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VARIATION IN LAND USE/LAND COVER AND AIRCRAFT SOUND LEVELS AROUND ABU DHABI INTERNATIONAL AIRPORT

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Abstract

More than 23 million passengers passed through the terminals of Abu Dhabi International Airport (AUH) during 2017, with an average of over 14,000 flights each month that increase levels of aircraft sounds and vibrations associated with airliners. This paper focuses on analyzing the variation in land use and aircraft sound levels around AUH in order to understand how the local community has been affected and provide policy recommendations. The land-use change data around the AUH, extracted from secondary data sources using remote sensing and geographic information systems, show a major increase in urban areas during the twenty-year period considered (1993–2013), which is mainly due to the increase in population and growth of the tourism industry. While the current noise levels around AUH are found to comply with the standards of the Federal Aviation Administration, we recommend that authorities avoid allowing public institutions to be built near aircraft flight paths.

Keywords: *Abu Dhabi International Airport, aircraft sound, GIS, land use/land cover, remote sensing*

1. INTRODUCTION

Today, 55% of the world's population lives in urban areas (United Nations, 2018), and there is an average of 7% growth in air traffic globally (IATA, 2018). Science and technology have shortened the distance between people, and modern transportation has made it easier, more economically affordable, and faster for people to move in search of jobs, opportunity, education, and better quality of life (United Nations, 2017). As countries continue to grow, national and international migration demands have also increased in parallel.

The United Arab Emirates (UAE) is composed of more than 80% immigrants, and airports are the major gateway for immigrants to reach the country. Abu Dhabi International Airport (AUH) is one of the busiest airports in the country, with more than 23 million passengers passing through its terminals during 2017 and an average of 14,487 flights each month (Abu Dhabi: Airport Innovation in Aviation, 2017). As the capital city of the UAE, Abu Dhabi is one of the region's major economic hubs and has witnessed rapid development in recent decades due to increases in oil revenue, population, and tourism (more than 4.4 million visitors in 2016 with an 8% growth rate) (Department of Culture and Tourism, 2018).

The airport is considered one of the most important drivers of the development of the city, and, in the first four months of 2017, the number of passengers passing through AUH reached 8.2 million (Abu Dhabi: Airport Innovation in Aviation, 2017). Moreover, the number of flights arriving and departing from AUH has increased from 112,009 in 2010 to 172,069 in 2016 (CAPA, 2017).

We note that, while about 22% of Abu Dhabi's citizens are Emirati nationals, approximately 46% of the Emirate's total population resides in Abu Dhabi City. The increase in population in recent decades generated a need for more residential areas and supporting infrastructure, such as schools and hospitals, and newly developed communities that now fall in the affected zones around the airport include Khalifa City, Madinat Zayed, Shakhbout City, Al Shamkha, and Al Falah (Figure 1).

This study investigates the variation in land use/land cover in the areas surrounding AUH between 1993 and 2013 and measures the noise levels at several surrounding public facilities to assess AUH's environmental impact on local communities.

The resulting data highlight the extreme urban development that has taken place within a 15-km radius of AUH. Remote sensing is an extensively used technique to investigate such geographic changes because of its many strengths, which include the availability of temporal images, its ability to cover large or inaccessible areas, and the overall high cost/benefit ratio.

Aircraft noise is the most detrimental environmental effect of aviation; it is related to annoyance, negative effects on children's cognitive skills, sleep disturbances, and impairment of sleep recuperation (Basner et al., 2017). Our study also examines the effects of aircraft noise on the public by evaluating the noise levels in schools, hospitals, and hotels within the 15-km periphery of the AUH airport. There is no relevant research that has been conducted to address these issues; thus, this research will provide insight into the impact of aircraft noise pollution and land-use variations near AUH.

2. BACKGROUND

As noted above, assessing the environmental impact of noise pollution from the aviation industry on humans and nature is becoming an increasingly important field of research. Exposure to aircraft noise for extended periods has been linked with a number of psychological and physiological reactions such as disrupted breathing, increased nervousness, disturbed sleep, and overall annoyance (Bluhm and Eriksson, 2011; Hatfield et al., 2001; Ko et al., 2011).

Recent European reports have also provided evidence of a link between aircraft noise and hypertension (i.e., an increase in blood pressure) and self-reported hypertension (Rosenlund et al., 2001; Haralabidis et al., 2008). Even earlier, a report submitted to the U.S. Congress in 1973 highlighted the adverse health effects of aircraft–airport noise on millions of people living near airports worldwide (United States Environmental Protection Agency, 1973).

More generally, industrial noise has been recognized to interfere with verbal communication and to inhibit creative activities, which can decrease children's learning skills further (Goodfriend and Kessler, 1973). Thus, urban planners should consider these health considerations when planning new residential zones near existing (or new) airports.

Nowadays, the noise levels of offending sources (such as aircraft) cannot be fully controlled, so the abatement of noise pollution largely depends on our ability to control noise levels in the immediate proximity of the noise source through proper planning of land use and education of the public (United States Department of Agriculture–Forest, 2017).

Recently, a comparative land-use–based study conducted in Nigeria sought to quantify the magnitude of the noise associated with different land-use features and noise risk exposure and drafted a relationship between land use and noise levels (Baloye and Palamuleni, 2015). The study concluded that an increase in the noise level of an urban environment could have detrimental psychological and physical effects that may not have an immediate visible manifestation.

The World Health Organization (WHO) has published several guidelines in order to protect the public from the adverse effects of noise pollution. Their guidelines suggest that a noise level of less than 35 dB is required for comfortable sleep, while long-term exposure to noise levels of approximately 90 dB may lead to permanent hearing loss. In more serious cases, continued exposure to noisy environments of 100 dB may damage one's auditory organs, while noise levels near 120 dB are considered painful and may cause sudden loss of hearing (Mato and Mufuruki, 1999; WHO, 2009).

Furthermore, in one of the earlier studies, it was found that long-term exposure to loud noises was the cause of imbalances in an individual's stress-regulating mechanism and was related to an increased risk of cardiovascular diseases (WHO, 2011).

There are various sources of noise around AUH that contribute to the overall noise level, including traffic, utilities (electricity generation and water pumping), recreational facilities, aircraft, and construction. Of these noise-generating factors, aircraft noise proves to be one of the loudest, with most excessive noise occurring during landing, take-off, and the revving up of engines (Barber, 1992).

As there are many schools surrounding AUH, our attention was drawn to considering the probable environmental effects on children. In particular, children could be particularly susceptible to the effects of noise caused by aircraft and other responsible factors because of its potential to interfere in the learning process at a critical development stage and because they have a lesser capacity to cope with the stressors generated by these ambient noise polluting factors than do adults (Ben-Shlomo and Kuh, 2002).

A study conducted by Zannin et al. (2006) in Brazil measured the noise levels in urban parks and compared them with local permissible noise levels, classifying them into "acoustically polluted" or "acoustically unpolluted" zones. Comparison of our current study with these earlier studies is a good idea, as many schools, hospitals, hotels, and recreational parks and facilities lie within close proximity to AUH.

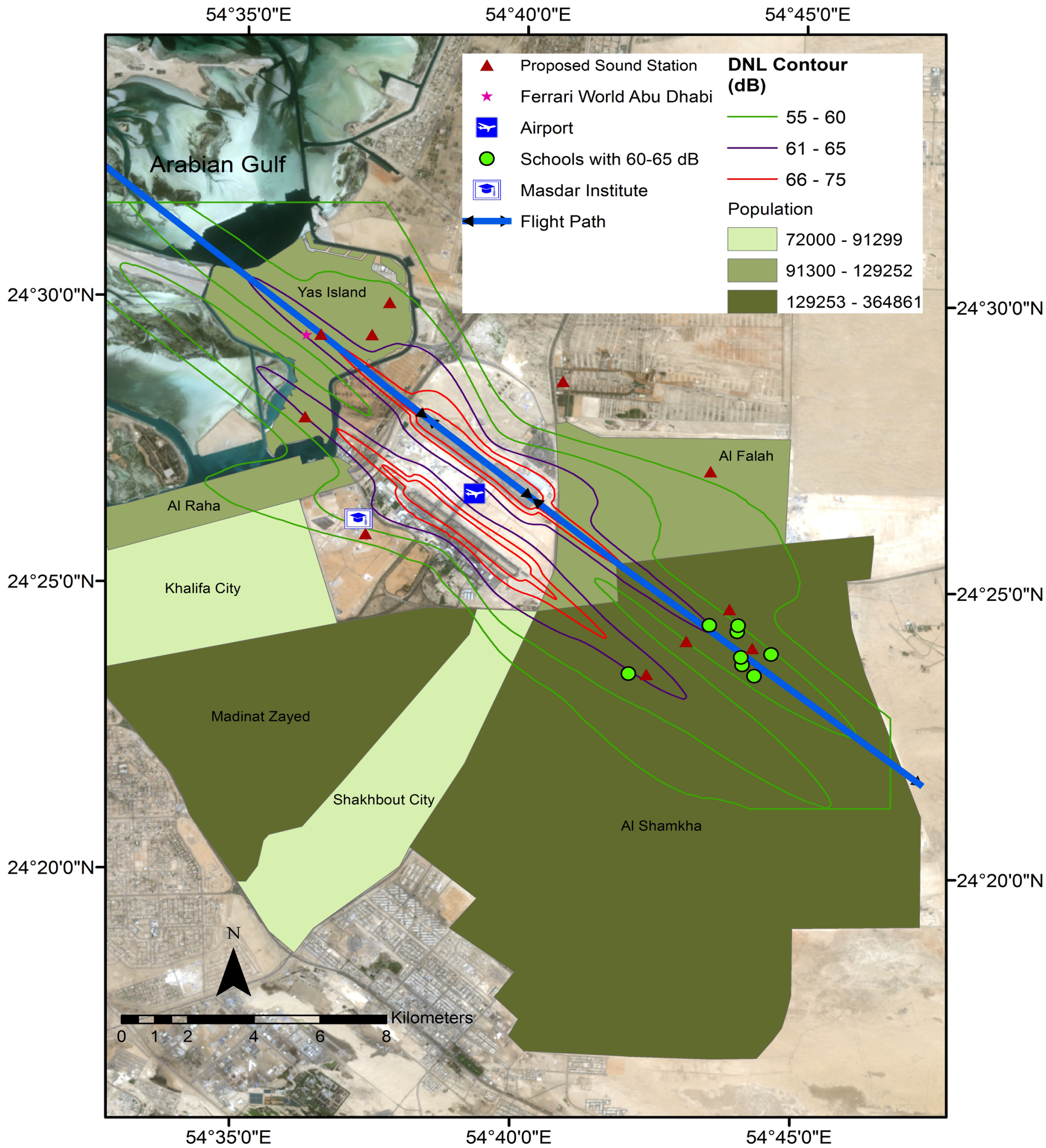

Figure 1. Aircraft sound distribution around Abu Dhabi International Airport (AUH)

Planning is merely a set of regulatory functions concerning the use and development of land; spatial planning goes beyond traditional land-use planning and seeks to integrate policies for the development and use of land into other policies (González, 2017). In this study, the assessment of land use and noise levels around AUH was conducted by using remote sensing and geographic information system (GIS) techniques. As each land use and land cover (LULC) class has regulated and recommended noise-level standards, a corresponding map was prepared, which shows the noise levels in the surrounding areas. We conclude this study with a short discussion of the future implications of the Abu Dhabi Action Plan 2030, highlighting the planning decisions and measures that need to be taken by the Abu Dhabi government with regard to the expansion of the city.

3. METHODS AND PROCEDURES

The Abu Dhabi City confines are located between a latitude of 24.33° and approximately 24.58° north and a longitude of 54.50° and 54.83° east. Landsat images with a resolution of 30 m were downloaded from the United States Geological Survey (USGS) database for the study area. The twenty-year period from 1993 to 2013 was selected for the analysis of the data; the collected data were rectified to the Universal Transverse Mercator (UTM) coordinate system (Zone 40) with World Geodetic System (WGS) 84 datum. The study area is about 40 km surrounding the AUH, and the rectified images were clipped to the study area. The resulting images were analyzed using the ENVI Image Processing & Analysis software package (Version 5.1) in order to classify and detect the geographic changes. Later, Adobe Photoshop and Adobe Illustrator software packages were used for converting the noise contour raster maps to vector format. Further details regarding our research methods and procedures are provided in the corresponding sections.

3.1. Classification of land use

Since the considered area of interest fell in a semi-arid region with different land-cover types with specific spectral profiles distinguished from other parts of the world, the study area was classified into ten types of land cover that best resemble the study area and are grouped into four major categories, as shown in Table 1. Unsupervised classification was applied by using the ISODATA method for all images and grouping the data into 24 classes after seven iterations. Afterwards, a supervised classification was implemented by using the Maximum Likelihood Method on carefully selected training sites, where more than 10 × N pixels of training data were used for each class, where N is the number of bands used for classification extraction. This method can sample all possible occurrences of different land-cover types by using the training sites and relating them to their appropriate classifications (Ramsey and Jensen, 1996).

Table 1. Land-cover classification

No.	Land cover	Description	Merged class
1	Deep Water	Deep sea water far from the coast	Water
2	Shallow Water	Shallow sea water near the coast	
3	Shallow Reef	Visible rocky or sandy areas covered with seawater	
4	Mangrove	Salt-tolerant trees that grow in the shallow tidal waters of coastal areas	Vegetation
5	Vegetation	Agriculture covers (natural or artificial)	
6	Built-up	Built-up or semi–built-up areas and roads	Built-up
7	Bare land	Natural or artificial land distinguished by a high reflectance for all wavelengths May include areas covered with white bright sand or land prepared for future urban expansion	Bare land
8	Sand	Areas covered with reddish sand or sand dunes	
9	Sand–Vegetation	Sandy areas planted with scattered trees or shrubs	
10	Sabkhah	Submerged salt flat areas	

In this study, six bands were used for classification purposes; each class required at least 60 pixels of training data, and these conditions were met accordingly. In order to ensure a suitable selection of training sites, the separability between the classes was calculated using the Jeffreys–Matusita (JM) distance. The JM distance model exhibits a saturating behavior with increasing class separation, in which values approaching "two" indicate a high degree of separability, while values near "zero" indicate a low degree of separability (Ramsey and Jensen, 1996; Thomas et al., 2003). The accuracy of the classification was assessed by comparing the classification map derived from the remote sensing data with references to the test data, where the error (confusion) matrix was used as an effective way to represent the accuracy of each category. In addition, a Kappa analysis (which incorporates off-diagonal elements as a product of row and column elements) was used as a discrete multivariate technique to assess the classification accuracy (Ramsey and Jensen, 1996). Due to the limitations of the overall accuracy assessment, both errors of inclusion (commission errors) and errors of exclusion (omission errors) were calculated to validate our land-use assessment.

3.2. Ground truthing of land-use classifications

The method of ground truthing was used to assess the accuracy of our remote-sensing land-use classification. Randomly selected ground truth sites distinct from the training sites were retrieved from the clipped images yielding a set of unbiased reference data. The overall accuracies of the 1993 and 2013 remote-sensing classifications were 91.59% and 86.22%, respectively (Table 2). The reduced classification accuracy of the 2013 dataset may be due to a higher level of confusion between the land-cover types. This confusion could be due to our method failing to distinguish between built-up areas and bare land, or perhaps between built-up areas and vegetation (e.g., some houses and roads include vegetation). The Producer's Accuracy is the map accuracy from the point-of-view of the mapmaker (the producer), which indicates how often real features on the ground are correctly shown on the classified map; the User's Accuracy is the accuracy from the point-of-view of a map user, which indicates how often the class on the map will actually be present on the ground (GSP: Introduction to Remote Sensing, 2015).

Table 2. Classification accuracy

Land cover	**1993**		**2013**	
	User	**Producer**	**User**	**Producer**
Water	84.07	87.63	84.92	96.15
Vegetation	84.16	79.43	92.11	69.62
Built-up	86.49	63.59	89.48	90.07
Bare land	93.60	96.99	75.14	81.45
Overall	91.59%		86.22%	
Kappa	0.7933		0.7603	

3.3. Noise-level extraction

In order to extract the noise-level data presented in this paper, the ArcGIS software package (Version 10.4) was used for the georeferencing of noise contours, digitizing of flight paths, and further spatial analysis. The noise-level data were extracted from a noise exposure map (dated December 2010) provided by the AUH, which indicated the average day–night sound levels (DNL, Ldn). The map was created based on the number of annual flights, aircraft types, flight tracks, airport layout, land use in surrounding areas, and other inputs. The same map was used for planning and mitigation purposes. As the map collected from the authority was in Portable Document Format (PDF), it was converted to a high-resolution image (600 dpi) by using Adobe Photoshop; in addition, this image was georeferenced in Arc Map. Since digital maps contain a greater number of contour lines and altitude information than does a draft map/noise exposure map provided by the AUH, a digital map is recommended for extracting the contour data (Ko et al., 2011). In order to extract the noise contours accurately in vector format, Adobe Photoshop was used to make the contour lines more distinguishable before reading the contour lines with Adobe Illustrator. The resulting drawing (DWG) data were imported into Arc Map and georeferenced using the shape file. The “Topo-to-Raster” tool in Arc Map was used to interpolate the noise contour lines with a digital elevation model raster surface. The noise levels were extracted for each feature by using the “Extract Values to Point” tool in ArcMap. The two airport runways were digitized using an Abu Dhabi Spatial Data Infrastructure Service base map, and the two flight paths were determined using the contour lines as a guide.

In order to study the noise levels surrounding AUH, we considered a buffer zone that extended 15 km from both sides of the flight paths. For the noise-level study in Gatwick Airport, a flexible boundary line was chosen to ensure entire roads and communities are included, and the noise contour boundary was drawn along the flight paths to 15 km east and west of the airport (Gatwick Airport Ltd, 2017; Essen et al., 2005). This zone was selected due to its proximity to the airport and the comparatively high density of public institutions and residential complexes (our study mostly focuses on the public institutions because we have done research specifically for residential areas near the airport (Alkaabi, 2017)). The distances of each feature from the two flight paths were calculated using the “Near” function analysis in the ArcGIS software. We have outlined the datasets used in our assessment of the noise levels around the airport in Table 3 below.

Table 3. Datasets used for the assessment of noise levels

Data Type	Primary / Secondary	Date	Format	Source
Noise-level contours	Secondary	12/2010	PDF	Abu Dhabi Int. Airport
Schools	Primary	2014	X, Y data	ADEC*
Higher Education Institutes	Primary	2014	X, Y Data	AD SDI **
Hospitals	Primary	2014	X, Y Data	AD SDI
Hotels	Primary	2014	X, Y Data	AD SDI
Cultural Facilities	Primary	2014	X, Y Data	AD SDI
Ikonos Image (1 m)	Primary	2014	Raster	AD SDI
Base map	Primary	2014	Vector	AD SDI
Recreational Areas & Parks	Primary	2011	Shape File	UAEU, Geog. Dept.
Abu Dhabi Precincts	Secondary	2014	Shape file	AD SDI

** ADEC: Abu Dhabi Education Council*
*** AD SDI: Abu Dhabi Spatial Data Infrastructure, provided by the Abu Dhabi Systems & Information Centre*

3.4. Permissible noise levels

Various guidelines have emerged over the years regarding the maximum permissible levels of noise exposure. In a joint effort, the WHO and the Organisation for Economic Co-operation and Development (OECD) collected global data and developed their own assessment criteria regarding the exposure of the public to environmental noise (The World Bank Group, 1998).

The World Bank has also compiled a “Pollution Prevention and Abatement Handbook” in order to emphasize its environmental policies that are used for all its funded projects (The World Bank Group, 1998). The Federal Aviation Administration (FAA) has also set guidelines and standards regarding the noise levels generated by airports.

According to the FAA, all land uses are considered to be compatible with noise levels below Ldn = 65 dB. Areas with Ldn values above this limit are considered incompatible with residential communities and are eligible for mitigation such as soundproofing (FAA, n.d.). Based on the nature of the data collected in this work, we find that the FAA guidelines are the most appropriate set of standards to use in our analysis.

3.5. Noise assessment

The study area is limited to the 15-km periphery of the AUH and the public institutions and amenities such as schools, higher education colleges, hospitals, and recreational parks within the 15-km buffer area.

We have termed these as "features" in our noise-level map, and detailed assessments of the noise levels for each feature listed in Table 4 are presented in the following section. We believe that our study will be a useful reference for future urban development of the region.

Table 4. Number of features within 15 km of a flight path

Feature	Number
Schools	29
Higher Education Institutes	1
Hospitals	1
Hotels	8
Recreational Areas & Parks	5

4. RESULTS AND DISCUSSION

4.1. Detected changes in land use and land cover

Through change detection analysis, the LULC conversion matrix can be produced for a period between 1993 and 2013, which shows the relationship of some major LULC classes (Table 5), and significant changes in the geographic landscape are evident (Table 5, Figures 2 and 3).

In both years, the largest LULC class in the area surrounding the airport is bare land, accounting for 71% (1993) and 64% (2013) of the region. Similarly, the water LULC class accounted for 25% and 22% of the surrounding region in the respective years (1993 and 2013; Table 5). More significantly, built-up urban areas have increased from 2.8% (175 km^2) of the total region of interest to 11.6% (733 km^2) between 1993 and 2013, while areas of vegetation have also seen a minor increase (Table 5).

This increase in vegetation is due to various conservation attempts and more vegetation along roadsides and in parks, as well as a number of wetland conservation schemes. However, it is very clear that the biggest change (+8.8%) has been in the urban development around the airport (Table 5, Figures 1 and 2).

Table 5. Change in land use/land cover (1993–2013)

Class	1993 (km^2)	%	2013 (km^2)	%	Change (km^2)	Change (%)
Water	1605	25.4	1422	22.5	−183	−2.9
Vegetation	51	0.8	119	1.9	68	1.1
Built-Up	175	2.8	733	11.6	558	8.8
Bare Land	4477	71.0	4034	64.0	−443	−7.0
Total	6308	100	6308	100	0.0	0.0

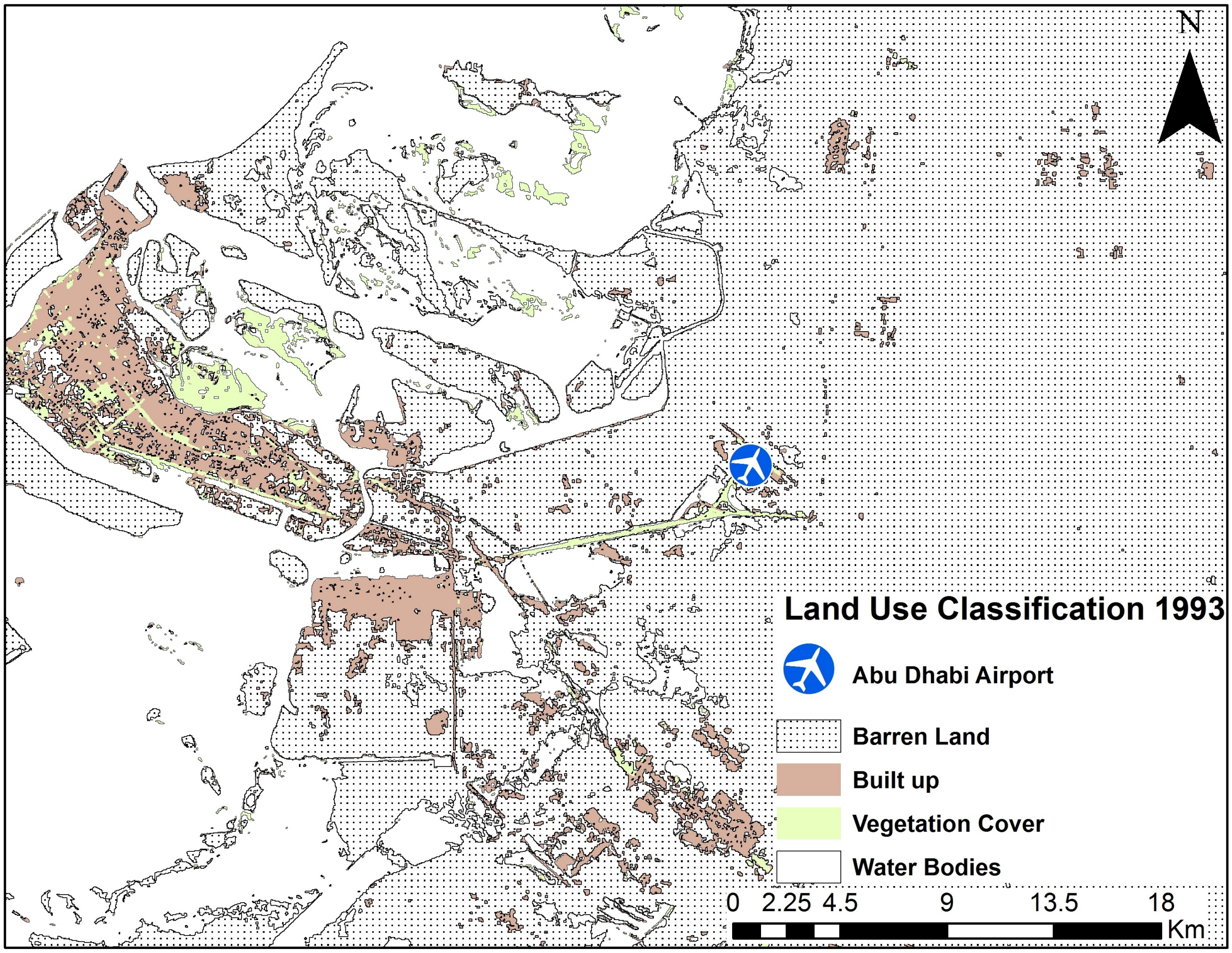

Figure 2. Land-use classification around AUH in 1993

The noise-level data provided by the airport authority indicates that noise in the 15-km buffer area is within the permissible limit of the noise level (65 dB). As per the FAA guidelines on noise, sensitive land-use states that sound insulation is necessary at exposure levels above DNL 65 dB around the airport. The noise-level studies presented in the following subsections provide further details regarding the current situation for all mentioned features, along with some suggestions of interest to planners and authorities.

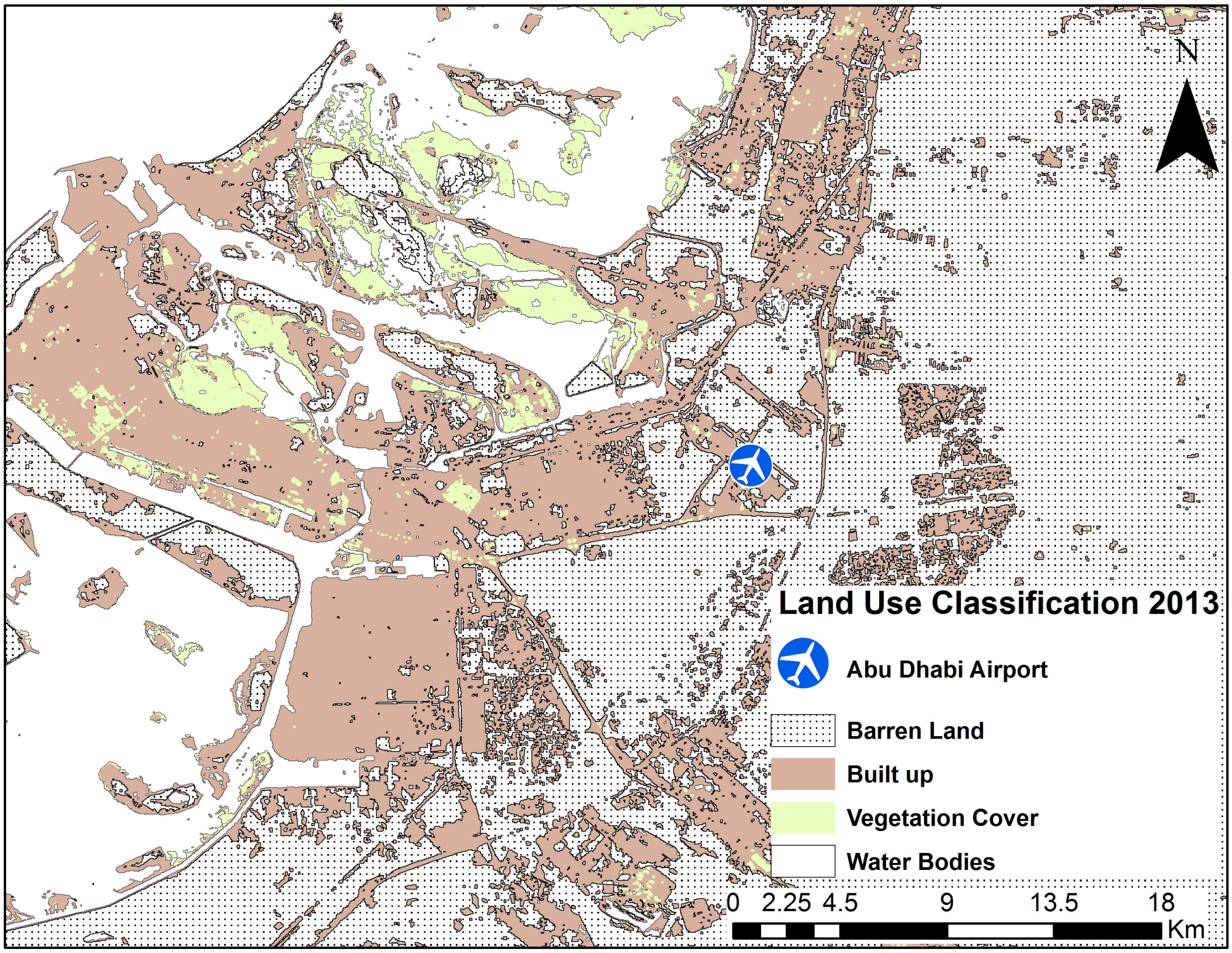

Figure 3. Land-use classification around AUH in 2013

4.2. Educational institutes

The noise-level data for educational institutes were divided into two broad categories: schools (both primary and secondary level) and higher education institutes (both colleges and universities). Within the buffer zone of 15 km on both sides of the flight paths, we found one higher education institute (Masdar) and 29 kindergartens/schools.

The Masdar Institute of Science and Technology is situated around 1.88 km from the runway at AUH and has a noise value of Ldn = 61.6 dB. As per the FAA guidelines, all land uses are to be compatible with noise levels below Ldn = 65 dB (GSP: Introduction to Remote Sensing, 2015), and it was observed that two kindergartens (i.e., 7% of the 29 schools) in the Al Shamkha district were in an Ldn range of 64–65 dB (Table 6). In fact, all of the schools/kindergartens with an Ldn value greater than 60 dB are found in the Al Shamkha district; this is mainly due to their location along the flight path (Table 6, Figure 1).

Table 6. Noise levels at some schools near the airport (Al Shamkha district)

School name	No. of students	Distance to flight path (m)	Noise level L_{dn} (dB)	Distance to runway (m)	Grades
Al Tafawoq School	934	101	61.0	7,171	1–5
Al Shamkha KG	292	126	65.0	5,915	KG 1–2
Al Hosn School	1002	271	60.8	7,303	10–12
Al Taqadom School	818	334	60.6	7,781	1–5
Al Jeel KG	272	457	64.7	4,606	KG 1– 2
Al Erteqaa School	1052	480	60.6	6,789	6–9
Bunat Al Ghad KG	259	538	60.2	7,989	KG 1–2
Al Asala School	863	651	60.1	6,756	1–5

There are many common reasons for not noticing aircraft noise, such as classroom noise levels, noise-proof building designs (i.e., sound attenuation), sound insulation around airports, quieter aircraft, and aircraft movement schedules (Faber et al., 2012; Kucha, 2014). From Table 7, we observed that the number of flights arriving and departing AUH (i.e., 16.8% of total flights) during school hours (08:00–14:00) is lower than at any other time of the day. This may further justify why no disturbances from aircraft noise were reported by the schools. It is very clear that around 73% of the flight movement is at night and early morning. Many studies show that exposure to noise pollution makes classroom discussion more difficult, increases blood pressure, and can result in bad temperament, headaches, nervousness, and increased mental stress (Haines et al., 2001; Evans et al., 1995).

Table 7. Number of flights arriving and departing from Abu Dhabi International Airport

Time (LST)	Jan. 2014	Feb. 2014	Total	%
00:00–08:00	4368	4054	8422	36.9
08:00–14:00	1948	1902	3850	16.8
14:00–23:59	5546	5034	10580	46.3
Total	11862	10990	22852	100

4.3. Hospitals

The health of local residents living in proximity of an airport is closely related to their noise exposure, and a patient's health risk is increased if the hospital they are being treated in lies within the noise-affected zone of influence (Morrell et al., 1997). Provita International Medical Center LLC is the only hospital within the study area, and it is a rehabilitation hospital with 32 beds that operates between 09:00–13:00 and 17:00–21:30 LST. It is located 4.734 km from the flight path and 5.286 km from the runway at AUH with a noise value of Ldn = 53.7 dB. This indicates that the hospital is compatible with existing noise-level standards.

4.4. Hotels

Airlines are a good example of the positive and negative impacts of externalities and environmental economics on the leisure and tourism sector (Bieger and Wittmer, 2006). The negative externalities caused due to aircraft noise pollution affects an individual's consumption of goods and services. Some of the effects of aircraft noise pollution on the leisure industry include inhibiting guests from listening to music, relaxing, taking part in other diversions, or even sleeping (Tribe, 2011). The noise-level data of several hotels located within the noise-affected zone are presented in Table 8. The distance of each hotel from the flight path is less than 7 km, and five hotels fall within 500 m of the flight path. This proximity to the flight path increases their noise exposure to nearly the permissible limit of Ldn = 70 dB for commercial buildings (FAA, n.d.); however, current levels have not crossed this limit and thus remain at acceptable levels. This limit could be crossed in the future, however, posing a significant health threat to guests of hotels in the area.

Table 8. Hotels within the study area

No.	Name	Distance to flight path (m)	Noise level (dB)	Distance to runway (m)	Guest rooms
1	Yas Viceroy Hotel LLC	14	66.2	3,345	499
2	Park Inn Yas Island Hotel	344	64.2	4,040	204
3	Tilal Liwa Hotel	425	63.6	3,954	111
4	Radisson Blu Hotel Yas Island	435	62.9	4,063	397
5	Yas Island Rotana Hotel	439	63.3	3,942	308
6	Centro Yas Island Hotel - By Rotana	538	62.1	3,963	259
7	Crowne Plaza Hotel Yas Island	592	61.1	4,121	428
8	Hotel And Chalets Of Al Raha Beach Shopping Centre	4,525	54.8	6,348	134

4.5. Recreational areas and parks

In relation to both humans and wildlife, the often near-silent ambient noise of parks can be disturbed by aviation noise generated miles away. Five recreational parks lie in the study area that were categorized as sports or amusement complexes (Table 9). As per the FAA guidelines, amusement parks and resorts are compatible with a noise level of Ldn between 70–75 dB. Therefore, all parks found within the study zone are within the permissible sound levels. However, Ferrari World Abu Dhabi may need to invest in some sound reduction measures, as the number of flights will likely continue to increase in the future.

Table 9. Recreational areas and parks within the study area

No.	Name	Distance to flight path (m)	Noise level (dB)	Distance to runway (m)	Type
1	Ferrari World Abu Dhabi	294	65.4	4,529	Amusement Park
2	Yas Marina Circuit	643	60.7	3,636	Sports Complex
3	Al Ghazal Golf Club	1,554	55.9	1,547	Golf Course
4	Amiri Stables	4,465	52.8	13,609	Sports Complex
5	Al Asayl Racing & Equestrian Club	4,465	52.8	13,609	Sports Complex

Due to the rapid urbanization in the UAE, the sustainable development of urban areas should be equally important as other societal demands. The Abu Dhabi Urban Structural Framework Plan 2030 involves many key urban infrastructure projects that are located around AUH. The market projections for the year 2030 predict that the population will be increased to 3.1 million residents, with 7.9 million tourists visiting annually, corresponding to an associated increase in aircrafts passing through AUH (Abu Dhabi Urban Planning Council, 2016), which will certainly lead to demand for new office/rental spaces, hotel rooms, schools, tertiary institutions, hospital beds, recreational areas, etc. This study shows that most of the amenities/institutions within the 15-km buffer area are under the noise-level limit, but a few of the amenities are at the edge of the noise level (65 dB) suggested by the FAA. The increasing population and number of tourists in the coming decades will necessitate more aircraft and lead to increases in the regional noise levels.

5. CONCLUSIONS AND FUTURE WORK

In this study, the variation in land use around AUH was classified and investigated. With the help of noise-level data provided by the airport authority, we analyzed the environmental impact of the air traffic and noise levels at several important facilities close to the airport. This research also demonstrates the use and importance of Landsat classification and change detection techniques to analyze the effects of noise pollution on local communities.

The spatial variation in noise levels is characterized by various sound levels identified within the study area and evidenced by the statistics provided. Sound measurement devices should remain at public places and schools that are vulnerable to noise pollution in order to generate useful data for further analysis and to alert authorities when further preventive actions are required to safeguard the public.

While noise pollution is known to have adverse health effects, in order to properly assess the effect of aircraft noise on patients in hospitals, a larger population sample surrounding the airport should be considered with greater variations in the exposure to aircraft noise. The study analysis demonstrates that the noise levels in most of the region's educational institutions comply with sound-level guidelines approved by several international organizations.

Two kindergartens are recommended for soundproofing because of the noise levels in those schools being close to the upper permissible limits. In the near future, due to high aircraft traffic, the current situation could deteriorate, and more areas could be negatively affected by high-intensity sound levels. We therefore also recommend addressing the amenities that already have noise levels between 60–65 dB and considering those locations for noise-insulation programs. In addition, new technologies should be developed to reduce aircraft noise, and authorities should monitor the aircraft noise levels.

Overall, the results of this study indicate that the existing acoustic conditions of the area surrounding the airport and the amount of noise generated by aircraft traffic comply with internationally acceptable norms. However, as air traffic is likely to increase in the future, authorities may need to revise their noise-level standards in public areas, formulate new regulations and strategies for urban expansion in noise-affected zones, and follow the FAA or other standards on noise abatement to reduce the impact of aircraft noise on neighboring communities. In addition, we suggest that noise-monitoring stations be installed in public zones around the airport because this will provide more accurate data than computer-generated models will. Moreover, the authors recommend that AUH allocate a budget to enhance the soundproofing at public institutes and residential zones near the airport where sound levels exceed 65 dB DNL. It is important to note that this paper is based on a quantitative research model carried out using GIS software and needs physical verification to better understand and measure the adverse effects of noise (annoyance) and the perspective of the local community.

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