Landfill Site Selection for Solid Waste Using GIS-based Multi-Criteria Spatial Modeling: TaqTaq Sub-district in Iraqi Kurdistan Region as a Case Study

Rostam S. Aziz

Department of Geography, Faculty of Education, Koya University,
Koya KOY45, Kurdistan Region – F.R. Iraq

***Abstract*—This study gains insight into landfill sites with the observance of all the political, economic and environmental difficulties for the implementing appropriate site measures by adopting a collection of geospatial technique and weighted linear combination (WLC) in TqaTaq sub-district. In the current study, there are several areas determined as appropriate sites for landfill location. In this study, the criteria of distance from the roads, the city center, rivers, surface water, and land use map were used. According to this analysis, only 25.21% of the TaqTaq sub district is suitable for a landfill. Thus, basing on the findings, 20.93% of the concerned sub-district is regarded as least adequate site for this mission, whereas only 3.25% of the area is regarded as moderate suitable. Thus, this study has found out that 1.03% area is the most suitable. The majority of suitable area was located in the North of the Town, where waste production is more than other locations. It should be noted that based on the outcome of this study, the amount of waste produced in the TaqTaq Town for the next 10 years, from 2022 to 2032, is predicted to be about 4080 tons. According to the density calculated for the waste of this area and considering the height of 4 m for the landfill center, in the next 10 years, about 3000 m^2 of land is required for the landfill location. Since the suitable area found in this research is about 15 hectares.**

***Index Terms*—**Geographic information systems, Landfill sitting, Multi-criteria evaluation, Solid waste management, WLC process

I. Introduction

The level of solid waste is daily growing due to the increase of human population and their activities and consumes. Hence, it is regarded as one of the problematic issues in almost all urban areas of the world. These increases in human activities, consumes, and municipal solid waste (MSW), causing a severe menace to both environment and human health. This can be obviously observed in developing countries where tremendous amount of MSW are dumped randomly. Consequently, this randomness in burying solid wastes has negative impact on all the natural issues, especially on water resources that are used for human consumption. Thus, it considerably affects the health of the consumers, especially on those people who have incredible exposure to it (Omang, et al. 2021).

There are many definitions of MSW given by many researchers, (Schübeler, Christen and Wehrle, 1996) states that MSW is regarded as a rejected from of domestic garbage, as well as non-dangerous solid wastes that came from industrial, commercial, health and institutional foundations in addition to the waste productions from other outdoor human activities. States that nearly 80% of the MSW that has been produced all over the world are buried under land. Although the components of land filled MSW are to a great extent different among countries with various cultural and economic frameworks, they are to some extent similar in some organic and non-organic materials. For instant, organic materials often consist of paper, wood, clothes, food, and garden rubbish, whereas non-organic substances include building debris, electronic and mechanical tools, metal, glass, and plastics. Organic material which is naturally putrefy by microbes into carbon dioxide (CO_2) and methane (CH4) to take part with the rate 6–18% in global methane production (Bingemer and Crutzen, 1987).

The most prevalent and dangerous source that intimidate the world environmental health is municipal solid waste. On this basis, it is crucial that engaged systems of waste handling be noticed within the way toward obtaining constant progress. The ingredients of (MSW) handling minimize the waste, reutilizing, recycling, power recovery, incineration, and land filling (Limoodehi, et al. 2017). Although the abovementioned techniques are utilized, and if the right understanding for waste declining is adopted, the availability of a healthy landfill is important to a MSW administrative system. Hence, healthy landfilling is crucial element of MSW management system (Kouloughli and Kanfoud, 2017).

ARO-The Scientific Journal of Koya University
Vol. X, No. 2 (2022), Article ID: ARO.11017. 7 pages
DOI: 10.14500/aro.11017
Received 28 June 2022; Accepted: 30 October 2022
Regular research paper: Published: 17 November 2022
Corresponding author's e-mail: rostam.salam@koyauniversity.org

Adequate site nomination of landfills may have a great contribution in decreasing the environment contamination.

Concerning the issues connected to the nomination of appropriate landfill location it can be deduce that making mind up is not easy in this respect, so the speed and accuracy are considerably declined as a result of the absence of standards (Moeinaddini, et al., 2010).

Landfill has become very hard process to proceed, because land is among the most precious and restricted resources that should be exploited cleverly. Appropriate sites should be selected on the basis of technical, economical and socio-environmental aspects and meet the recommended global criteria. The utility of MCE method looks very suitable. Making use of geography information system provides the spatial decision support systems (SDSS) in the process of determining appropriate landfills in terms of health, economy, social, and environment.

In all the urban areas in KRG, the waste proportion has risen suddenly over last decade. Therefore, this study aims at considering TaqTaq sub-district for the foundation of disposal centers for this sub-district. Therefore, to fulfill this purpose some significant parameters in disposal center are introduced (*We can list distance from roads, rivers, surface water the city center, and a map of land use as some of these factors*(. Later, the factor maps of studied area are made ready. There are several map combination processes which are in the form of Waited Linear Combination (WLC), index overlay combination. In this study, WLC considerably was utilized for merging maps. Ultimately, the appropriate sites for the establishing disposal center are nominated.

II. Materials and Methods

A. Study Area

Taq Taq Sub-District is located in Koysinjaq district, Erbil Governorate about 31 Km southwest of Koi Sanjaq city, about 61 Km northeast of Kirkuk, and 85 Km southeast of Erbil, Fig. 1, includes 19 villages. The study area has shared borders with lower zap on the east, Erbil City on west and koysinjaq town on north and Kirkuk City on south. The study area approximately located between 44° 32′ 46” and 44° 17′ 35” eastern longitudes and 36° 2′ 44” and 35° 50′ 49” northern latitudes an area of around 280 km^2 which constitutes 13.6% of the gross KoiSanjaq district area of the highest point of the field area is located at an elevation of 605 m and the lowest point 300 m above sea level. The rainfall average of 350 mm (Average of rainfall in the study area 1995 – 2018 is taken from TaqTaq Meteorology Department). The main land covers the following types of pastures, fallow lands, agriculture, water, and inhabitant zones. Economic flourishing in the last decade has resulted in a considerable raise in inhabitants and consequently in solid waste production. The population of TaqTaq sub-district is nearly (29078) persons, which equals 26.5% of the total population of Koi Sanjaq district statistics and expected to be (37721) in 2032 account by a population increase proportion is about 2.8% per annum concerning the distribution of population according to rural community and civilized community in the study area. The number of TaqTaq town population is (23812) persons, but the number of its rural population is (5264) persons Table I.

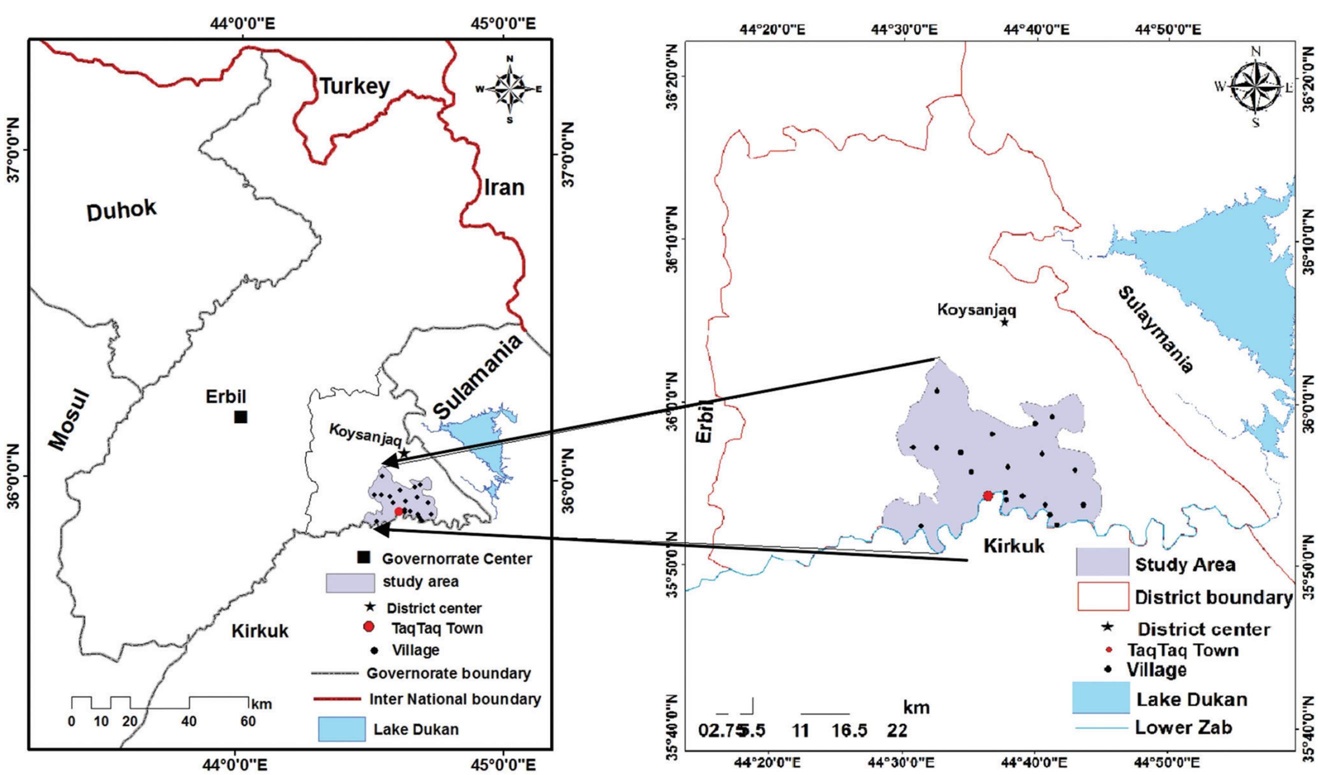

Fig. 1. Location map of the study area.

TABLE I
Population of TaqTaq Sub-district by Rural and Town Areas (2009–2032)

Sub-distric	2009	2014	2022	2032
TaqTaq Town	17004	19394	23814	31388
Rural	3434	4220	5264	6938

It is rated that solid waste production of TaqTaq is nearly 30 tons/day. The available solid waste landfill locations have been in a constant service for nearly 10 years in a way that the current waste burying places is located 1 km a way in the southeast of TaqTaq Town. In this area, probably 30 tons of waste is the daily produce (Taq Taq municipality, total quantity of MSW Generation [2016–2020]). As a consequence of the absence of suitable measures to cover the waste with soil in a standard way, there is a constant dissemination of parasitic and infectious diseases in the area, and this will be also a source of disturbing of the travellers who make the use of the main road (TaqTaq - Kirkuk) or the secondary roads within 2 km from the site, its bad smell can be felt. Because it is to a great extent close to the residential area and this causes health problems and sometimes social problems for the inhabitants. Thus, the available solid waste landfill site is not adequate. To Protect and support ecosystem in terms of ecology, indicating a suitable location is crucial, and this requires a sort of cooperation and collaboration of other concerned organizations. In this respect, a study to gain insight into the appropriateness of landfill is recommended to be placed within 5–10 km of the TaqTaq Town as it has been approved and addressed in this article.

B. Calculating the Amount of Waste and the Required Land Area

This study aims at selecting an appropriate site landfill as well as figuring out the number of land sites needed for burying rubbish. This can be fulfilled by considering some factors such as garbage production rate, population, and density of compact material. Thus, number of residents, annual production of rubbish, height, and shape of land in which the waste will be buried in are the main issues that should be taken into account. For estimation of inhabitants of TaqTaq, we depend on the latest public demography with the adaptation of the below equation.

$$P_t = P_o. (1+r).t \quad (1)$$

In this equation P_t, $P_{o,}$ and r are the number of the residents of TaqTaq Town in 2009, 2014, and increasing proportion of population, respectively; thus, the number of population has been anticipated as 23814 by a 2.8% a population increase proportion.

Regarding to the amount of rubbish for one person per day is 1.3 kg/day (Data Collection available by Koi Sanjaq municipality 2016–2020) with average density of 430 Kg/m^3, where the weight and volume of rubbish will be about 4080 tons and 1186 m^3, respectively, during the horizon of 10 years.

American Planning Association (APA) states that the following empirical formula has been offered to determine the required space for sanitary waste disposal (Krizek and Power, 1996).

$$V=R/D\ (1-P/100) + CV \quad (2)$$

V=Required space (volume) during the year
CV=The volume of required covering soil
D=Average density of waster
R=Rate of per capita (waste) production
P=Percent of waste reduction due to condensation.

In the similar way, the amount of produced waste during (2022–2032) is calculated. Next, the amount of produced waste of each estimated year were added and the divide it by the density of regional waste 430 Kg/m^3, the volume of waste for the following 10 years is 4080438 kg which is equivalent to 4080 tons. Based on the density *waste* of TaqTaq Town (0.430 kg/m^3) and the formula for calculating the amount of waste in the following 10 years is as follows:

$$P = M/V$$

$$V = m/v = 4080438/430 = 9489\ m^3$$

With regard to the selected sites which are valley shape –if square –like base of waste disposal sites is taken into account whose side is on the ground level and its height has been confined from the level, of the hole to the high point of the level, we can have estimated the concerned volume, using by covering soil that is 1–4 cm is as follows:

V = R/D (1-P/100) + C V (Eq. 2)
V = Required space (volume) during the year
CV = The volume of required covering soil
D = Average density of waster
R = Rate of per capita (waste) production
P = Percent of waste reduction due to condensation
CV = The volume of required covering soil=9489/4=2372
V = Required space (volume) during the year = 2372 + 9489 = 11861 m^3 (the estimated volume of the following 10 years is 11861 m^3) = 11861/4 = 2965 m^2.

C. Analysis Method

The identification of suitable landfill location needs very influential criteria assessment to increase social, economic, environmental, and health costs (Siddiqui, et al., 1996). The methodology makes use of a developed digital GIS database, in which spatial information is provided. Due to the diversity in the measures on which criteria (*distance from the city center, roads, rivers, surface water, and land use map*) are built, it is essential that factors be standardized before combination. All the contributes of input data were given scores. The scores show land composition for siting a

http://dx.doi.org/10.14500/aro.11017

landfill to extend from 0 to 5. A score of 0 points out no constraint, and a score of 5 shows a total constraint. Weight is also employed to these maps in a way that the total weight should be increased up to 100% to make the output map to be meaningful and consistent, and the contribute scores must be selected with the use of a scheme that was similar for each map. In this query, the maps of input data were not paid enough attention, because some factors were more effective than others while choosing appropriate landfill locations. Nevertheless, the significance of each factor may be different from one study area to another based on the local condition of each. The major criteria used in this study are shown in Table II. For further clarification, all the maps are geographic data layers stored in the GIS raster-based with the 30 m × 30 m grid cells. After taking out matrix relative importance and criteria weights, pair-wise comparison consistency should be recognized. The process of consistency index is known as (CR). Consistency ratio illustrates the probability of matrix ratio haphazard producing. The consistency rate should be <0.1; otherwise, there will be a requirement to reassess the relative significance. Whereas the consistency proportion is lower than threshold limit, accounted weights are affected by the criteria (factors) map layers Table II.

TABLE II
Criteria Weight and Ranking

Criteria	Weight	Buffer zone	Ranking
Slope	0.0525	0–10	5
		10–20	4
		20–30	3
		30–40	2
		>40	1
River	0.11	0–1000	1
		1000–1500	2
		1500–2000	3
		2000–2500	4
		>2500	5
Water bodies	0.15	0–250	1
		250–500	4
		500–1000	5
		1000–1500	3
		>2500	2
Land use	0.1125	Water (pond and	0
		stream)	0
		Wheat and barley	1
		Orchard	1
		Plow and barley	5
		Forestry	6
		Rangeland	7
Road	0.08875	0–250	1
		250–500	3
		500–1000	5
		1000–1500	4
		>1500	2
Residential	0.21	0–250	1
		250–500	3
		500–1000	5
		1000–1500	4
		>1500	2
Boundary of town	0.25	0–2000	1
		2000–3000	5
		3000–3500	4
		3500–4000	3
		>4000	2

D. Uses of GIS in Waste Management

It is evidence that one of the crucial utility of GIS is the presentation and the analysis of data to aid environmental decision-making. A decision is recognized as a selection among the choices, where the alternatives may be diverse activities, locations, objects, etc. For instance, a concerned establishment may need to determine the best location for dangerous waste stuffs, or probably determine the areas which will be best choice for a new progress. The function of GIS in (SWM) is also observable as many other issues as its planning and operations are incredibly dependent on spatial data. Overall, GIS highly contributes in achieving account data to make collection procedures easier. Therefore, issues such as customer service, analyzing optimal locations, the transfer system across different places in an urban area to the landfill, and vice versa are also performed by GIS. Thus, GIS is a tool that not only saves time and money in the process of selecting appropriate place, but also supplies a digital data base for upcoming consideration of the site (Tomlinson, 1990).

E. Waited Linear Combination Model

Weighted linear combination method (WLC) is the most popular and scientific method in assessing the multi scale evaluation. This method usually draws on the content of weight average. Analyzer or responsible figures should base on "relative importance" weighted directly to the scales. Then through multiplying relative weight in feature value, ultimate amount can be gained for each choice (Zadeh, et al., 2013). After determining the ultimate value for each option, alternatives which have higher value, will be most adequate choice for the intended purpose. A GIS based MCE technique, using WLC analysis, gaining insight into a number of possible choices for the problem related to the process of selection, and also take into account multiple criteria and conflicting objectives. With making use of GIS for site determination, data were taken from various sources, and kept in the GIS system. The data that are utilized in this study are useful for software uses a weighted sum analysis that is act as a WLC analysis (Al-Hanbali, Alsaaideh and Kondoh, 2011). A weighted sum analysis provides the ability to weight and gather multiple inputs to conduct an integrated analysis, that is, it joins together multiple raster inputs and represents multiple factors of different weights or relative importance. It is one of most effective and popular methodologies that are utilized for indicating suitable location in general, and for indicating solid waste disposal locations in specific.

III. Results and Discussion

Based on the findings derived over conducting this study, an appropriate landfill should be located and constructed to fulfill the required criteria for avoiding pollution of the soil, groundwater, or surface water to guarantee enough collection of filtration. In addition to that, a landfill site must be placed away from residential density for decreasing pollution influence to residential health. Moreover, also we should take the distance between the landfill and the available road access to it into consideration because it is better to be located close to the existing roads for making sure that the transportation facility is available instead of constructing new roads (Gorsevski, et. al., 2011). Eight appropriate criteria are utilized in this work and an exclusive map is drawn for each suitable criterion, and these result in designing the final composite map that is produced by WLC process. The criteria analysis for landfill site determination is illustrated in paragraphs below.

A. Slope

Land structure is regarded as an essential issue in the landfill selection. Land structure is assessed by its slope degree as it is shown either in percentage or in degrees. Steep slopes are not appropriate for landfill foundation where the construction expenses of excavation usually rise in higher slopes. However, an adequate slope of land is significant in avoiding the leach ate. The slope layer map was achieved from the TaqTaq Sub-district area DEM map drawing on pixel size in percentage. The slope of more than 40% was regarded inappropriate. The slope of <10% with 5 value was regarded as an appropriate selection, Fig. 2a, (Rezaeisabzevar, Bazargan and Zohourian, 2020).

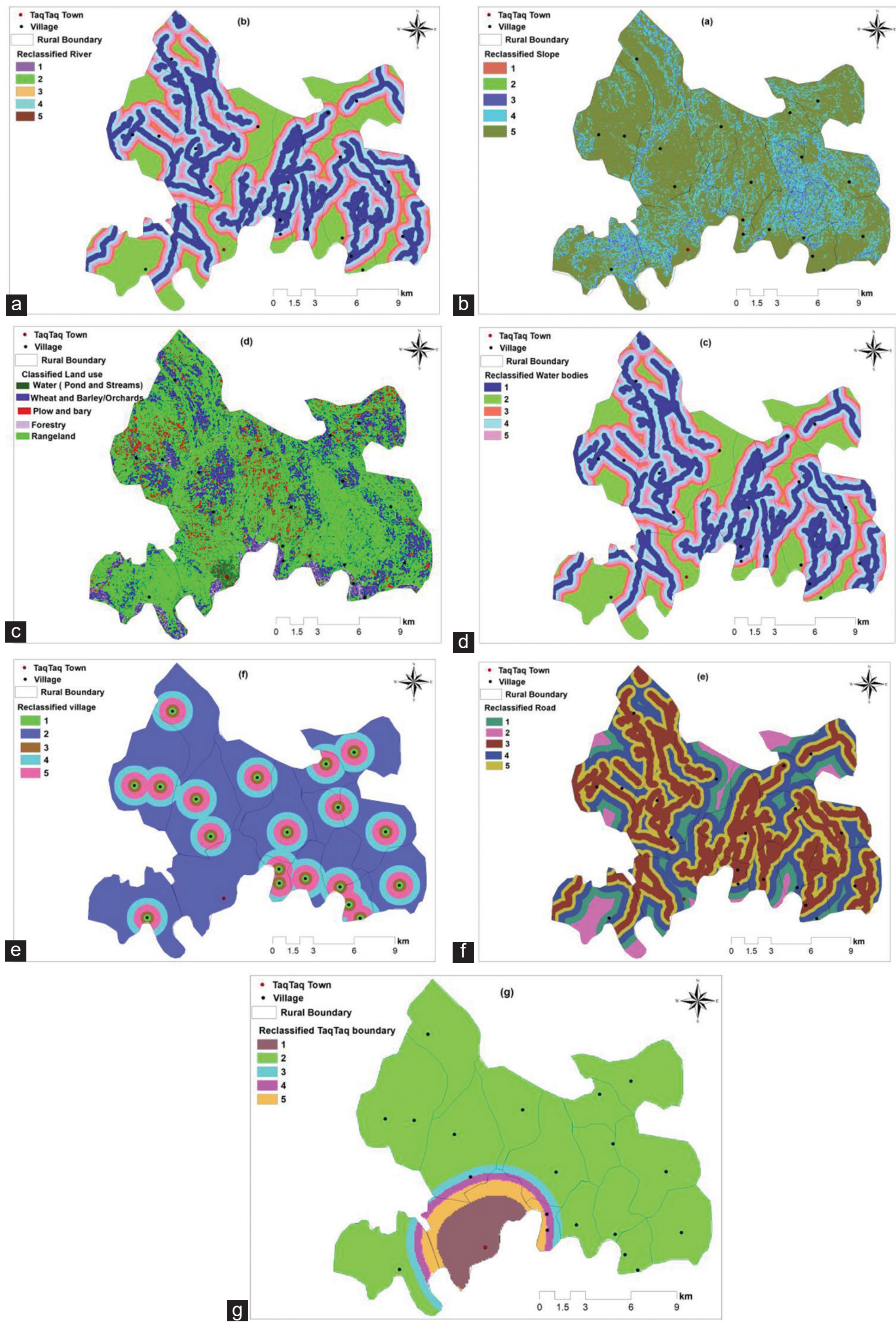

Fig. 2: (a-g) Geospatial data Maps in the study area.

B. Distance to river

Landfill location should not be built close to river because it usually leads to water pollution which can occur such as contaminating the water as a consequence of the arisen of leachate from the landfill site area. More than 1000 m buffer zone was constructed for each of the water body in the study area, Fig. 2b, Rezaeisabzevar, Bazargan and Zohourian, 2020).

C. Water bodies

A landfill must be far enough from surface streams and rivers. Proximity to sub river and stream was a significant criterion to evaluating the landfill site. Landfills emits noxious gases and leach ate that make them inappropriate to be near to water stream as to avoid its health dire consequences and the spread of disease, because these influences can extend to areas up to 250 m distance away from water streams, Fig. 2c.

D. Land use

The LU//LC map was taken from Land Cover Categorization in Rural Area of Taq Taq sub-district (Aziz, Hamadamin, and Omer, 2019). Various sorts of land utility in the study area have been adopted. Thus, values were determined to each land use sort depended on its adequacy level. Areas with water (pond and stream), wheat, barley, and farms were identified with 0 scores whereas areas such as vacant and agricultural lands (rangeland, plow, and barley) were given the scores of 6 and 7 successively, Fig. 2d, (Rezaeisabzevar, Bazargan and Zohourian, 2020).

E. Road network

To avoid constructing special roads for landfill access is affordable. Hence, the assigned locations must be near to the main roads to avoid the interference of solid waste transferring vehicles with the public vehicles. The minimum pixel value (0 value) assigned to 250 m distance from available roads. Moreover, the distance with more than 1500 m is regarded unsuitable because of demanding more transportation costs, Fig. 2e.

F. Residential areas

Landfill site must be placed far from residential areas; otherwise, it annoys inhabitants who are living close to the area. Therefore, the distance of the selected areas for burying wastes must be between 500 and 1000 m away from the inhabitants in the rural areas. However, if the selected location exceeds more than 1500 m away from rural areas, it is regarded as inadequate, Fig. 2f, (Aziz, Hamadamin, and Omer, 2019; Rezaeisabzevar, Bazargan and Zohourian, 2020).

G. Distance from TaqTaq boundary

The safe distance from urban boundary must be at least 2–5 km. Minimum distances from the residential areas in the study area were assigned as at least 2 km for urban boundary is suitable. However, the distance with more than 4 km is regarded unsuitable, because as much the distance of the landfill is far from town, the costs of transportation will be increased. Although the cost is an important issue, considering environmental and safety issues should be inevitably observed, Fig. 2g.

H. Geospatial Operation for Site Selection

To do the process of site selection of suitable lands of land fill, a method of combining layers by WLC Model was used. Then WLC was adopted for indicating proper site as the best location. Finally, by WLC process, an area has been found. In general, in WLC overlay, the sites with high appropriateness were determined as suitable sites for landfill foundation and suitable sites are illustrated in Fig. 3. According to

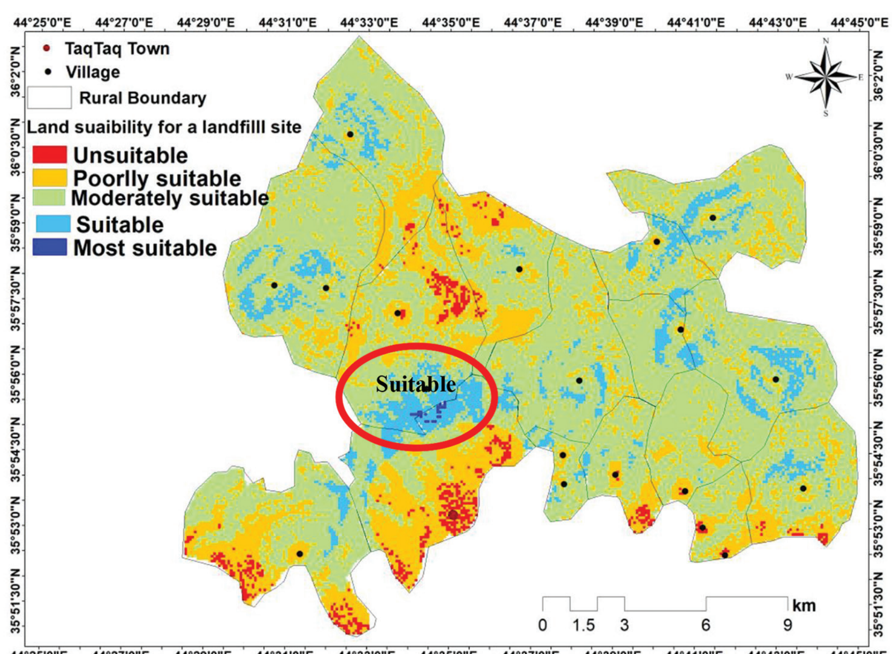

Fig. 3: Landfill site suitability in the study area.

hydrologic and hydrogeology factors, adequate locations have more ideal conditions than other locations due to its distance from surface water with the range of 1500 m and ground water with the range of 300 m. On land use suitable site is placed in dray farmland class and is far away from fertile agricultural zones and farms. Moreover, this study also recommends that the nominated landfill locations should be at least 2000 m. far from TaqTaq Municipal boundary. Finally, landfill sites were obtained for landfill in TaqTaq sub-district including rural area; the most recommended sites are illustrated in Fig. 3.

IV. Conclusion

This study demonstrates both GIS, WLC have been gathered in Model to implement a multi criteria evaluation techniques in determining the adequacy in the selection of right solid waste landfill site. The location appropriateness was determined by employing seven criteria. The achieved results from experts' view state that among sub criteria, water body, groundwater, slope and within social and economic sub criteria, residential areas, land use, and available network roads are significant successively. The extension of some proper locations is more than needed landfill site, so it is possible to organize the related equipment's of recycling in addition to address solid waste better despite decreasing transition costs.

Adopting GIS and multi criteria decision evaluation is intended in the process of site determination problems. GIS is flexible in considering criteria and it is possible to improve this method by considering other influential criteria. A GIS is the most useful tool that is helpful in the indication of appropriate locations for landfill sitting. In addition, the possibility of GIS usage in WLC and having cell information allows that the traits of the TaqTaq sub-district land structure are examined accurately at small area.

A multi criterion decision analysis also highly contributes in the process of observing various criteria regarding site determination assessment problem as a result it helps decision makers in their selections. GIS gathering with decision analysis as decision assisting system can help responsible figures in each site selection problem as an effective tool. Therefore, for making the ultimate decision, field investigation of the recommended landfill sites should be proposed with the consideration of the costs, social, administrative, and political aspects. The recommended procedures can help responsible figures in the disposal and solid waste management activities.one site that is very adequate for landfilling, but it is about 3 km away from TaqTaq Town.

References

Al-Hanbali, A., Alsaaideh, B. and Kondoh, A. 2011. Using GIS-based weighted linear combination analysis and remote sensing techniques to select optimum solid waste disposal sites within Mafraq City, Jordan. *Journal of Geographic Information System*, 3(4), p.267.

Aziz, R.S., Hamadamin, R.R. and Omer, M.K. 2019. August. Land Cover Classification in Rural Area of Koya District Using Remote Sensing and GIS. In *Koya on the Road of Civilization, KRC 2019 International Conference*. Koya University, pp.355-362.

Bingemer, H.G. and Crutzen, P.J. 1987. The production of methane from solid wastes. *Journal of Geophysical Research Atmospheres*, 92(D2), pp.2181-2187.

Gorsevski, P.V., Donevska, K.R., Mitrovski, C.D. and Frizado, J.P. 2012. Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: A case study using ordered weighted average. *Waste Management*, 32(2), pp.287-296.

Kouloughli, S. and Kanfoud, S. 2017. Municipal solid waste management in constantine, algeria. *Journal of Geoscience and Environment Protection*, 5(1), pp.85-93.

Limoodehi, F.A., Tayefeh, S.M., Heydari, R. and Abdoli, M.A. 2017. Life cycle assessment of municipal solid waste management in Tehran. *Environmental Energy and Economic Research*,1(2), pp.207-218.

Moeinaddini, M., Khorasani, N., Danehkar, A., Zienalyan, M. and Darvishsefat, A.A. 2010. Siting MSW landfill using weighted linear combination and analytical hierarchy process (AHP) methodology in GIS environment (case study: Karaj). *Waste Management*, 30(5), pp.912-920.

Omang, D.I., John, G.E., Inah, S.A. and Bisong, J.O. 2021. Public health implication of solid waste generated by households in Bekwarra Local Government area. *African Health Sciences*, 21(3), pp.1467-14763.

Rezaeisabzevar, Y., Bazargan, A. and Zohourian, B. 2020. Landfill site selection using multi criteria decision making: Influential factors for comparing locations. *Journal of Environmental Sciences*, 93, pp.170-184.

Schübeler, P., Christen, J. and Wehrle, K. 1996. *Conceptual Framework for Municipal Solid Waste Management in Low-income Countries* Vol. 9. St. Gallen: SKAT Swiss Center for Development Cooperation.

Siddiqui, M.Z., Everett, J.W. and Vieux, B.E. 1996. Landfill siting using geographic information systems: A demonstration. *Journal of Environmental Engineering*, 122(6), pp.515-523.

Tomlinson, R.F. 1990. *Current and Potential Uses of Geographic Information Systems: The North American Experience*. In: Peuquet, D. and Marble, D. (eds.), Introductory Readings in Geographic Information Systems, New York, Taylor and Francis.

Zadeh, M.A., Ngah, I., Shahabi, H. and Zadeh, E.A. 2013. Evaluating AHP and WLC methods in site selection of waste landfill (Case Study: Amol, North of Iran). *Journal of Basic and Applied Scientific Research*, 3(5), pp.83-88.