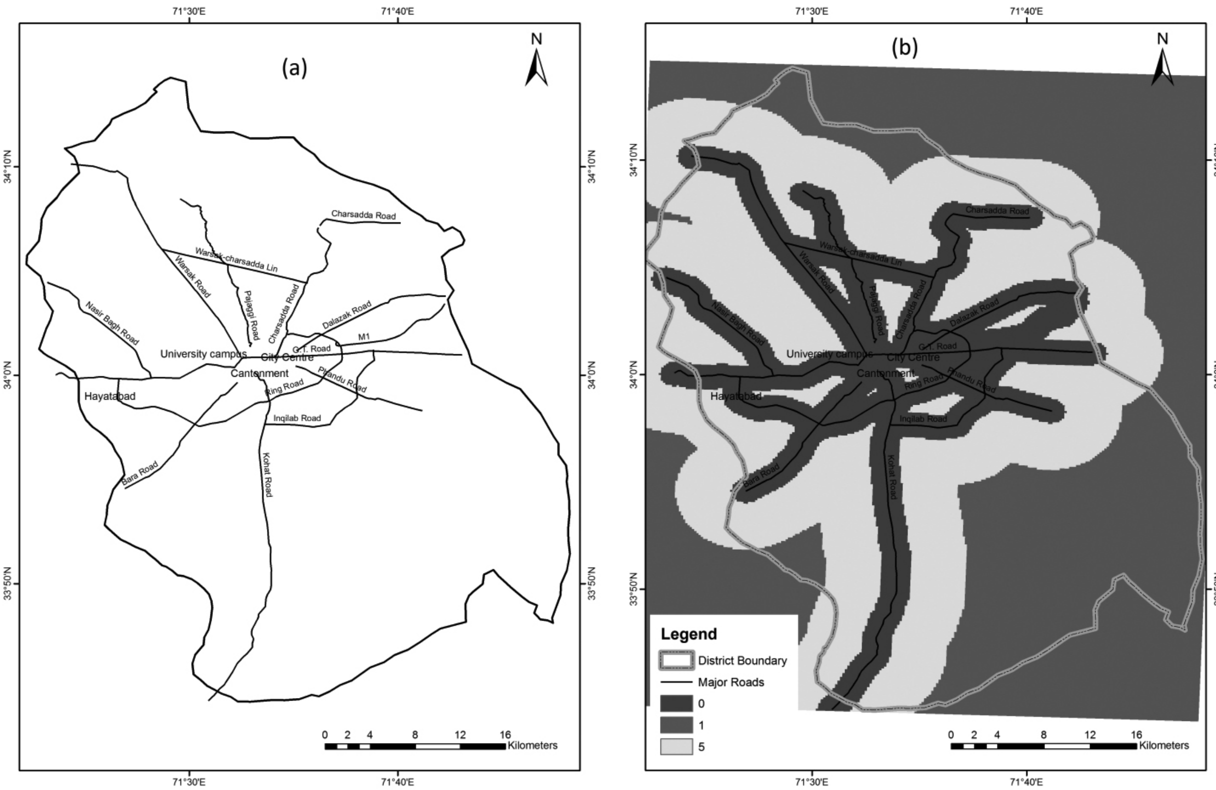

Fig. 5. **(a)** Major roads after SPOT image, 2010; **(b)** Weighted road network.

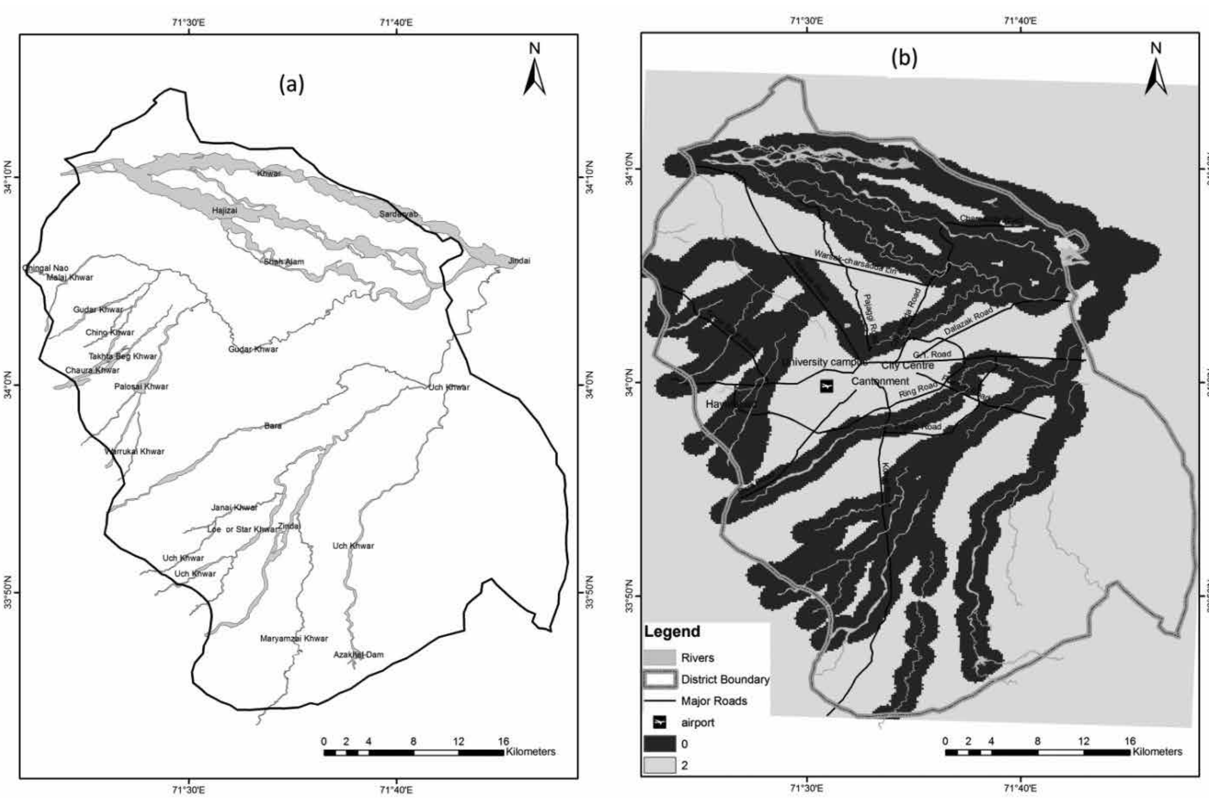

Fig. 6. **(a)** Major rivers (Source: Survey of Pakistan), **(b)** Weighted major rivers.

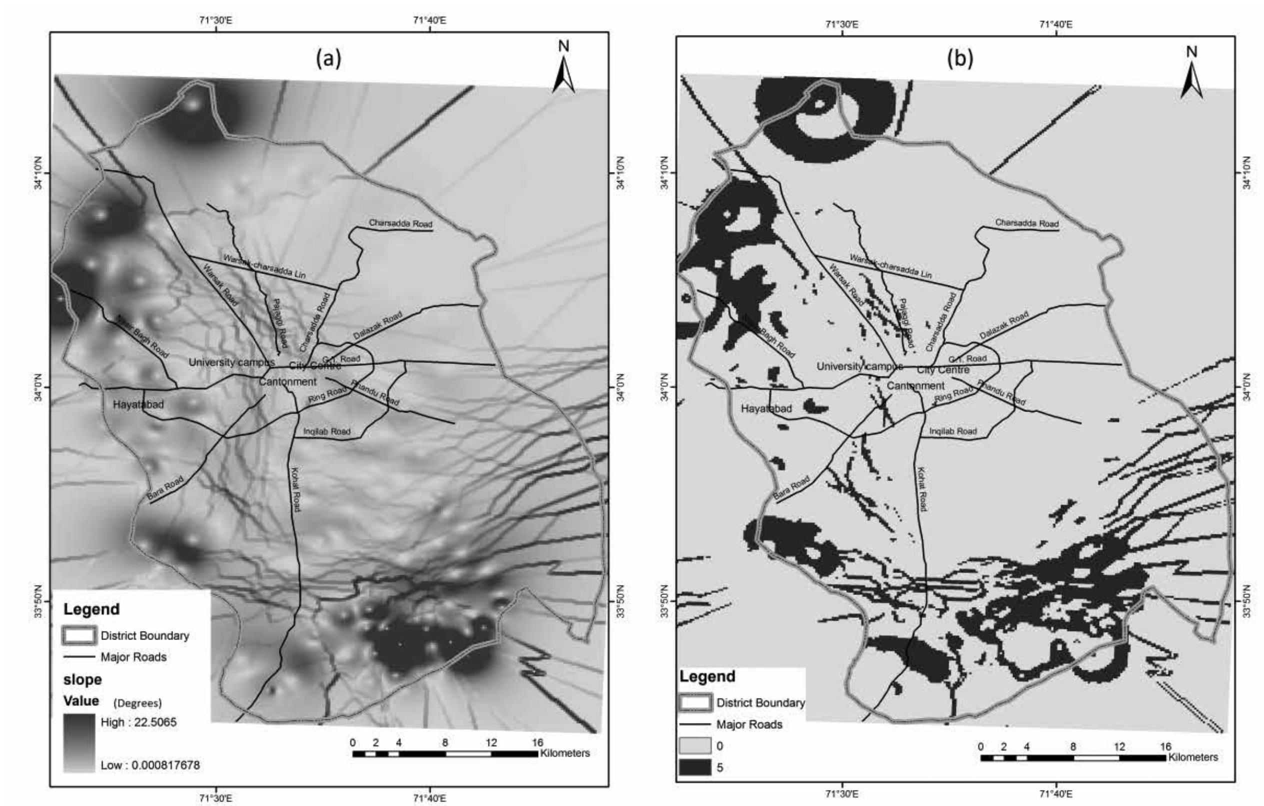

Fig. 7. (a) Slopes in degrees (Source: Survey of Pakistan); **(b)** Weighted slope.

Therefore, areas with steep slopes and very gentle slopes were given low values in the reclassified map so that they should have less chances of selection. As such areas' having a slope of less than 1 degree and more than 4 degrees was given a 0 value. Slopes between 1-4 degrees were given a value 5 (Fig. 7b). Steep slopes are usually less stable and very gentle slopes encourage percolation to the ground water table. Therefore, both of them were given low values to avoid these areas from the final selection.

3.7 Water Table

Another layer was prepared to show a general pattern of water table for the whole city. The map shows that water table was very shallow in the northern part of the city district particularly near the rivers. In southern part of the city district the water table was very deep (Fig. 8a). Water table was deepest in southern and western parts of the city district [33]. As shallow water table is not suitable for landfill site therefore lowest values were given to areas with most shallow water table. An area where water table was deeper than 15 meters was given 5 values while area where water table was shallower than 10 meters was given 3 value (Fig. 8b). The result indicates that southern parts of the city, i.e., Town IV was more suitable for solid waste disposal in terms of water table.

3.8 Airport

In the selection of landfill site, areas near airports should be avoided to as it may not cause inconvenience for the airplanes. Therefore, a layer indicating location of airport was also included in the study. Like other layers Euclidian distance was calculated for airport (Fig. 9a). In the reclassified map an area of 5000 meters around airport was given 0 value so that it has less chances in the final selection (Fig. 9b).

3.9 Final Selection of Site

All above data was prerequisite for the final selection of the site. Data about land use, land values, transport network, rivers and water bodies, slopes, airport and water table was used as separate layers for final analysis. Theses layers were combined using raster calculator to get the final combined weighted map

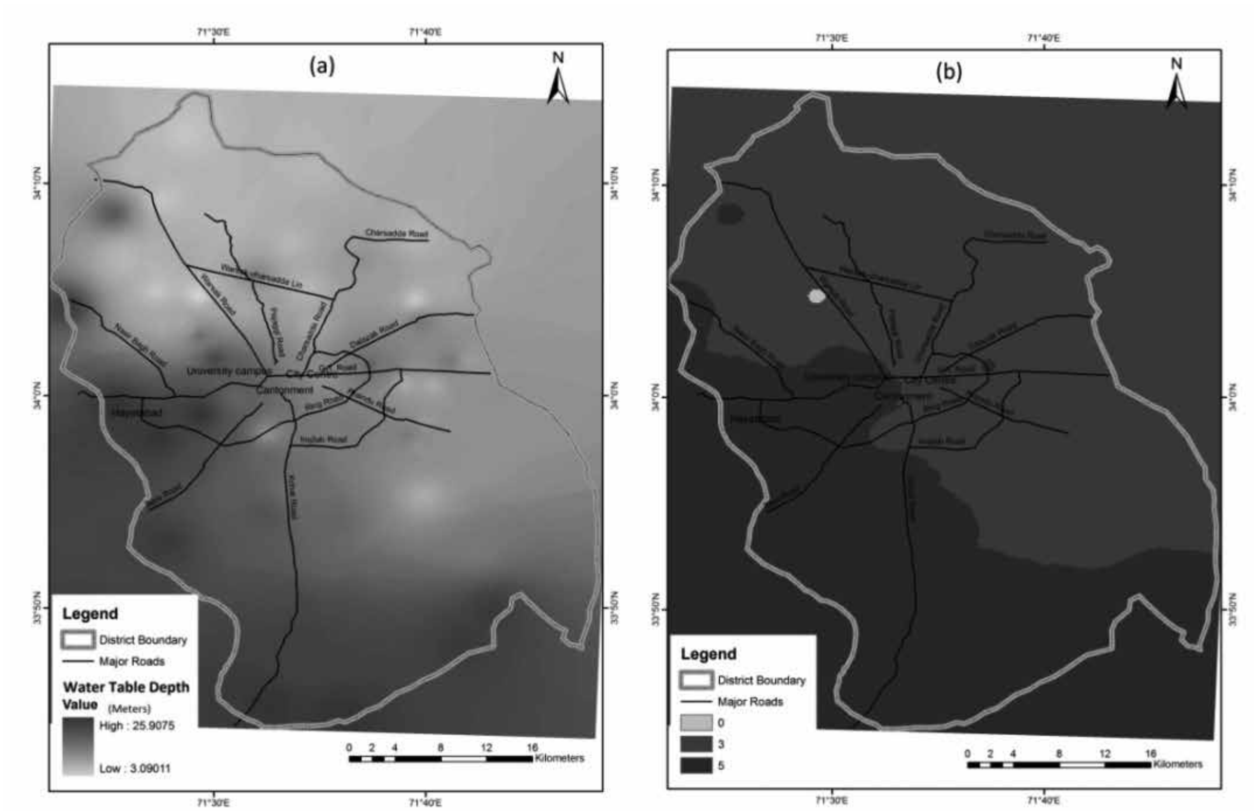

Fig. 8. (a) Water table depth (Source: GoKP); **(b)** Weighted water table

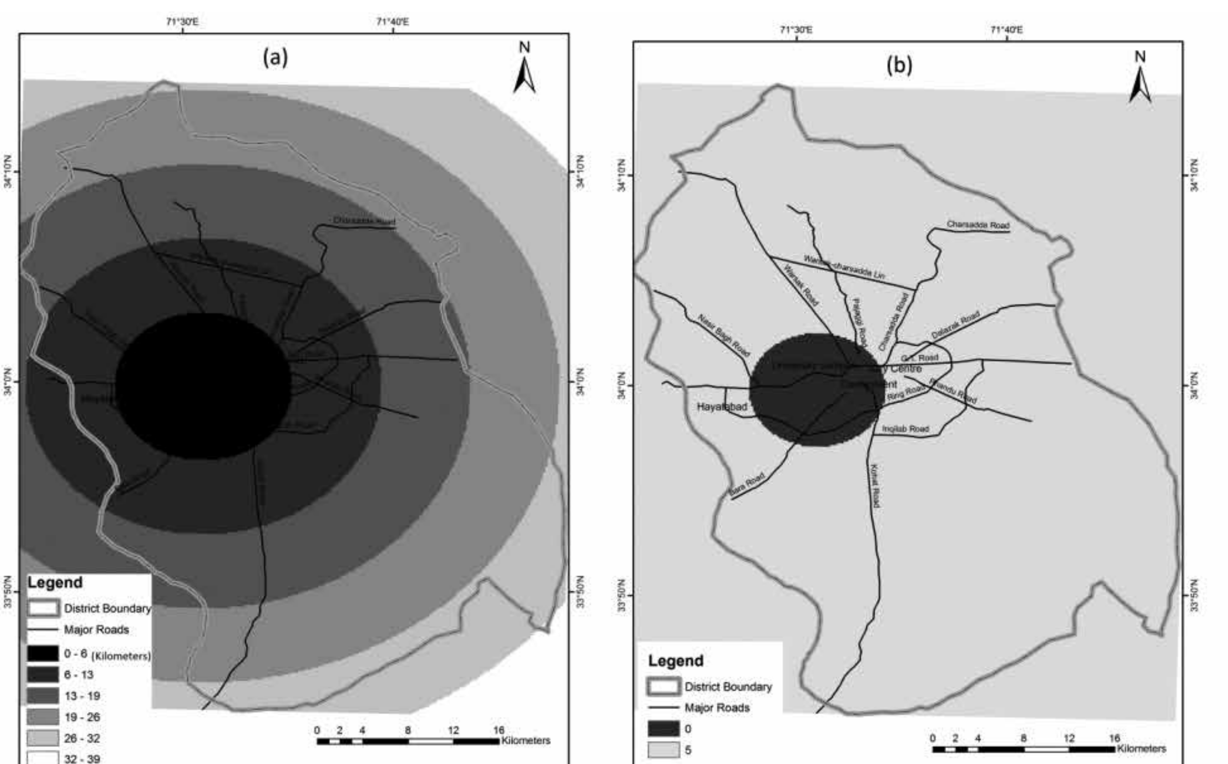

Fig. 9. (a) Airport distances; **(b)** Weighted airport.

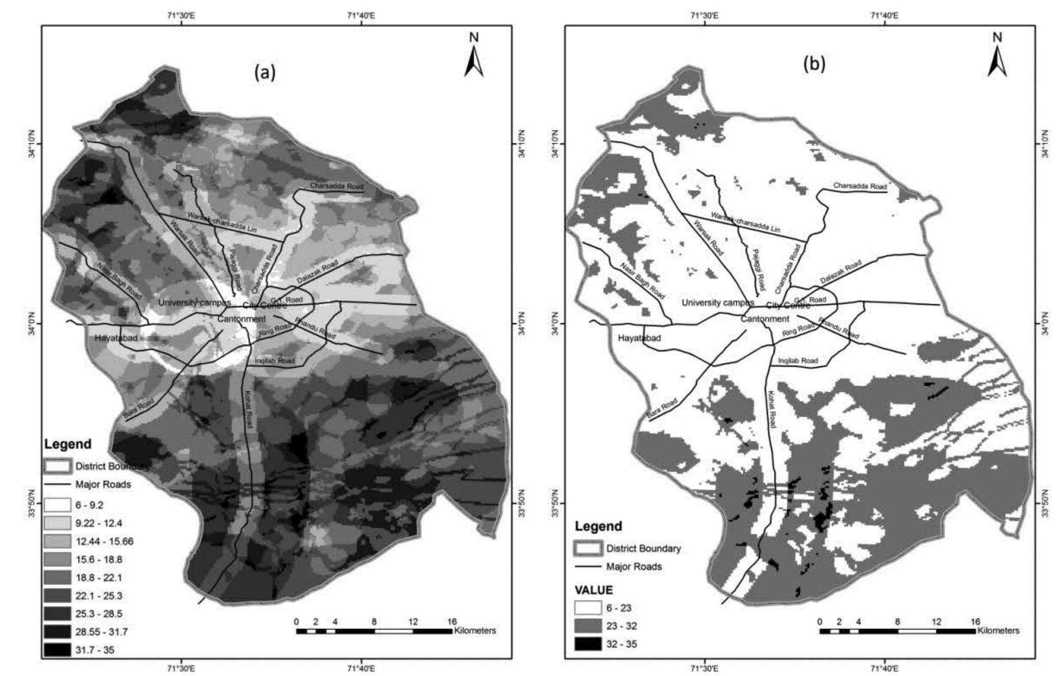

Fig. 10. (a) Combined weighted map; **(b)** Reclassified weighted map..

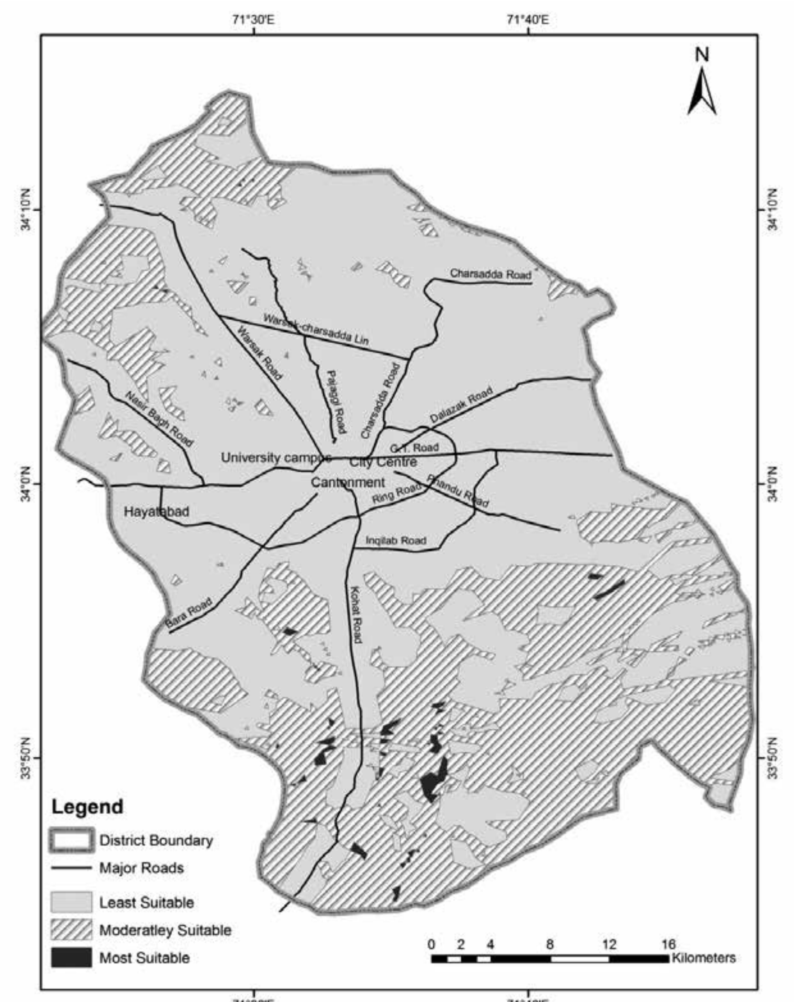

Fig. 11. Final suitability map..

(Fig. 10a). New layer was built in which each was processed to fit in the selection criteria. This layer served as a base on which depend the selection of suitable site for solid waste disposal. In this layer each data set was reclassified to fit in the layer according to criteria.

Weights were reclassified into three classes for the optimal sites (Fig. 10b). The optimal sites according to the above criteria are shown in the final map (Fig. 11). The whole city district was divided into three categories. Areas having highest weights were designated as most suitable while areas having lowest weights were lest suitable for the landfill. Most suitable sites were mostly located in southern part of the city. In the north the slope is very gentle and water table is also very high that is why it was not selected although some other conditions were suitable. The selected sites were located within 5000 meters from the major roads. They were also outside the buffer of 1000 meters from the built up area so as there is no adverse consequences from the land fill sites. Slope was also very reasonable, neither too steep nor too gentle as is evident from the slope map. The sites are also located outside the buffer zone of 1000 meters from the existing rivers as well as the canals. The land use at all these sites was rain fed agriculture. The sites identified as most suitable have sufficient area to cope for at least twenty years. Sites declared as most suitable cover an area of 36 ha in different sizes ranging from smallest 1.2 ha to 12 ha largest fragment. As it is evident from the land use map that most widespread land use in Peshawar was agriculture and it was very difficult to avoid agricultural land. Because the barren and range land in Peshawar city district were located in unsuitable location in terms of slopes, accessibility and stability of slopes.

4. CONCLUSIONS

Use of technology for real life problems have made it easy to find their proper solution without wastage of time and resources. The analysis criteria used in the identification of suitable sites for solid waste disposal in Peshawar city district indicated that using the GIS/RS technology can help local planning authorities to identify proper disposal sites. Presently solid waste is disposed at open spaces just outside the municipal boundary creating health hazards for the surrounding population. Some of the waste is thrown to larger water channels particularly the Bara River, making its water unfit for drinking purpose. GIS is now most widely used instrument to assist in the finding of suitable sites for landfill siting purposes. Using GIS for assessment of potential dumping sites will save time and resources. Usually local planning authorities have only limited resources and expertise to execute a sustainable siting procedure which causes considerable harm to the environment. This requires analysis of a great deal of spatial information and factors that can affect the optimum selection of site. Though there is a limitation of data availability. For this study seven different thematic layers were taken for GIS analysis. Some other factors like industrial areas, geological structure and wind direction that may also affect the sitting of suitable sites but they were not included in the present study due to data limitations. After analyzing the thematic layers, most suitable waste disposal landfill sites were identified. These sites in general meet the required criteria of the suitable sites. Amongst them the local planning authorities must select the "potential landfill" sites by a careful ground preliminary survey.

5. REFERENCES

1. Tchobanoglous. G. Solid waste management. In: *Environmental Engineering: Environmental Health and Safety for Municipal Infrastructure, Land Use and Planning, and Industry.* Wiley, New Jersey, USA, p. 177-307 (2009).
2. Shafiullah. *Hospital Solid Waste Management*. M.Sc. thesis, Department of Geography/ Urban and Regional Planning, University of Peshawar, Peshawar, Pakistan (1996).
3. Sasikumar, K., & S. G. Krishna. *Solid Waste Management*. PHI Learning Pvt. Ltd, Delhi, India (2009).
4. Batool, S.A., & M.N. Chaudhary. Municipal solid waste management in Lahore city district, Pakistan. *Waste Management* 29(6): 1971-1981 (2009).
5. Ishii, A. *Final Report for Domestic Solid Waste Management in Pakistan*. JICA Short Term Expert Publisher, Karachi, Pakistan (2002).
6. GoP(Government of Pakistan). *Statistical Year Book*. Pakistan Bureau of Statistics, Islamabad, Pakistan (2014).
7. Khan M.A., & A.Z. Samiullah. Dynamics of Urban

Spatial Growth and Planning: A Case Study of Peshawar. *Journal of Engineering and Applied Sciences* 31(2): 1-16 (2012)
8. Hussain, M.M. *Solid Waste Management in Peshawar*. http://www.bioenergyconsult.com/peshawar-swm/ (2015)
9. GoP (Government of Pakistan). *Brief on Solid Waste Management in Pakistan*. Ministry of Environment, Islamabad, Pakistan (2010).
10. Chang, N. B., G. Parvathinathan, & J.B. Breeden. Combining. GIS with fuzzy multicriteria decision-making for landfill siting in a fast-growing urban region. *Journal of Environmental Management* 87(1): 139-153 (2008).
11. Kinobe, J.R., T. Bosona, G. Gebresenbet, C.B. Niwagaba, & B. Vinnerås. Optimization of waste collection and disposal in Kampala city. *Habitat International* 49: 126-137 (2015).
12. Paul, K., Dutta, A., & A.P. Krishna. A comprehensive study on landfill site selection for Kolkata City, India. *Journal of the Air & Waste Management Association* 64(7): 846-861 (2014).
13. Hannan, M.A., M.A. Al Mamun, A. Hussain, H. Basri, & R.A. Begum. A review on technologies and their usage in solid waste monitoring and management systems: Issues and challenges. *Waste Management* 43: 509-523 (2015).
14. Allen, A.R. Containment landfills: The myth of sustainability. *Journal of Engineering Geology* 60: 3-19 (2001).
15. Nas, B., T. Cay, F. Iscan, & A. Berktay. Selection of MSW landfill site for Konya, Turkey using GIS and multi-criteria evaluation. *Environmental Monitoring and Assessment* 160(1-4): 491-500 (2010).
16. Ministry of Environment. *Data Collection for preparation of National Study on Privatisation of Solid Waste Management in Pakistan*. Ministry of Environment,Government of Pakistan, Islamabad, Pakistan (1996).
17. Kirkwood, C.W. *Strategic Decision Making: Multiobjective Decision Analysis with Spreadsheets*. Duxbury Press, Belmont, USA (1997).
18. Malczewski, J. Propagation of errors in multi-criteria location analysis: A case study. In: *Multiple Criteria Decision Making,* p. 154-155. Springer, Berlin, Germany (1997).
19. Janssen, R. *Multiobjective decision Support for Environmental Management* (Vol. 2). Springer Science & Business Media (1992).
20. Eastman, J.R. *IDRISI: A Grid Based Geographic Analysis System*, version 4.1. Graduate School of Geography, Clark University, Worcester, MA, USA (1993).
21. Siddiqui, M.Z., J.W. Everett, & B.E. Vieux. Landfill siting using geographic information systems: a demonstration. *Journal of Environmental Engineering* 122(6): 515-523 (1996).
22. Erkut, E., & S.R. Moran. Locating obnoxious facilities in the public sector: An application of the analytic hierarchy process to municipal landfill siting decisions. *Socio-Economic Planning Sciences* 25(2): 89-102 (1991).
23. Lober, D.J. Resolving the siting impasse: modeling social and environmental locational criteria with a geographic information system. *Journal of the American Planning Association* 61(4): 482-495 (1995).
24. Ouma, Y. O., E.C. Kipkorir, & R. Tateishi. MCDA-GIS integrated approach for optimized landfill site selection for growing urban regions: an application of neighborhood-proximity analysis. *Annals of GIS* 17(1): 43-62 (2011).
25. Yesilnacar, M. I., M.L. Süzen, B.S. Kaya, B. Ş., & V. Doyuran. Municipal solid waste landfill site selection for the city of Şanliurfa-Turkey: an example using MCDA integrated with GIS. *International Journal of Digital Earth* 5(2): 147-164 (2014)
26. Kontos, T.D., D.P. Komilis, & C.P. Halvadakis (2003). Siting MSW landfills on Lesvos Island with a GIS-based methodology. *Waste Management & Research* 21(3): 262-277 (2012).
27. Sarptas, H., N. Alpaslan, & D. Dolgen. GIS supported solid waste management in coastal areas. *Water Science & Technology* 51(11): 213-220 (2005).
28. Şener, B., M.L. Süzen, & V. Doyuran. Landfill site selection by using geographic information systems. *Environmental Geology* 49(3): 376-388 (2006).
29. Delgado, O. B., M. Mendoza, E.L. Granados, & D. Geneletti. Analysis of land suitability for the siting of inter-municipal landfills in the Cuitzeo Lake Basin, Mexico. *Waste Management 28*(7): 1137-1146 (2008).
30. Gómez-Delgado, M., & S. Tarantola. GLOBAL sensitivity analysis, GIS and multi-criteria evaluation for a sustainable planning of a hazardous waste disposal site in Spain. *International Journal of Geographical Information Science* 20(4): 449-466 (2006).
31. GoP. *Topogarphical Sheets 1:50,000 Scale*. Survey of Pakistan, Rawalpindi (1984).
32. GoP (Government of Pakistan). *SPOT Image 2.5 m Resolution*. SUPARCO Regional Office, Peshawar (2010).
33. GoKP (Khyber Pakhtunkhwa). *Pak CDP Report*. Public Health Engineering Department, Peshawar (2008).