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Using Remote sensing and GIS in waste assessment and Management, Liwa case study

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Abstract. Remote sensing is the acquisition of data about object(s) without making physical contact with it. Remote sensing images are very useful data for the management and assessment of hazardous wastes. For example, remotely sensed data have been used in numerous applications to detect and analyze the presence of hazardous waste, waste-disposal sites and landfills. The ability to monitor sites over time is very effective to assess environmental impacts and also to evaluate compliance in remediation cases. Moreover, historic aerial photographs supply the documentation required for analysts to compile a record over time of uncontrolled waste disposal site boundaries, points of access and adjacent land use. Comparative temporal studies of a waste disposal site using historical aerial photos, help to determine how an area has changed over time and in turn offers a better understanding of current site conditions. The examination of a site over time allows for the analysis of succession or replacement of land cover to determine the status of an abandoned site and to identify a hazardous site that is currently obscured due to new development. Multispectral satellite images have been utilized to monitor hazardous waste sites with respect to land use, regional risk and the spectral characteristics of specific disposal sites and their pollution profile. This paper reviews the literature of using remote sensing and GIS in the context of waste management and assessment. Moreover, a case study of using GIS for landfill site selection of Liwa walayat, Oman will be presented with some recommended sites according to planning and environmental criteria.

Key words: Waste assessment, waste management, Landfill, Site Selection, GIS, Remote sensing

1. Introduction

Landfill is an integral component of waste management chain (waste reduction, reuse, recycling, composting and land filling). Landfill as described by Sumathi, Natesan, and Sarkar (2008), is a waste disposal method in which key engineering principles are applied. This is achieved by spreading waste into thin cells, compressing it into small volumes and, finally, covering it with a soil layer. Landfill previous studies such as (Chang, Parvathinathan, & Breeden, 2008; Delgado, Mendoza, Granados, & Geneletti, 2008; Ekmekçio_glu, Kaya, & Kahraman, 2010; Geneletti, 2010; Higgs & Langford, 2009; Kontos et al., 2005; Sharifi et al., 2009; Siddiqui, Everett, & Vieux, 1996) are wealthy with methodologies for Municipal solid waste (MSW) landfill site selection. The identification of suitable municipal landfill is a multifaceted process which requires planning criteria that involve environmental, ecological, social, economic and technical considerations. Geographic information system (GIS), are computer systems to collect , process, store, analyze, output, and distribute of data and spatial information for specific goals. GIS helps in decision-making processes, especially in Urban Planning issues such as site selection. Multi-criteria Decision Analysis (MCDA) is used in GIS to involve varied criteria and create some planning alternatives to help in decision-making processes.

Remote sensing is the acquisition of data about object(s) without making physical contact with it. Remote sensing images are very useful data for the management and assessment of hazardous wastes. Slonecker et al. (2010) reviewed the literature of remote sensing and overhead imaging in the context of hazardous waste and discussed future monitoring needs and emerging scientific research areas. They found that remote sensing has an extensive history of providing significant data to the process of identifying, characterizing and remediating hazardous waste problems (Lyon, 1987), (Titus, 1982), (Barnaba, et al., 1991).

Aerial photographs have been used in numerous applications to detect and analyze the presence of hazardous waste, waste-disposal sites and landfills. Aerial photos generally have sufficient spatial resolutions for detecting small features and historical archives for comparative temporal analysis. The ability to monitor sites over time is very effective to assess environmental impacts and also to evaluate compliance in remediation cases. USEPA has utilized an extensive archive of aerial photography dating back to the 1930s to reconstruct the waste handling and disposal history of hazardous waste sites. Over 4,000 historical aerial photographic reports on hazardous waste activity have been produced and used in environmental cleanup programs, (Slonecker, 2007), (Benger, 2004).

Surveys using historical and current aerial photography have been employed to produce detailed databases on locations of present and former waste sites and adjacent environmental features (e.g., wetlands) and built features (e.g., impoundments). The examination of a site over time allows for the analysis of succession or replacement of land cover to determine the status of an abandoned site and to identify a hazardous site that is currently obscured due to new development

(Lyon, 1987), (Garofalo, 2003). Compared to other forms of remotely sensed imagery, aerial photo interpretation is generally a straightforward process due to the map-like qualities of imagery and because it includes wavelengths recognizable, or easily understandable, to the human eye (Kroeck, and Shelton, 1982).

On the other hand, Multispectral sensors digitally collect reflectance or emittance energy levels in discrete portions of the Electro Magnetic Spectrum (EMS); often 4–10 separate bands. Advantages of these systems include statistical processing and analysis of the data and extension into sections of the EMS beyond aerial photographic capabilities. Data from multispectral imaging systems such as the Landsat Multi Spectral Scanner (MSS) and Thematic Mapper (TM) and a variety of aircraft-based systems have been utilized to monitor hazardous waste sites with respect to land use, regional risk and the spectral characteristics of specific disposal sites and their pollution profile. Bølviken showed that basic MSS data could be used to identify heavy metal contamination based on basic spectral differences (Bølviken et al., 1977). Herman et al. (1994) showed that CIR aerial photography, SPOT and Landsat TM imagery could be used collectively to monitor vegetation stress and recovery at a Superfund site in Michigan. Similarly, Airola and Kosson (1989) demonstrated the value of digital analysis of high-resolution aerial photographs and aircraft scanner data as well as Landsat data for broader scale issues such as groundwater migration. Jones and Elgy (1994), determined that multispectral data could be used to monitor landfill gas migration and its effect on vegetation.

2. Area of Study

Al Batinah Region occupies a vital location on the northern coast of Gulf of Oman. On 28 October 2011, Al Batinah Region was split into Al Batinah North Governorate and Al Batinah South Governorate. Al Batinah North Governorate consists of 6 wilayats (province) ; Sohar, Shinas, ***Liwa***, Saham, Al Khabourah and Al Suwaiq. Wilayat of Liwa lies north of Sohar between latitudes: 24° 31' 03" N and 24° 31′ 6″ N, and longitudes**:** 56° 33′ 39″ E and 56° 34' 41" E, figure 1. Liwa has a lively market place where local produce and fresh fish are sold. The fortress of Awlad Ya'rab, built of white clay, is located on the beach in the Harmul area. The area also has a number of rural features such as springs, falajs and caves: Ain al Azam cave faces the creek and is surrounded by mangrove trees, while Jebel Abu Kahif is home to some of the largest caves in the province (Wikipedia, 2013). With its 58 villages, Liwa is 270 Kilometres from the Governorate of Muscat. It has numerous castles, forts and towers including Liwa Fort. Liwa's white coral limestone mosques are an unusual feature of this area with their ventilation holes like small windows high up in their walls. Some of these mosques have attractive minarets; the prettiest is the minaret of al Bahlul mosque in Hillat al Husn (Ministry of Information, Oman, 2013).

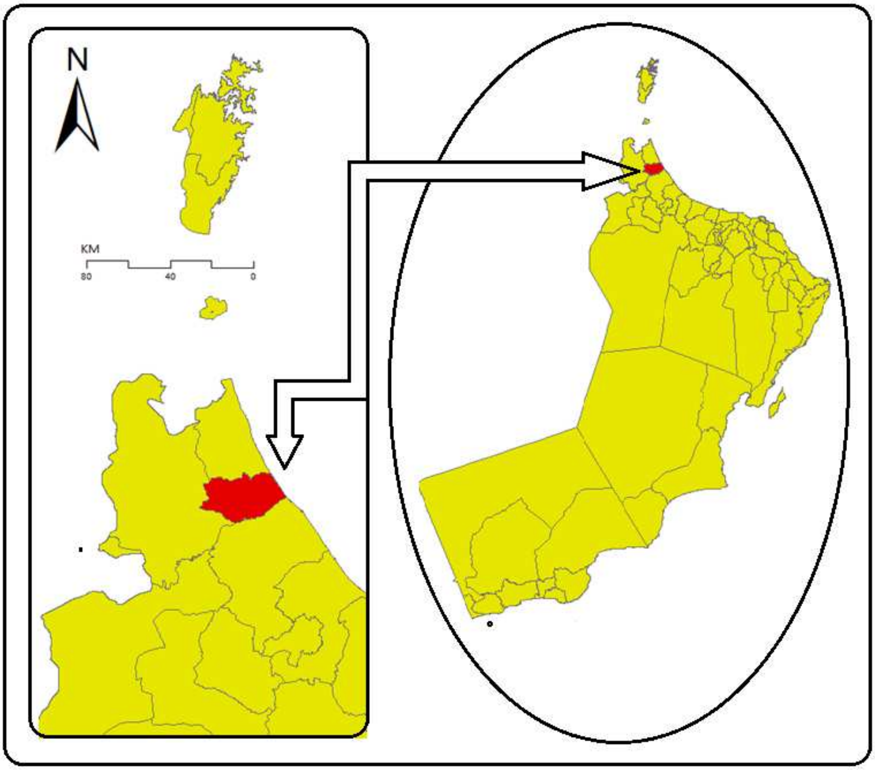
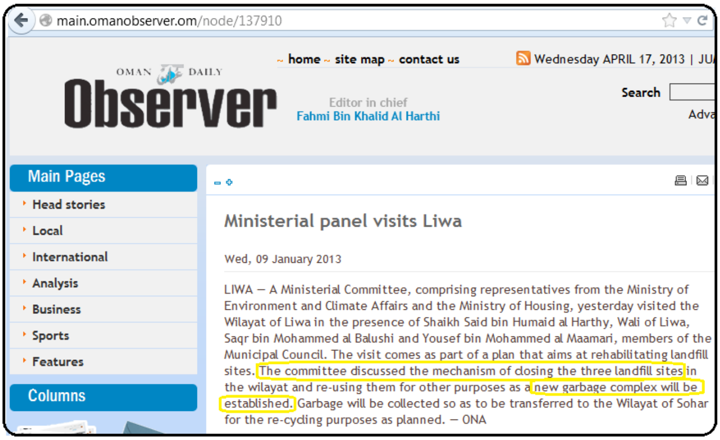


Figure 1: Liwa Location

3. Statement of the problem and objectives

On 08 January 2013, A Ministerial Committee, comprising representatives from the Ministry of Environment and Climate Affairs and the Ministry of Housing visited the Wilayat of Liwa. The visit was part of a plan aims at rehabilitating landfill sites. The committee discussed the mechanism of closing the three current landfill sites in the wilayat and re-using them for other purposes as a new garbage complex will be established, figure 2 (OMAN DAILY Observer, 2013). Therefore, Wilayat of Liwa is selected to be the subject of this study. The main purpose of this study is to define the best locations of the proposed landfill of the Wilayat of Liwa using GIS and Multi-criteria Decision Analysis (MCDA).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- Head stories
- Local
- International
- Analysis
- Business
- Sports
- Features

Columns

Ministerial panel visits Liwa

Wed, 09 January 2013

LIWA — A Ministerial Committee, comprising representatives from the Ministry of Environment and Climate Affairs and the Ministry of Housing, yesterday visited the Wilayat of Liwa in the presence of Shaikh Said bin Humaid al Harthy, Wali of Liwa, Saqr bin Mohammed al Balushi and Yousef bin Mohammed al Maamari, members of the Municipal Council. The visit comes as part of a plan that aims at rehabilitating landfill sites. The committee discussed the mechanism of closing the three landfill sites in the wilayat and re-using them for other purposes as a new garbage complex will be established. Garbage will be collected so as to be transferred to the Wilayat of Sohar for the re-cycling purposes as planned. — ONA

Figure 2: Ministerial Panel visit to Liwa news

4. Data and Methods

The proposed model for the identification of a potential landfill site has been made possible through the integration of varied environmental, social factors according to planning criteria that are mentioned in the "Guide of Physical Planning" of Oman (SCTP, 2003) as follows:

1. It must be away from the streams.
2. It must be away from the current and future built-up areas with a minimum distance of 1500 meters.
3. It must be close to the roads.
4. It must be away from the Airports.

Moreover, some criteria are added by the author to enhance the selection of best site processes.

4.1 Data

Vector based GIS data are collected to act as inputs in Multi-criteria Decision Analysis (MCDA) as follows:

1. Streams (wadis) layer.
2. Built-up areas layer.
3. City extent layer.
4. Population settlements layer.
5. Roads layer.
6. Green lands layer.

4.2 Methodology

1. The data collected were entered into ArcGIS 10 System. Liwa vector map was exported. The required spatial data was clipped (i.e. Streams (wadis) layer, Built-up areas layer, City extent layer, Population settlements layer, Roads layer, Green lands layer).

2. Spatial analysis (Figure 3) was started using "Buffer" option from Geoprocessing tools of ArcGIS 10 System where excluded areas were extracted for each data layer as follows (Figure 4);

a. 1000 meter away from Streams (wadis).

b. 1000 meter away from Green areas

c. 1500 meter away from Built-up areas.

d. 1500 meter away from City extent layer.

e. 1500 meter away from Population settlements.

f. 100 meter away from Roads.

3. Merging all six buffered layers into one layer to compose unsuitable areas for proposed land fill site (Figure 5).

4. The suitable areas for landfill site were extracted and the final output was produced on a map (Figure 6).

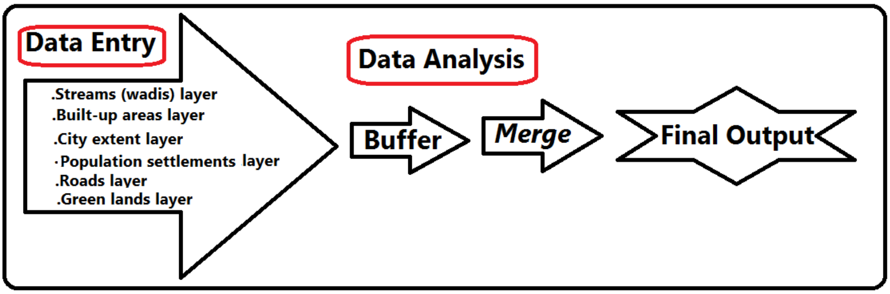

Figure 3: Spatial Analysis stages of Liwa landfill site selection

Results and discussion

Results of the present study are summarized in Figures 4-6. Figure 4, shows the stages of buffer preparation for six spatial data layers used in this study, where excluded areas were extracted for each data layer using Buffer option according to planning criteria. Figure 5 illustrates merging all six buffered layers into one layer to compose unsuitable areas for proposed land fill site. Figure 6 demonstrates the suitable areas for landfill site. These areas have been generated using ArcGIS 10 system.

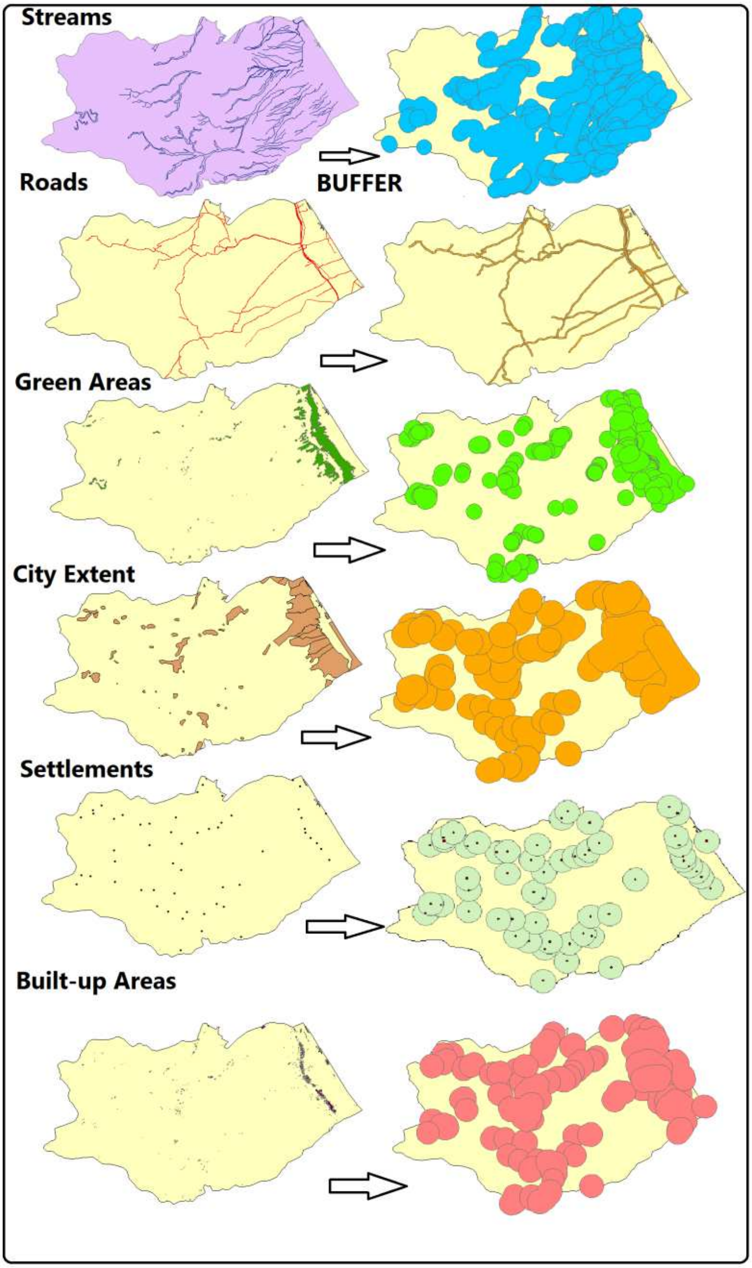

Figure 4: Excluded areas were extracted for each data layer using Buffer option

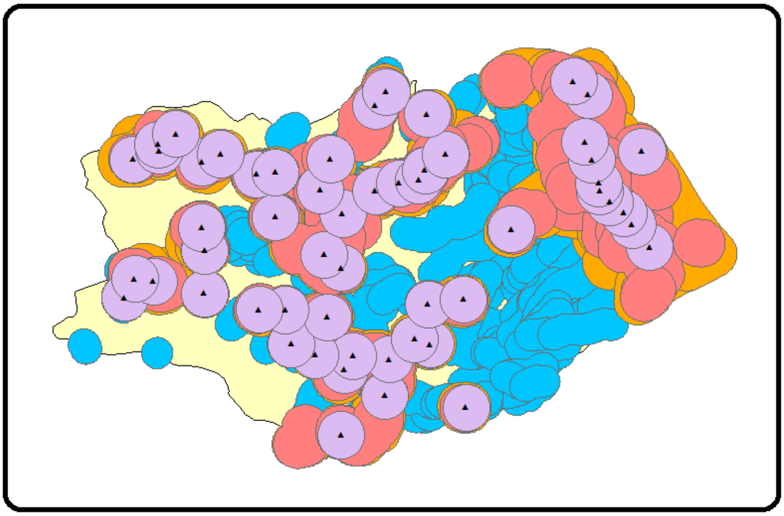

Figure 5: Merging all six buffered layers into one layer to compose unsuitable areas for proposed land fill site

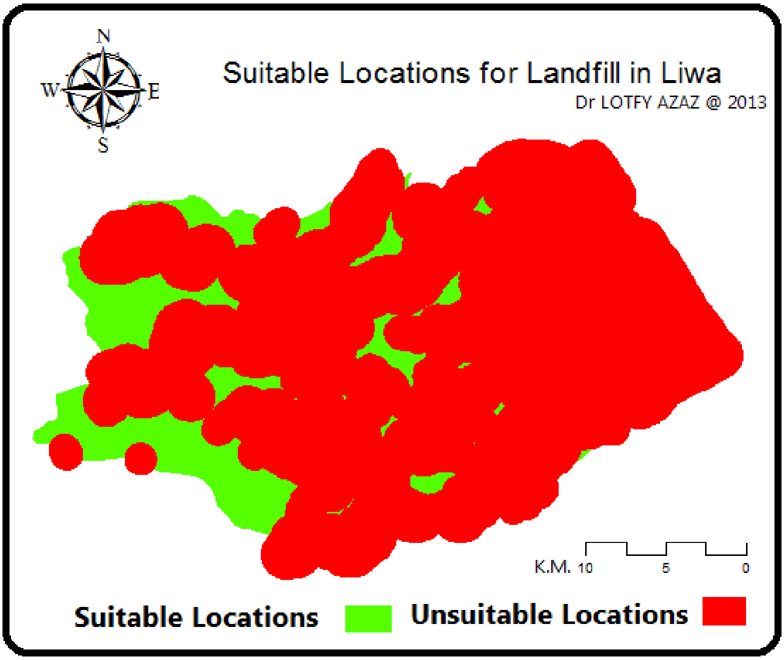

Figure 6: The suitable areas (green-coloured) for landfill site

The total Area of Liwa wilayat is 659.971 Square Kilometers. The total suitable areas for landfill site are 54.925 Square Kilometers (Table 1). This means that about % 91.68 of Liwa wilayat is not suitable for landfill site; while only % 8.32 is appropriate for such critical project. These small available lands may be reduced as well if other isolated areas within the buffer zones were excluded from suitable areas.

Table 1: Suitable Areas for Landfill site in Liwa wilayat

Layer name	Suitable areas (²K.M.)
Streams (wadis) layer	**11.361**
Built-up areas layer	**16.186**
City extent layer	**9.510**
Population settlements layer	**7.069**
Roads layer	**2.054**
Green lands layer	**8.745**
Total Suitable Areas	**54.925**

Conclusions and Recommendations

As this review has indicated, there have been numerous successful applications of remote sensing for the location and monitoring of hazardous wastes. Those applications have included traditional visual interpretation of temporal profiles of aerial photography, more generalized spectral signature analysis of hazardous wastes using multispectral sensors (Slonecker et al. 2010).

Moreover, this study tried to find out the suitable areas for proposed landfill site selection in Liwa wilayat according to varied environmental, social criteria that are mentioned in the "Guide of Physical Planning" of Oman. The total suitable areas for landfill site is very limited (less than % 8.32) of the total area of Liwa wilayat due to the special nature of the proposed project. Most of these suitable lands are located in the north-western and south-western parts of Liwa (Figure 6). This study recommends carrying out more detailed study including site visits and field studies (interviewing local people by questionnaire (Public Participation Approach in Planning)) to implement complete Environmental Impact Analysis (EIA) and reach to a precise available lands for the proposed landfill site considering all planning, social and environmental criteria.

Based on the results obtained in our study, we can conclude that GIS are very useful techniques for the optimal sitting of landfills. This study shows that GIS has the potential to facilitate planning and decision-making process and help other stakeholders involved in the process of selecting suitable sites for landfills.

Moreover, this study proved that using of GIS and multi criteria decision analysis is desired in landfill site selection studies, as GIS is flexible in considering criteria and it is possible to develop this method by taking into account other effective criteria.

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استخدام الاستشعار عن بعد ونظم المعلومات الجغرافية في تقييم وإدارة النفايات، دراسة حالة ولاية ليوا

أ. د. لطفي كمال عزاز

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ملخص البحث. الاستشعار عن بعد هو عبارة عن جمع البيانات عن الظاهرات بدون الاتصال المادي بها، و تعد مرئيات الاستشعار عن بعد مفيدة جدا في إدارة و تقييم مخاطر النفايات. فعلى سبيل المثال ، فقد تم استخدام بيانات الاستشعار عن بعد في العديد من التطبيقات لاستكشاف و تحليل وجود النفايات الخطرة و اختيار مناطق التخلص منها. إن القدرة على مراقبة و رصد هذه المواقع عبر الزمن يعد فعالا لتقييم الآثار البيئية، و بالإضافة إلى ذلك فإن الصور الجوية القديمة توفر التوثيق المطلوب للباحثين لتسجيل عمليات التخلص الغير منظمة للنفايات عبر الزمن و حدود مناطق التخلص من النفايات، و نقاط الوصول لها ، و استخدام الأرض المجاور لها . إن الدراسات المقارنة عبر الزمن لمواقع التخلص من النفايات باستخدام الصور الجوية القديمة يساعد على تحديد كيفية تغير المنطقة عبر الزمن و تقدم فهم أفضل للظروف الحالية لها. إن رصد الموقع عبر الزمن يسمح بتحليل إحلال و تغير الغطاء الأرضي لتحديد حالة المواقع المهجورة و تحديد المناطق الخطرة. كما تم استخدام الصور الفضائية متعددة الأطياف رصد مواقع النفايات الخطرة من ناحية استخدام الأرض و الخطر على المستوى الإقليمي و الخصائص الطيفية لهذه المواقع و نمط التلوث. وفي هذا البحث تمت مراجعة الدراسات السابقة التي استخدمت الاستشعار عن بعد و نظم المعلومات الجغرافية في إدارة و تقييم النفايات، بالإضافة إلى ذلك فقد تم تنفيذ دراسة حالة باستخدام هذه التقنيات لاختيار الموقع الأمثل لمردم نفايات بولاية لوى – سلطنة عمان و تقديم بعض التوصيات لعدد من المواقع المقترحة باستخدام المعايير التخطيطية و البيئية.