MONITORING URBAN GROWTH AND LAND USE LAND COVER CHANGE IN AL AIN, UAE USING REMOTE SENSING AND GIS TECHNIQUES

Muhammad U. Liaqat[1*] *and Rezaul K. Chowdhury*[1]
[1]*Department of Civil and Environmental Engineering, United Arab Emirates University, UAE*
[*]*Corresponding author: 201690338@uaeu.ac.ae*

Keywords: Land use land cover, Landsat, Urban growth, Change detection, Remote Sensing

Summary:
Urbanization and industrialization cause a serious land degradation problem, including an increased pressure on natural resources such as deforestation, rise in temperature and management of water resources. The Urban Heat Island (UHI) effects of urbanization are widely acknowledged. Increase of impervious surface is a surrogate measure of urbanization and their effects on local hydrology is well reported in literature. This study investigates the spatial-temporal dynamics of land use and land cover changes in Al Ain, UAE, from 2006 to 2016. The Landsat images of two different periods, i.e., Landsat ETM of 2006 and Landsat 8 for 2016 were acquired from earth explorer site. Semi-supervised known as the hybrid classification method was used for image classification. The change detection was carried out through post-classification techniques. The study area was categorized into five major classes. These are agriculture, gardens, urban, sandy areas and mixed urban/sandy areas. It was observed that agricultural and urban land increases from 42,560 ha to 45,950 ha (8%) and 8150 ha to 9105 ha (12%), respectively. Consequently, the natural sandy area was reduced. It was also found that the urban area was expanded dramatically in the west and southwest directions. The outcomes of this study would help concerning authorities for a sustainable land and water resources management in the Al Ain region.

1. Introduction

Land use and land cover are two separate terminologies often used interchangeably. Land cover refers to the physical characteristics of the earth's surface, such as distribution of vegetation, water, soil and other physical features of the land, including built environments. On the other hand, land use refers to the way in which land has been used by humans and their habitat, usually with the accent on the functional role of land for economic activities (Rawat et al., 2015). Hence, information on land use land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for human needs and welfare. This information also assists in monitoring the dynamics of land use changes (Cheema and Bastiaanssen, 2010).

Various organizations used to collect data about land, but in many cases it is observed that they work independently without coordination. Too often this has meant duplication of effort, or it has been found that data collected for a specific purpose were of little or no value for a similar purpose later (Andersen et al., 2001). Monitoring the Earth surface from space is now decisive to understand the impact of human activities on the natural environment. High spatial resolution satellite images provide a way to assess the remote areas, which is extensively used for estimation of crop statistics at regional level. The Remote Sensing (RS) data also assist in strengthening the existing institutional capacity for land use land cover (LULC) change detection (Yang and Lo, 2002).

Several studies have been conducted on LULC classification and changes, using various techniques. The process of classification involves assigning the image pixel values to different classes based on some threshold criteria. Different modeling techniques were applied for LULC classification. Richard and Jia (2006) argued that conventional modeling techniques are tedious and data intensive. They divided the classification into two major parts known as supervised and unsupervised classification. In supervised classification, modeling algorithm classifies the image on the bases of personal knowledge of users, field experience, threshold values of vegetation and field observation. However, some areas are difficult to access for classification and ground correction. In this situation, unsupervised classification provides an alternative solution for image interpretation. An alternative approach developed by Gammal et al. (2007, 2010) combines both classification approaches to develop semi-supervised classification algorithm. Based on Principle Component Analysis (PCA), Red, NIR and MIR bands were selected and added to vegetation to segregate agriculture as well as urban area based on threshold values. The developed classes exhibited an improvement for distinguishing classes.

In order to check the efficiency of both classification methods, a study was conducted by Coskun et al. (2008) in Kucukcekmece Water Basin (Istanbul, Turkey) to analyze the urbanization using multi-temporal satellite data. Firstly, the ISODATA, one of the supervised classification methods, was incorporated for all satellite images with 0.95 vegetation threshold values using 20 iterations. It produced 50 clusters of classified area. However, these clusters were not very efficient to detect uncultivated land, excavation sites, roads and urban areas due to similarities in reflected pixel values. The unsupervised classification did not perform well in LULC classification. Whereas the supervised classification technique using ground truth data and orthophotos performed well in that region to monitor urban changes with R^2 84%, 84%, 83.33% and 86%, respectively, for the 1992, 1993, 2000 and 2006 satellite data.

The LULC classification is important to monitor the urban growth and change detection for effective land and resource management. However, selection of the best classifier is not straightforward, which is because the characteristics of each image and the circumstances of each study vary significantly. Historically, research investigating the land use changes has focused on five major methods, these are cross–correlation analysis, object–orientated, neural networks, supervised classifier, and traditional pixel–based or unsupervised classification method (Adepoju et al., 2006 Gammal, et al., 2007, 2010; Rawat et al., 2015). Each method has its own advantages and disadvantages. A common constraint observed in every algorithm is that they are unable to detect differences among crops. In this study, an attempt has been made to investigate the efficiency of LULC changes in Al Ain, UAE using the semi-supervised classification method. The study also investigated the urban growth trends in the Al Ain region from 2006 to 2016. The outcomes of this study would help to plan coordinated development of land and water resources in the region.

2. Material and Methods

The study area Al Ain is one of the fastest growing cities in the UAE, located at approximately 240 03' N–240 22'N and 550 28' E–550 53' E as shown in Figure 1.

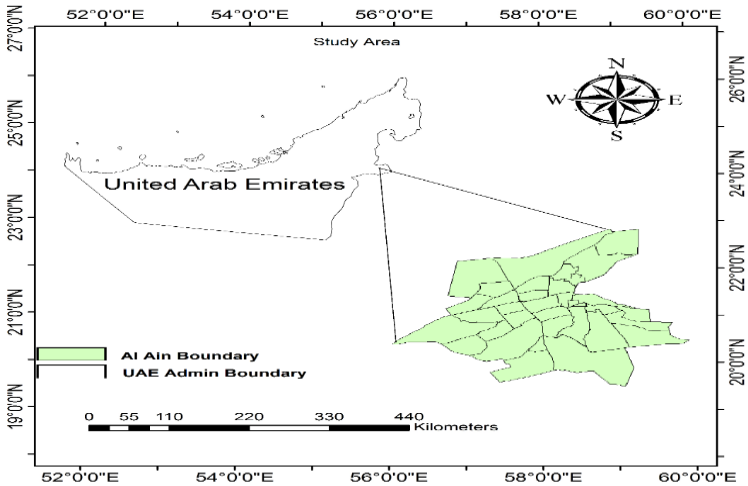


Figure 1 Administrative boundary of Al Ain

The Al Ain city is known as the garden city of UAE. The region is attractive because of the availability of ground water, low humidity, oasis and the fact that it represents a transit between the Arabian Gulf and inland areas. The knowledge and understanding of its urban growth trends are needed for the sustainable planning and management of its resources, such as urban planning, management of water and land resources, market analysis, service allocation, etc. Therefore, the RS and GIS techniques are considered in this study to monitor the urban growth rate (Yang et al., 2003 and Muthusamy et al., 2010).

2.1 Data Collection

Table 1 summarizes the data used in this study and their sources.

Table 1 Summary of data used in the study

Data type	**Data product**	**Data source**	**Data specification**
Satellite data	• Landsat 7 ETM and Landsat 8	• https://earthexplorer.usgs.gov	30m spatial resolution image
Ancillary data	• Previous agriculture census data • Shape file of study area	• Al Ain City Municipality • Land Use Yearly Bulletin by Central Bureau of Statistics and Abu Dhabi Agriculture Department	Information regarding agricultural pattern, conventional historical record data and shape files for boundary, roads, etc.
Sample	• Ground trothing point	• Google Earth	Land cover field data

2.2 Vegetation Indices

The spectral vegetation indices (VIs) are mathematical expressions of various spectral bands, mostly in the visible and near-infrared regions of the electromagnetic spectrum, which provide composite property of leaf chlorophyll, leaf area, optical measures of canopy greenness and canopy architecture. In this study, the Normalized Difference Vegetation Index (NDVI) was used. The NDVI can be estimated using the equation 1.

$$\mathbf{NDVI = (NIR\text{-}RED) / (NIR+RED)} \quad (1)$$

The RED and NIR stand for the spectral reflectance measurements acquired in the red (visible) and near-infrared regions, respectively. The value of vegetation indices, field information and expert knowledge enabled us to understand and classify the image. The higher value of vegetation index indicates an agricultural area, whereas lower values differentiate among other classes such as urban, barren and water bodies.

3. Results and Discussions

The LULC classification was carried out using the semi-supervised based hybrid classification method. For the current study, the year 2006 and 2016 were selected for the LULC and change detection in the Al Ain region. The LULC maps using the Landsat ETM and Landsat 8 are shown in Figure 2.

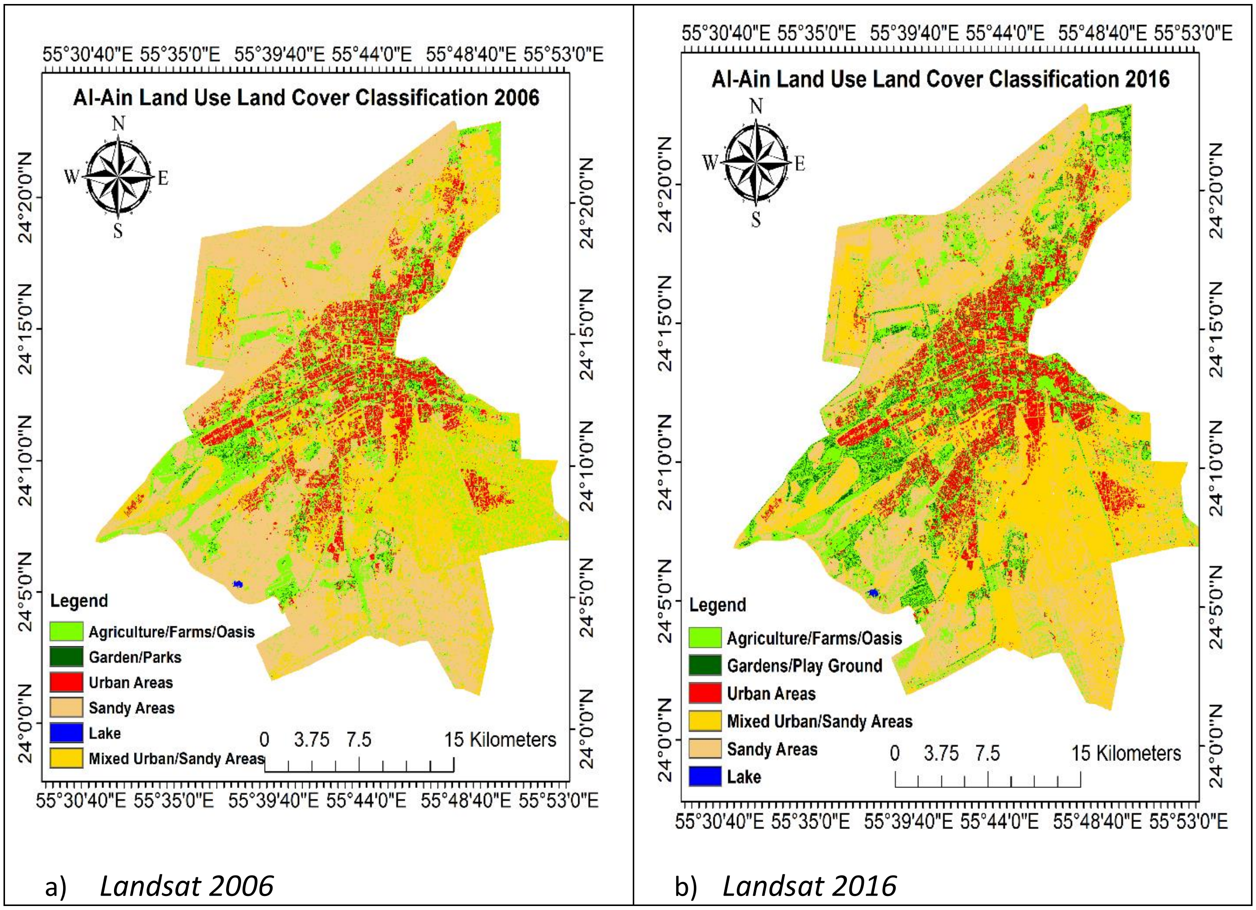


Figure 2 Al Ain LULC classes for the year 2006 and 2016

Figures 2 (a) and 2 (b) show the LULC classification of the Al Ain region for the year 2006 and 2016, respectively. Five LULC classes were developed as shown in Figure 2. The iterative unsupervised classification technique was applied to the Landsat images. Initially, 50 spectral classes were developed. The google earth points were used for signatures of these spectral classes to distinguish the objects. Afterwards, classes were merged into subclasses on the basis of similarity in spectral signatures. The LULC results showed that the total area of Al Ain is 77 million hectares. The results depicted that agriculture occupies the major portion of the region in both years. In 2006, the estimated agriculture area was 41,500 ha whereas in 2016 it was 46,970 ha, increased by 7.38%. The urban area increased from 8,150 ha to 9,105 ha from 2006 to 2016, increased by 10.49%. The land use changes in the region are shown in Table 2.

Table 2. Land use changes in Al Ain from 2006 to 2016

Land use land cover class	Estimated Area in 2006 in hectare	Estimated Area in 2016 in hectare	% change
Agriculture/Farms/Oasis	42,400	45,780	7.38
Garden/Parks	160	170	5.88
Urban Area	8,150	9,105	10.49
Sandy Area	16,727	15,474	-8.10
Mixed Urban/Sandy Areas	9565	6471	-32.5

3.1 Accuracy Assessment

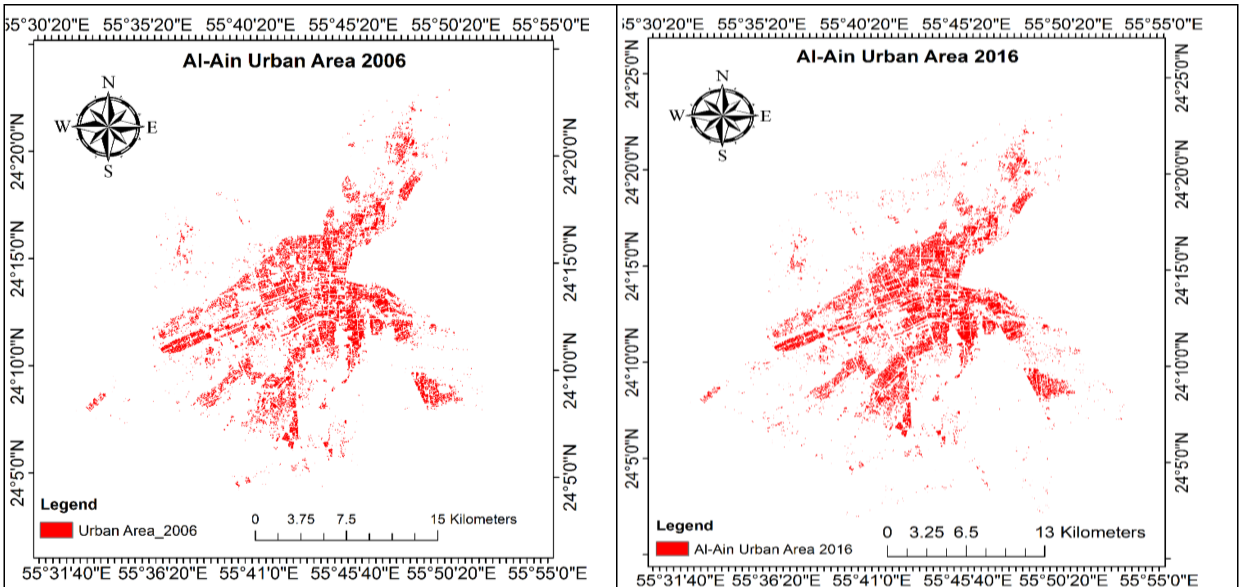
Accuracy assessment is considered an integral part of land use and land cover classification. The reliability of land use classification highly depends on the data quality, its processing and classification techniques (Usman et al. 2015). In this study, error matrix was developed with the help of Google earth data to check the accuracy level of classified maps. The user and producer accuracy of classified map is shown in Table 3.

Table 3. The accuracy of LULC classification

LULC class	User accuracy (%)	Producer accuracy (%)
Agriculture/Farms/Oasis	71	77

Garden/Parks	64	56
Urban Area	70	74
Sandy Area	71	67
Overall Accuracy	70	
Kappa Coefficient	63	

Table 3 shows the overall accuracy of 70% with a Kappa coefficient of 63. Higher values are observed in agriculture and urban areas whereas garden/parks exhibited a lower accuracy. The accuracy assessment table for all images shows that due to constraints of spatial resolution of Landsat ETM images, it is difficult to classify the agricultural lands, gardens and parks (playground) with a very high accuracy. The presence of sand in urban areas was found difficult to distinguish, which results an over estimation of urban areas. This constrains could be minimized by using high resolution images. The urban area change is shown in Figure 3. It is observed that the urban area in Al Ain is expanding in the west and south-west direction, which is mainly due to the construction of Al Ain - Abu Dhabi road networks as well as easily access of water and electricity facilities in that directions. Similarly, a slight expansion of urban area in the north-east direction is also observed.



a) *Al Ain Urban Area 2006* b) *Al Ain Urban Area 2016*

Figure 3 Urban area change in Al Ain region

4. Conclusion

This study shows the trends of land use changes in the Al Ain region (UAE) form 2006 to 2016. It is found that the land use land cover has been changed significantly in the region from 2006 to 2016, in particular the urban area has been increased by about 10.5%. This study provides the base information for detecting urban sprawl in the region. Future work will concentrate on LULC classification of the whole UAE using high resolution datasets.

5. References

Anderson, J.R., Hardy, E.R., Roach, J.T. Witmer, R.T. 2001. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964.

Adepoju, M., Millington, A. and Tansey, K. 2006. Land use/land cover change detection in metropolitan Lagos (Nigeria): 1984-2002," in ASPRS 2006 Annual Conference Reno, Nevada May, pp. 1-5.

Coskun, H.G., Alganci, U. and Usta, G. 2008. Analysis of Land Use Change and Urbanization in the Kucukcekmece Water Basin (Istanbul, Turkey) with Temporal Satellite Data using Remote Sensing and GIS. Sensors, 8, 7213-7223.

Cheema, M.J.M. and Bastiaanssen, W.G.M., 2010. Land use and land cover classification in the irrigated Indus Basin using growth phenology information from satellite data to support water management analysis. Agricultural Water Management 97, 1541-1552.

Gammal, E.A., Salem, S.M. and El Gammal, E.A. 2010. Change detection studies on the world's biggest artificial lake (Lake Nasser, Egypt). The Egyptian Journal of Remote Sensing and Space Science, 13 (12): 89-99.

Richards, J. and Jia, X. 2006. Remote Sensing Digital Image Analysis: An Introduction, 4th Ed., Springer. Yang, X. and C. Lo. 2002. Using a time series of satellite imagery to detect land use and land cover changes in the Atlanta, Georgia metropolitan area. International Journal of Remote Sensing 23(9): 1775-1798.

Rawat, J.S. and Kumar. M. 2015. Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Sciences. 18, 77–84.