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THE IMPACT OF CLIMATE CHANGE ON THE UNITED ARAB EMIRATES LAND USE: PAST AND PRESENT

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ABSTRACT

Globally, population growth and changes in land-use practices affected the dryland ecosystems. Land use can stimulate changes in communities under climate change. The aim of this study was to detected the impact of climate change on land use in UAE (Abu Dhabi, Al-Ain and Sharjah) by assessing the change in air temperatures through the different land use classes. The research question was; what is the relationship between the increase in the air temperatures and the change in the land use/ land cover classifications through the past 20 years. Eight classes were recognized in the study area; Costal Sabkhas, Inland Sabkhas, Mixed Class (Urban and Vegetation), Urban, Rock Outcrops, Rocky Surfaces, Type 1 soil (Sand Dunes) and Type 2 Soil (Bare Land). In the year 2001, Coastal Sabkhas, Mixed Class and Urban experienced increase in temperature by (0.67, 1.14 and 1.16), respectively. In 2008 there was a drop in the temperatures from 35.43°C to 33.65°C in Mixed Class (1.78°C) and from 35.62°C to 33.54°C in Urban Class (2.08°C). Future detailed study in the area to monitor the change in land use due to climate change and vice versa is a good opportunity for the researchers who are interesting in the region.

Keywords: UAE, air temperature, climate change, LULC, remote sensing.

INTRODUCTION

Climate change impacts are expected to be more noticeable by time, because our region will experience higher stresses (Elhakeem and Elshorbagy, 2015). Based on Verner (2012), climate change forecasts suggest that average temperatures in the Arab countries will increase by up to 3°C by 2050. This increase will lead to different changes in evaporation and rainfall rates, sea level rise, vegetation areas, consumption of water and electricity. UAE is part of the Arabian Peninsula which is an arid region where rapid global population increase joined with urbanization and industrialization led to the deterioration of water quality and shortages of fresh water supplies (Mohamed and Al-Mualla, 2010). To study the change in climate, LULC is among the best indicators. Recently, LULC change analysis has become an essential tool used to measure the environmental and ecological consequences of human activities (Flamenco-Sandoval *et al*., 2007). Industrial breakdown accompanied with LULC change donate globally systemic changes as GHG buildup in the troposphere, and stratospheric ozone depletion (Turner *et al*., 2007). LULC changes are universal in a way that when combined globally, they ominously affect key aspects of earth system functioning, causing major changes such as; global climate warming (Lambin *et al*., 2003).

Many areas were degraded in the Arab region due to different factors such as drought and urbanization crawling. IPCC reported that over the past two decades, the land surface temperatures warmed at a rapid rate compared to oceans of about 0.27°C vs. 0.13°C per decade (Solomon *et al*., 2007). Long trends in temperature and precipitation in the Arabian Peninsula is not clearly known. This is because the region covers a wide range of countries, with poor data availability, quality and consistency in some countries (Zhang *et al*., 2005; Kwarteng *et al*., 2009; Nasrallah and Balling, 1993). The United Arab Emirates (UAE) has narrow arable land, harsh climate, and limited renewable water resources. Consequently, the country has limited land use types. In addition, since 1970s, the human population growth and economic development put an increasing pressure on land use (Ammar, 2013). Human activities influence land use change in various ways; high population density, growing demand of land for agriculture, prohibited forests cutting, and overgrazing (Wakeel *et al*., 2005; Kadıo˘gulları, 2013; Kennedy and Spies, 2005). In the UAE, the land use change impacts both water resources and the environment (Ammar, 2013).

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Land use change for expanding agricultural areas, resulted in direct habitat loss, but also caused fragmentation of remaining habitat and magnified agrochemical inputs into surrounding habitats (Oliver and Morecroft, 2014). In 2008 the total cultivated areas in the UAE have increased to over 200,000 ha compared to 1991 (40,000 ha). This expansion was close to the existing agricultural farming area in Al Ain; by time, the expansion occurs to the other surrounding arable areas (Ammar, 2013). Population growth and changes in land-use practices affected the dryland ecosystems of the world, which increased the concern over the human impact on drylands (Evans and Geerken, 2004). Varghese and Singh (2016) reported that, Jodhpur region showed that the increase in human population (by 400%) and livestock population (by 127%) during the past century caused a major alteration in land use pattern and put great pressure on surface and ground water resources (Rao, 1996).

In the UAE, forestry plantation was made following the government policy to combat desertification and moderate climate affect and to clean the environment with the slogan "greening the desert." Natural or wildlife forests do not exist in the UAE. Most of the mangrove forest areas are located in Abu Dhabi (305,000 ha) and Dubai (47,000 ha) emirates (Ammar, 2013). According to Turner *et al*. (2007) the causes, impacts, consequences, and dynamics of socio-ecological systems, can be better understood through LULCC integrated research across different fields. Mendoza-Ponce *et al*. (2018) has conducted a research into complex LULCC phenomenon focusing on analyzing historical trends and patterns. Few case studies consider collaborating feedback between LULCC and climate change under different scenarios (Oliver and Morecroft, 2014). Land use change has a close link between access to land as affected by land tenure, and land value. What binds all these together is that land is becoming scarce and essential, which become a principal tool for wealth and income generation (Alqurashi and Kumar, 2013; Muringaniza and Jerie, 2016). Land use can stimulate changes in communities under climate change. For example; extreme climate events, such as intense prolonged drought, can lead to a severe impact on the structure of communities and this is with no doubt facilitated by land use (Oliver and Morecroft, 2014).

Researchers focused on land use and land cover changes and conducted studies on several parts of the world (Muringaniza and Jerie, 2016). It is believed that land use change is expected to continue to be a major driver especially in the tropics, while the amount of change in temperature is projected to be highest towards the poles (Oliver and Morecroft, 2014). Moreover, some of the studies focused on the reasons behind the occurrence of land use changes through a socio-economic perspective (Muringaniza and Jerie, 2016). The aim of this study is to detect the impact of climate change on land use in UAE (Abu Dhabi, Al-Ain and Sharjah) by assessing the change in air temperatures through the different land use classes.

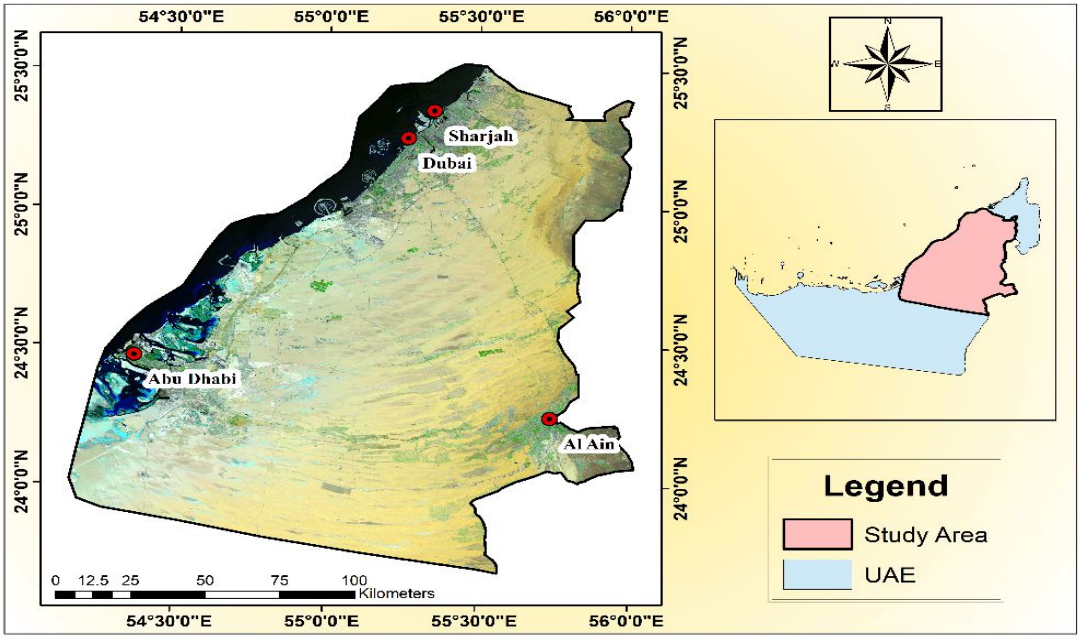

Fig. 1. Study area (Abu Dhabi city, Al-Ain and Sharjah).

MATERIALS AND METHODS

The present study focuses on average monthly temperatures collected from NOAA (https://www.ncdc.noaa.gov/cdo-web/datatools/findstation) Land-Based Station Data, for Abu Dhabi, Al-Ain) and Sharjah. Each location represents a different bio-climatic zone within the UAE. The study area is shown in Figure 1. Because Dubai is located between Sharjah and Abu Dhabi it was included in the area and was covered in the analysis.

The period of the historical data is between June 1997 and June 2017. In this study, the used Landsat images were downloaded from USGS (http://earthexplorer.usgs.gov/) and captured in summer (Table 1).

Table 1. Landsat images used in the study.

Image	Path	Row	Date
Landsat 4-5	160	42/43	20-06-1997
Landsat 4-5	160	42/43	02-08-2001
Landsat 4-5	160	42/43	17-06-2008
Landsat 8	160	42/43	16-06-2013
Landsat 8	160	42/43	11-06-2017

The average monthly temperatures of the three cities (Abu Dhabi, Al-Ain and Sharjah), was downloaded from NOAA which provides weather data from airport stations. The study period was decided to be a 20 years' period from 1997 to 2017. That is due to the availability of the historical weather data and accordingly the Landsat images were downloaded. Table 2 shows the airport station sites that average temperature used in the study are taken from.

Table 2. List of airport stations sites with their geographic coordinates.

Location No.	City	Lat	Long
1	Abu Dhabi	54.651	24.433
2	Al-Ain	55.609	24.262
3	Dubai	55.364	25.255
4	Sharjah	55.517	25.333

The following steps were followed for the Landsat images downloaded from USGS:

1. Image mosaic to combine the two images in different rows (42/43) in one.
2. Atmospheric correction was done to reduce the effects of atmospheric components and to retrieve spectral reflectance from hyperspectral radiance images. Using FLAASH in ENVI which incorporates the MODTRAN radiation transfer model to compensate for atmospheric effects.
3. An unsupervised classification was done using k-mean algorithm using 10 iterations to generate eight recognized classes which were combined from 10 classes. The recognized classes were; costal sabkhas, inland sabkhas, mixed class (vegetation and urban), urban, rock outcrops, rocky surfaces, type 1 soil (sand dunes) and type 2 (bare land). Classification maps are shown in Figure 2.
4. Ground truthing was done with a combination of two methods; visiting the areas that are reachable and visualizing the unreachable areas using google earth high resolution images with historical tool.

The average monthly temperatures downloaded from NOAA, were used to create maps that show the differences in atmospheric temperatures in the three cities (Abu Dhabi, Al-Ain and Sharjah). The following steps were done:

1. Interpolation between the 4 stations (Abu Dhabi, Al Ain, Dubai and Sharjah) was applied.
2. The atmospheric temperature maps were overlaid with the classification maps to find the attribute table of the classes in relation to atmospheric temperatures.
3. To generate the maps, standardization for the temperature was applied to make sure that all the maps show the same pattern of temperature change, where the minimum temperature was set to 32°C and the maximum to 39°C (Fig. 3).

RESULTS AND DISCUSSION

Our study results show that in 2001, UAE has experienced an increase in the temperatures through all classes. The increase is from 33.70°C to 34.37°C by 0.67°C for class coastal sabkhas and from 34.29°C to 35.43°C by 1.14°C for vegetation and urban mixed class. For the urban class the temperature was 34.46°C in 1997 and it has increased to 35.62°C by 1.16°C. In 2008 there was a drop in the temperatures from 35.37°C to 32.77°C for coastal sabkhas 2.6°C, from 35.43°C to 33.65°C in mixed class 1.78°C and from 35.62°C to 33.54°C in urban class 2.08°C. Another slight drop was noticed in 2013 by 0.15 degrees in coastal sabkhas and by 0.49°C and 0.07°C for mixed and urban respectively. In 2017, the temperatures increased again by 2.33°C from 32.62°C to 34.95°C in coastal sabkhas, 2.51°C from 33.16°C to 35.67°C in mixed class and by 2.29°C from 33.47°C to 35.76°C in urban class (Table 3).

Table 3. Mean monthly temperature (°C) change over time in the different eight classes.

Year	Coastal Sabkhas	Inland Sabkhas	Mixed	Urban	Rock out Crops	Rocky Surfaces	Sand Dunes	Bare Land
1997	33.70	33.71	34.29	34.46	34.25	34.11	34.25	34.47
2001	35.37	35.38	35.43	35.62	35.52	35.60	35.53	35.82
2008	32.77	32.77	33.65	33.54	33.47	33.49	33.49	33.46
2013	32.62	32.70	33.16	33.47	33.38	33.39	33.38	33.25
2017	34.95	35.11	35.67	35.76	35.68	35.69	35.77	35.62

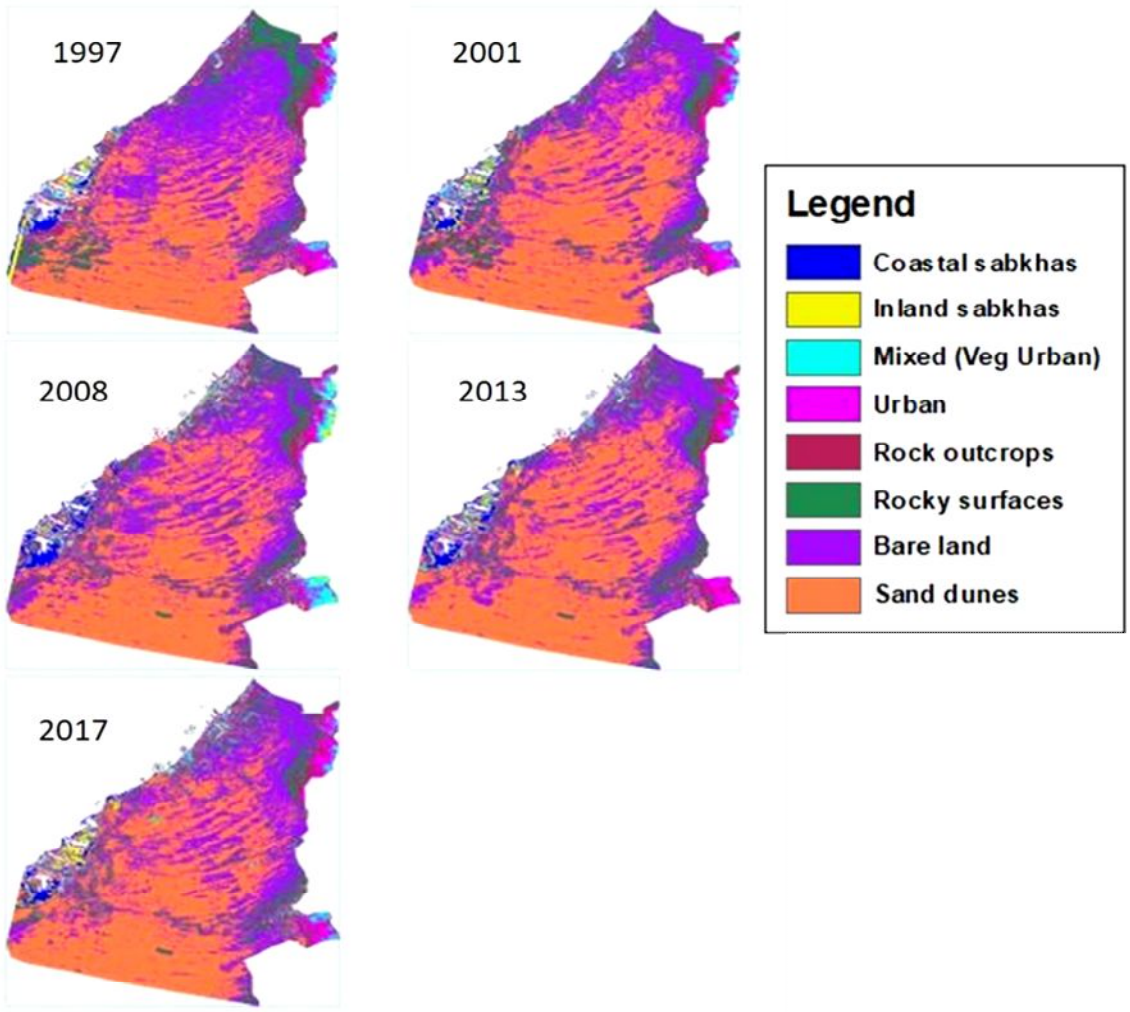

Fig. 2. The eight recognized classes change in the study area over time.

Table 4. Area (Km^2) change over time in the different eight classes.

Year	Coastal Sabkhas	Inland Sabkhas	Mixed	Urban	Rock out Crops	Rocky Surfaces	Sand Dunes	Bare land
1997	338	244	404	771	1155	2627	6969	9107
2001	335	209	384	770	1191	2199	5869	10746
2008	288	288	732	956	1302	2121	6195	9552
2013	319	197	404	945	1230	1915	5500	11302
2017	181	309	565	969	1277	2042	6050	10324

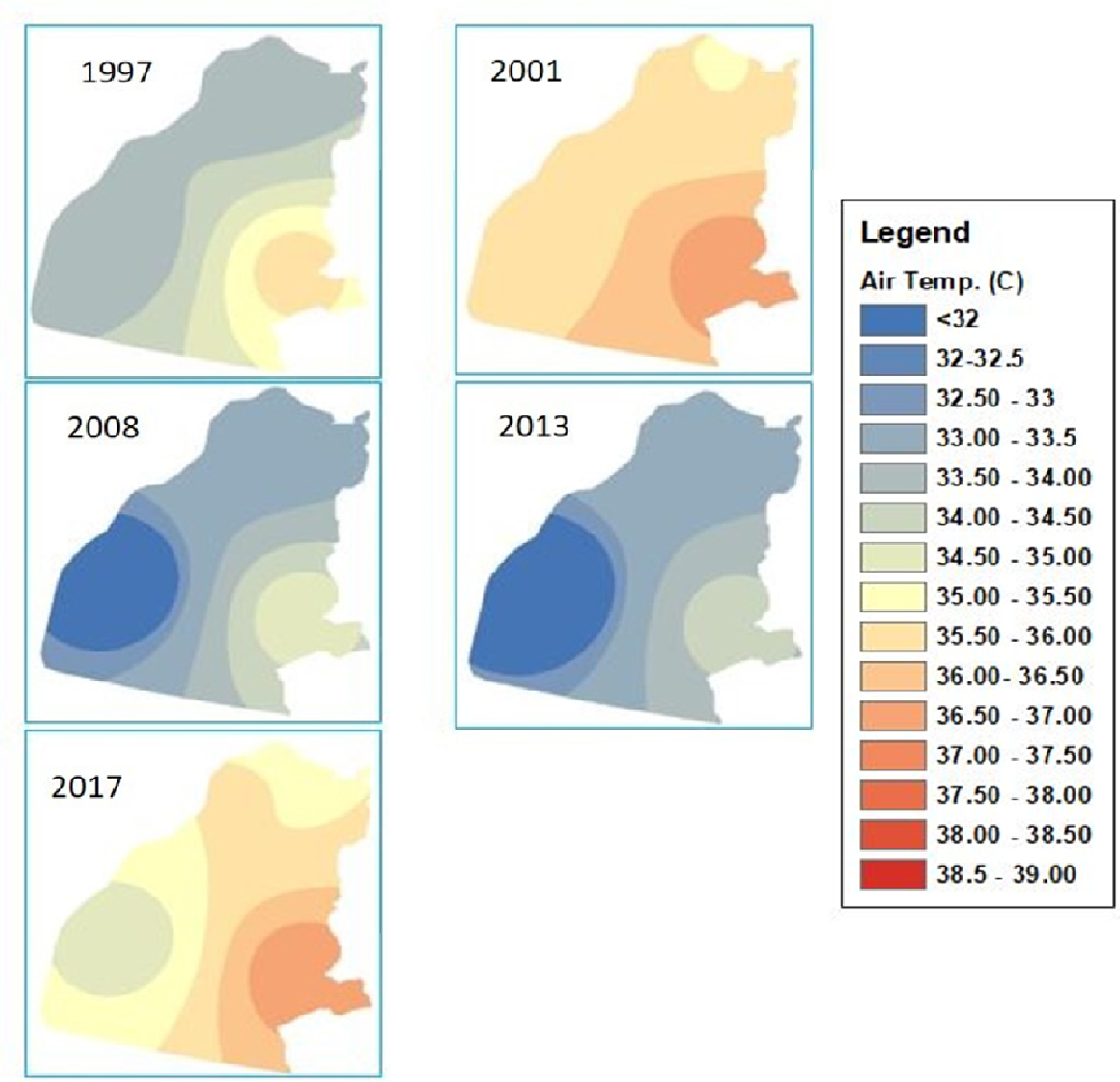

Fig. 3. Mean temperature change in AD, AA and Sharjah over the study period.

The area has changed through the eight classes from 1997 to 2017. The results show that coastal sabkhas has decreased in area from 338 km^2 in 1997 to 181 km^2 in 2017. The mixed class (urban and vegetation) increased from 404 km^2 to 732 km^2 in 2008 then drops to 565 km^2 in 2017. The urban class increased from 771 km^2 in 1997 to 969 km^2 in 2017, while rocky surfaces decreased from 2627 km^2 to 2042 km^2. Bare land area has increased from 9107 km^2 to 10324 km^2 in the past 20 years (Table 4).

Our results show that the mixed class (urban and vegetation) increased from 404 km^2 to 732 km^2 in 2008 then drops to 565 km^2 in 2017. It was hard to separate vegetation from urban areas because the reflection of both is similar due to planted areas surrounding built-up areas. The explanation of the increase in the area from 1997 and 2008 is because of the spread of the urban areas through UAE. The drop in the area can be due to loss of vegetation in abandoned farms. Urban areas increase by 198 km^2 in twenty years. The results showed that, in 2001, the coastal sabkhas, the mixed class and the urban areas experienced increase in temperature by (0.67, 1.14 and 1.16), respectively. While in 2008 the same classes became cooler by (2.6, 1.78 and 2.08) respectively. Coastal sabkhas decreased in area, while both mixed and urban classes has increased from 1997 and 2008. Coastal sabkhas are located on the coasts of Abu Dhabi, which has dramatically changed in terms of urbanization in the past 20 years. The artificial islands and other projects along the coast has undeniably influenced the coastal sabkhas. Only (36%) Of the 150 km of coastal sabkha present along the Abu Dhabi coastline in the 1960s, remains today (Lokier, 2013).

Figure 4 shows the mean temperature and area comparison in the urban class and the mixed class (vegetation and urban). In UAE, vegetation comes with urbanization. Buildings and roads are often accompanied with plantation except in industrial areas. The drop in temperature can be a reason of the increase in vegetation in the mentioned areas. In 2017 the mixed and the urban classes became warmer. It is probably because of the UHI effect or other factors.

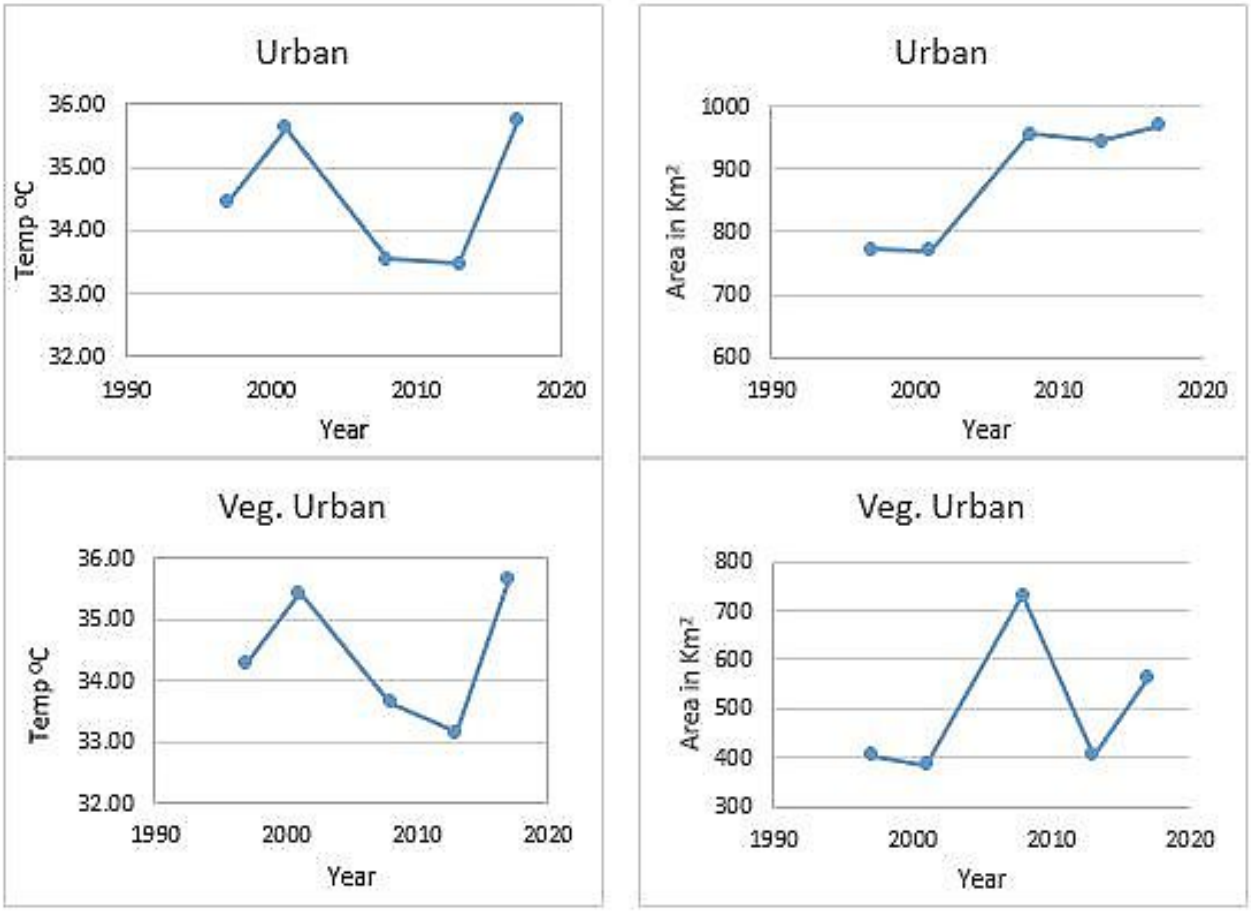

Fig. 4. Mean temperature and area comparison (Urban and mixed classes).

On a case study in Altay Prefecture, China by Fu *et al*. (2017), it was found that the primary land use change was the spreading out of cropland and the drop of bare land areas. Where humans started to exploit desert resources, instead of exploiting mountain resources. In Abu Dhabi, Managed lands (plantation and improvements) from 1990 to 2000, expanded due to regular social forestry and plantation activities (Yagoub and Kolan, 2006). This was not noticed in the findings due to different study period. In the same study, they reported that, built-up areas have been increased from 1990 to 2000, which is a period of rapid urbanization (Yagoub and Kolan, 2006). Our results showed that from 1997 to 2001 the urban area was the same and increase by 184 km^2 in the next seven years (in 2008). In a study by Shanableh *et al*. (2018) they found that there is an overall expansion of built areas and shrinkage of open areas in Sharjah during the study period of 1976–2016 (Shanableh *et al*., 2018). The results showed expansion of urban areas and decrease in both rocky surfaces and sand dunes (Table 4). The explanation can be the urban and industrial expansion, where different types of rocks in mountainous areas are crushed and used in building materials. Sand dunes soils are used as rangelands for camels, the increase in temperatures in the past 20 years can lead to abandoning the areas that lost the types of plants that camels feed on.

CONCLUSION

Land use change is a good indicator to study the potential climatic changes. Anthropogenic activities influence land use change in different ways such as the increasing populations, high demand for agriculture and urban expansion. Trends in temperature and rainfall in the Arabian Peninsula is hard to clearly detect due to limited related studies. In 2001 AD, Sharjah and Al-Ain experienced an increase in the temperatures through all classes. The increase was 0.67°C for coastal sabkhas and

1.14°C for vegetation and urban mixed class. In 2017, the temperatures increased again by 2.33°C in coastal sabkhas, by 2.51°C in mixed class and by 2.29°C in urban class. The area of coastal sabkhas has decreased from 338 km^2 in 1997 to 181 km^2 in 2017. While the mixed class increased from 404 km^2 to 732 km^2 in 2008 then dropped to 565 km^2 in 2017. The urban class increased from 771 km^2 in 1997 to 969 km^2 in 2017, while rocky surfaces decreased from 2627 km^2 to 2042 km^2. This can be related to the use of rocks in building materials to fulfil the urbanization and increasing population demand. Detailed research in the area to monitor the change in land use due to climate change and vice versa is a good opportunity for the researchers who are interesting in the region.

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