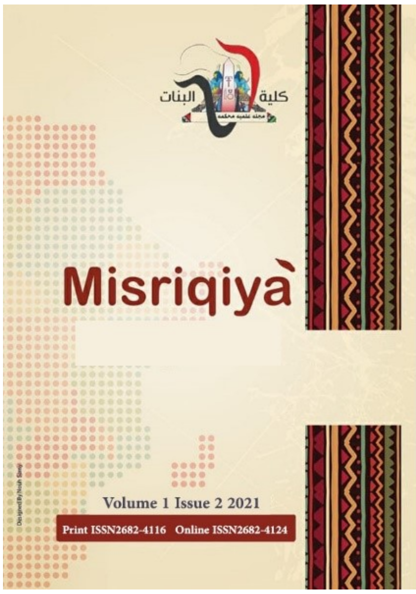

Land Use Land Cover Change of Marsa Alam, Red Sea, Using Remote Sensing and GIS.

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Abstract

Red Sea coastal cities (RSCC) are of great importance as they are an important economic, touristic and mining base for the government, society and environment as well. The city of Marsa Alam is globally known for its unique marine environment and El-Sukary Gold Mine. There has been an urgent need to obtain clear information about the status of the city during the past period for managing the city and its resource. This study aims at investigating land use land cover change (LUCC) and urban expansion of Marsa Alam during 1984-2020. For this purpose, Spectral angle mapper (SAM) classifier and Post classification comparison (PCC) change detection technique were used to analyse five Landsat datasets covering the study period. The results revealed an increase in the urban and green areas. Driving forces and constraints influencing the urban growth as well as the population growth were discussed. Population number of the city is so far from the planned/needed number and do not reflect the city importance in regard to tourism and mining. More governmental efforts are needed to encourage in-migration to the city and support private sector investments. Monitoring outputs obtained from remote sensing and GIS integration is still important in providing valuable basic information needed to manage the city, its resources and research. Further monitoring work of this line is needed to cover other RSCC at the local and regional levels.

Keywords: *Red Sea, Marsa Alam, Landsat images, Remote sensing, GIS, Land use land cover change.*

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1. INTRODUCTION

In the early 1980s, Red Sea coastal cities (RSCC) in Egypt represented one of the solutions that encouraged the population to move out from the narrow old Nile valley and spread to new areas of distinguished natural resources bases. RSCC have different economic bases that include: hotels and tourism, extracting, mining and quarrying, trade and services and agriculture. During the last four decades, coastal tourism has grown significantly, which economically benefited the RSCC and the State as well. Marsa Alam is one of the most important RSCC. It has tourism and mining economic base. Coral reefs and the wide range of underwater wildlife are the main attraction of the city for divers from all over the world, which has resulted in constructing various levels of hotels and camps as well as providing job opportunities for the locals and movers. Further, El-Sukary Gold Mine, west of Marsa Alam, started working few years ago, which is a promising project and expected to contribute well in the State economy. Administratively, Marsa Alm was connected to Quseir district before 1991. Meanwhile, by the issue of the Prime Minister No. 387-1991, Marsa Alam became an administrative district, which includes Marsa

Alam city, in addition to five villages: El- Sheikh El –Shazly, Shalatine, Branis, Aboul- Ghosoon and Abraq (Seoudy, 2000, p 27).
Marsa Alam is a very important RSCC. Since it was established, there were no studies covers its land use land cover changes (LUCC) or its urban monitoring. For better city and resources management, it is crucial to obtain clear information on the status of land use land cover (LULC) of Marsa Alam and explore its LUCC during the past period in order to help decision makers taking appropriate decisions for the city as well as the Red Sea region.

One of the most powerful advantages of remote sensing images is their ability to capture and preserve a record of conditions at different points in time, to enable the identification and characterization of changes over time (Lillesand et al., 2015, p 582). Change detection (CD) is the process of identifying differences in the status of an object by observing it at different dates (Singh, 1989, p 989). CD involves the application of multi-temporal datasets to quantitatively analyse the temporal effects of the phenomenon (Lu et al., 2004, p 2366). In post classification comparison (PCC) technique, two dates of registered imagery are independently classified, and pixels whose class changed between dates are identified (Lillesand et al., 2015, p 583). Spectral angle mapper SAM is a supervised classification technique that classifies the imagery based on the spectral similarity between image spectra and the reference spectra (Kruse et al. 1993, p 146). SAM has a number of advantages over other commonly used spectral-based classifiers namely: i) it is not affected by solar illumination factors, ii) it is an easy and rapid method for mapping the spectral similarity of image spectra to reference spectra, iii) it represses the influence of shading effects to accentuate the target reflectance characteristics, and iv) it does not require any assumptions on the statistical distributions of input data in performing classification (Kruse et al. 1993; Rowan and Mars, 2003; Petropoulos et al., 2010).

Various studies used PCC to investigate LUCC such as: producing land cover maps and change analysis of the Twin Cities (Minnesota) Metropolitan Area in USA (e.g., Yuan et al., 2005); analysing land use/cover changes and urban expansion of Nairobi city in Nigeria (e.g., Mundia and Aniya, 2005); analysing land use and land cover change in greater Dhaka in Bangladesh (e.g., Dewan and Yamaguchi 2009) and analysing land-cover change dynamics and coastal aquaculture development in the East Godavari delta in India (e.g., Rajitha, 2010 and Peiman, 2011). SAM was successfully used in various studies such as: mapping East African tropical forests and woodlands (e.g., Nangendo et al., 2007); obtaining burnt area in a Mediterranean setting (e.g., Petropoulos et al., 2010); for gold associated alteration zone mapping in Central Eastern Desert of Egypt (e.g., Hasan et al., 2016); detecting coastal urbanization and land use change in southern Turkey (e.g., Alphan and Guvensoy, 2016) and mapping of Oman Exotic limestone for industrial rock resource assessment (e.g., Rajendran et al., 2018). For Marsa Alam, it has many studies that covered its geologic and aquaculture sectors, but, there are no studies covered its LULC or LUCC.

Regarding LUCC, when investigating the relationship between Man and Land in Marsa Alam during 1984 and 2020, two main questions have to be answered by this study: 1. Which LULC types were changed, what are their quantities, where are the changes took place and what are the reasons of theses changes? and 2. What are the influences and driving forces affecting the urban growth?

The objective of this study is to investigate LUCC of Marsa Alam, 1984- 2020. Specific objective is to produce Marsa Alam LULC maps in the studied dates.

A descriptive approach was adopted to fulfil the objectives of this study using the integration between remote sensing and GIS. Analysing a time series remote sensing datasets (e.g. Landsat imagery) using a powerful classifier (e.g., SAM) through ENVI 5.3 software provide digital information in the sort of LULC maps of the study area in the studied dates. Further, Arc GIS 10.5 is powerful software for analysing the produced maps in consecutive pairs to obtain the LUCC in the studied intervals.

2. MATERIALS AND METHODS

2.1. Study area

Marsa Alam (Fig. 1) is a RSCC. It is among the most famous tourist cities in the Red Sea governorate (RSG). The city extends for about 32,00 km along the western coast of the Red Sea. It is located 280,00 and 135,00 km to the south of Hurghada (the capital of RSG) and Quseir, respectively. In 2018, population of the city was 8,693 inhabitants. The basic economic activities are fishing, tourism, quarries and mining (CAPMAS, 2019). The study area lies between

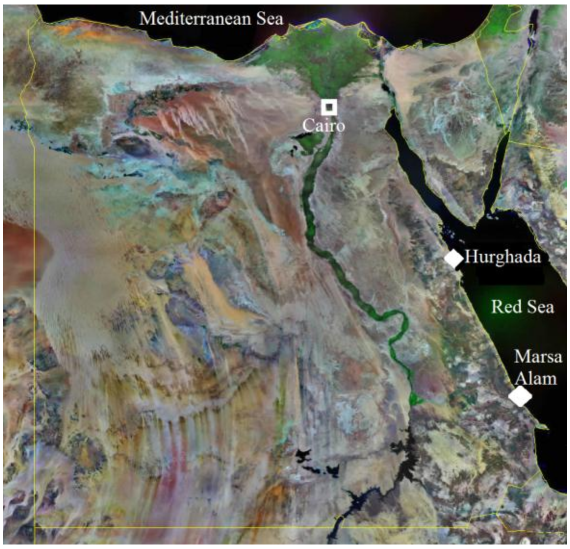

Fig. 1. The study area.

33° 34' 06" E, 27° 29' 17" N and 34° 04' 37" E, 26° 56' 11" N. Marsa Alam is served by the international Port Ghalib (20 km to the south of the city) and Marsa Alam international airport (70 km to the north of the city). The region of Marsa Alam is famous for its virgin natural on-shore areas (e.g., Wadi el-Gimal, Wadi Sikeit, Wadi Nuqrus, and Gabal Zabara); off-shore areas (e.g., corals and mangrove) and diving sites at its off-islands (e.g., Elphinstone, Shaab Samadai, Fury Shoals), which are supporting tourism, sport and recreational activities.

According to El-Akkad and Dardir, 1966, the general stratigraphic rock units in the area are of thickness varies from place to another range between 4 to 60 m., while the age of their formations could be Early Miocene, Middle Miocene, Mio-Plioceneas or Pliocene. The study area is divided into three units. i. Coastal plain: forms a narrow longitudinal strip of lowland attached to the Red Sea; ii. Pediment: it is the transitional zone between the coastal plain and the rugged mountainous basement terrain, which has a maximum elevation of about 190-meter and is mainly composed of sedimentary rocks and soft- sandy calcareous clay of Middle Miocene and Pliocene ages; iii. Mountainous Basement Terrain: comprise a series of Rugged Mountains of crystalline basement rocks of the Precambrian age (elevation of this unit is about 650 m.). Virtually all the main Wadis (e.g., Wadi Dubr, Wadi Iglah, Wadi Shagarah, Wadi Alam and Wadi Samadi) are originating from these mountains. Temperature of Marsa Alam varies between 37-26 °C in summer and 27-21 °C in winter. Precipitation varies between 5 to 23 mm/ annum (EMA, 2016).

2.2. Data set

To fulfil the study objectives, Landsat scenes of path 173/row 043 were used. The used data include five images: two Landsat-5, Thematic Mapper TMs, acquired at 01-10-1984 and 11-09-1994; a Landsat-7, Enhanced Thematic Mapper ETM+, acquired at 24-08-2002, in addition to two Landsat-8, Operational Land Imager, OLIs, acquired at 30-08-2013 and 17-08-2020. All the images were obtained free of charge from: http://earthexplorer.usgs.gov. The datasets were selected with similar calendar dates to minimize the seasonal differences on the change detection work (Lillesand et al., 2015, p 582). Only the 30 meters bands were used for the analyses of this study. Base map used for this work is a topographic map of scale 1:100,000 Egyptian Survey Authority (ESA, 2008).

2.3. Field work.

Number of field trips was conducted during August-September 2020 to collect region of interests (ROIs). By using hard copies of false colour composite FCC of Marsa Alam, 2013 and 2020, tourist map and Garmin 38 Global Positioning Systems GPS, extensive field surveys throughout the study area were performed in order to collect and document accurate ROIs. A field sampling sheet covers all the classes was represented. It was separated into two parts, where a part of it will be used in the classification work and the other will be used for the accuracy evaluation stage. Questions for the locals were about the changes of the urban and green areas as well as the serious problems that facing the city and affecting its population growth.

2.4. Digital images pre-processing.

All the 30 meter layers of the study images were first calibrated to reflectance. Then, by the aid of the parameters included with the Landsat metadata documentation, atmospheric correction was performed using Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) (Adler-Golden et al., 1999). All the images used in this work are ortho-rectified products, World Geodetic System (WGS 84) datum and the Universal Transverse Mercator (UTM) projection system, Zone 36 North. Then, all the images had to be carefully co-registered before processing using Second order polynomial geometric model in ENVI-5.3. Using sixteen tie points, the OLI, 2013 image was geo-referenced using the topographic map of ESA, 2008. Then, it was used as the base file image, while the other images were used as warp file image. The resulted total RMS Error for the warp images were around 0.025.

2.5. Change detection

2.5.1.Image classification.

Each classification is made to suit the needs of the user, and few users will be satisfied with an inventory that does not meet most of their needs (Anderson et al. 1976). Marsa Alam as a RSCC has some distinguished and special LULC characteristics that have to be highlighted in the classification outputs. Based on a modified list of Anderson classification system (Anderson et al. 1976), field work and previous knowledge of the study area, twelve classes could be recognized in Marsa Alam (Table 1).

Table 1. Scheme and definition of LULC classes of Marsa Alam

No.	**LULC class**	**Description**
1	Mixed urban/built-up areas	Residential, commercial, industrial, services, and utilities;
2	Green area	Parks, private/public green open-areas, botanical gardens, golf courses, etc;
3	Mangrove	Coastal wetland composed of forest and scrub dominated by *Avicennia marina*;
4	Sandy areas other than beaches	Sand and silt deposits with spares vegetation;
5	Mixed sand and gravel	Combination of sand, pebble, and gravel-field outcrops;
6	Wadi deposits	quaternary sediments;
7	Coastal sabkha	A flat salt-encrusted desert that is usually lacks any significant plant cover due to the high concentration of salts and sediments;
8	Basalt	Basaltic rocks;
9	Metamorphic	Metamorphic rocks;
10	Limestone	Limestone rocks;
11	Water	Sea-water;
12	Shallow water	Shallow seafloor.

Using Jeffries–Matusita (J–M) distance, the spectral separability between each ROI pairs was computed. According to Richards, 2013, Jeffries-Matusita values range from 0 to 2.0, where values greater than 1.9 indicate that the ROI pairs have good separability. The resulted Jeffries-Matusita values of the current work ranged between 1.90 and 2.00, which indicate good separation. Eventually, SAM was derived for each date using the ROIs set. The resulted classified images were then checked using the ROIs accuracy-set in order to compute the confusion matrices.

2.5.2.PCC

PCC change detection is the process of overlaying coincident thematic maps from different time periods to identify changes between them (Tewkesbury et al., 2015, p 6). PCC approach involves generating thematic maps from registered and independently classified images, after which a pixel-based comparison of the corresponding classes between each consecutive pair is used to produce change information in the form of cross tabulation and/or maps. For the current study, on the basis of the independently classified images, PCC change detection was employed to compute the internal change variations between each consecutive classified pairs in the first interval (1984-1994), second interval (1994-2002), third interval (2002-2013) and fourth interval (2013-2020).

3. RESULTS AND DISCUSSION

3.1. LULC maps and accuracy

To classify the studied images, SAM classifier was derived using a single maximum angle (radial) of 0.20 for all the classes (Fig. 2 (*a*, *b*, *c*, *d* and *e*)). SAM produced LULC maps of Marsa Alam in 1984, 1994, 2002, 2013 and 2020 with overall accuracies equal to 85.20 89.30, 90.08, 92.40, and 92.70 % and corresponding Kappa statistics equal to 0.8232, 0.8626, 0.8742 0.8916 and 0.8978 respectively.

3.2. LUCC of Marsa Alam, 1984-2020.

By employing PCC, descriptive and quantified information about the changes occurred between each consecutive pairs of classified images could be obtained.

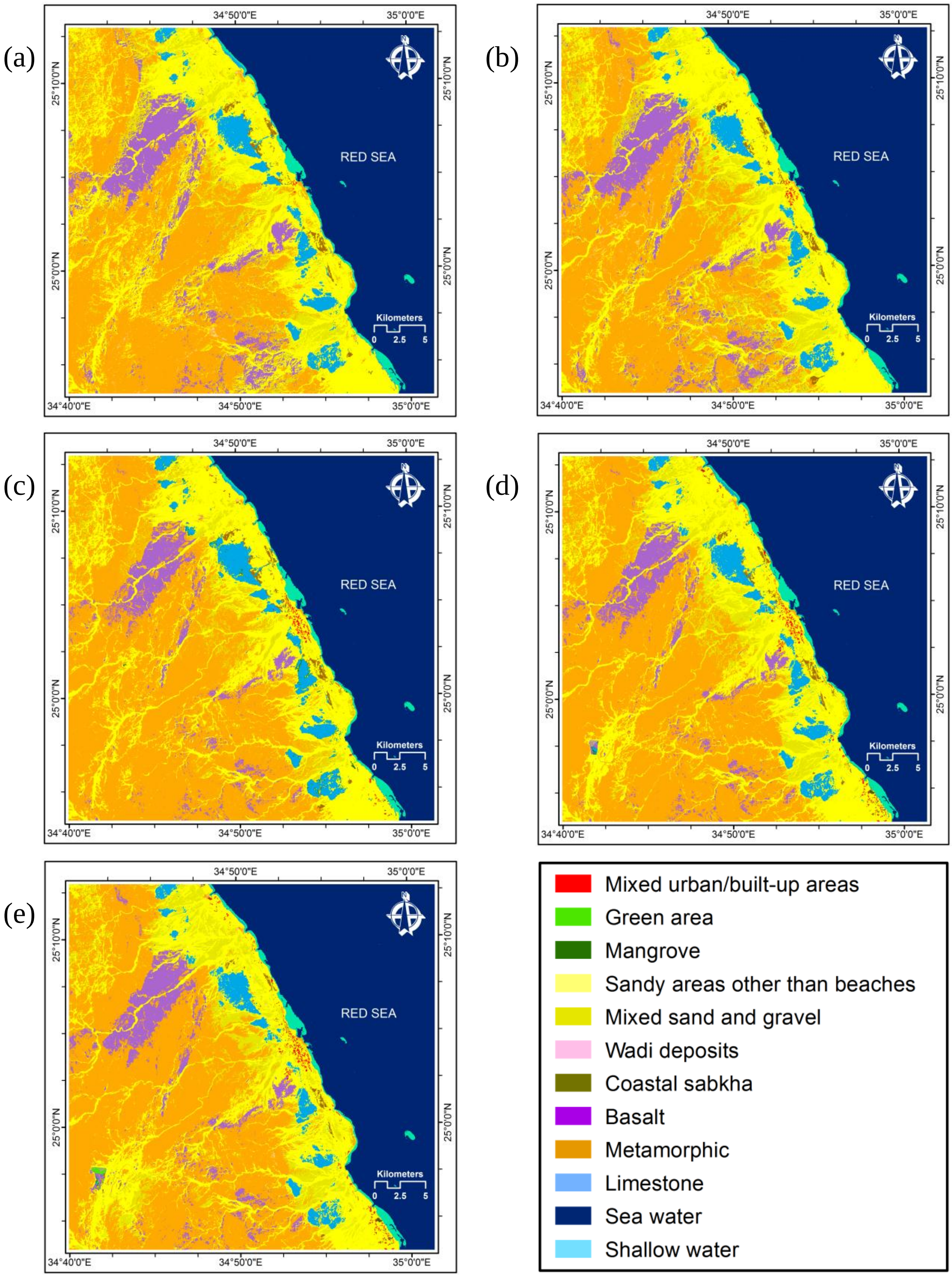

Fig. 2. LULC of Marsa Alam, (*a*) 1984, (*b*) 1994, (*c*) 2002, (*d*) 2013 and (*e*) 2020.

Table 2. Areas of Marsa Alam LULC, 1984-2020.

LULC class	Area 1984		Area 1994		Area 2002		Area 2013		Area 2020	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Mixed urban/ built-up areas	0.31	0.03	0.88	0.07	1.69	0.14	3.63	0.31	4.02	0.34
Green area	0.00	0.00	0.10	0.01	0.19	0.02	0.63	0.05	0.81	0.07
Mangrove	0.77	0.07	0.77	0.07	0.76	0.06	0.75	0.06	0.75	0.06
Sandy areas other than beaches	245.75	20.91	255.91	21.78	258.98	22.04	251.83	21.43	261.89	22.29
Mixed sand and gravel	74.88	6.37	69.31	5.90	59.95	5.10	63.94	5.44	57.28	4.87
Wadi deposits	11.46	0.98	7.83	0.67	8.14	0.69	5.05	0.43	5.43	0.46
Coastal sabkha	0.84	0.07	0.79	0.07	0.72	0.06	0.71	0.06	0.75	0.06
Basalt	55.97	4.76	54.08	4.60	49.07	4.18	52.69	4.48	50.46	4.29
Metamorphic	433.93	36.93	435.53	37.07	443.67	37.76	444.02	37.79	442.29	37.64
Limestone	36.56	3.11	35.25	3.00	37.27	3.17	37.19	3.17	36.64	3.12
Sea water	311.23	26.49	311.35	26.50	311.66	26.52	310.67	26.44	310.66	26.44
Shallow water	3.33	0.28	3.23	0.27	2.93	0.25	3.92	0.33	4.05	0.34
Total	1175.03	100.0	1175.03	100.0	1175.03	100.0	1175.03	100.0	1175.03	100.0

Further, by using the resulted LULC maps, the areas of each class were computed (Table 2). As most of RSCC, the Mountainous areas such as basalt, metamorphic and limestone were not changed and almost had the same areas along the four studied intervals (Table 2). Meanwhile, apart form the areas replaced by the urban and green areas; most of the changes related to areas covered by sand, mixed sand and gravel were mainly referred to the natural and meteorological conditions that affected the RSCC during the thirty six year study. Flash floods hit areas along the Red Sea coast on November, 1996; May, 1997 and January, 2010 (e.g., Abdel Fattah, 2015, p 3) and on October, 2016 (e.g., Elnazer et al., 2017, p 1389) that caused anthropogenic loss and economic damages as well as transferring sand, basalt and gravel from an area to another.

Green areas of Marsa Alam were not existed in 1984. Beginning from 1994, they began to increase from 0.10 to 0.19, 0.63 and 0.81 km^2 in 1994, 2002, 2013 and 2020 respectively (Table 2), which represent growth rate of 90, 231 and 28 % during the second, third and fourth interval respectively (Fig. 3 (*a*)). The increase of green areas in deserted coastal areas like RSCC was accompanied with the increase in establishing tourism villages, which led to abundance in producing sewage and liquid waste. In addition, most of the green areas were concentrated in the tourist villages and very small areas were located in the down town.

For mangrove patches located in the southern coastal areas, they had almost the same areas along the study period with little decrease of 0.02 km^2 between 2002 and 2013 (Table 2), which may be due to anthropogenic activities related to urban development in tourism sector.

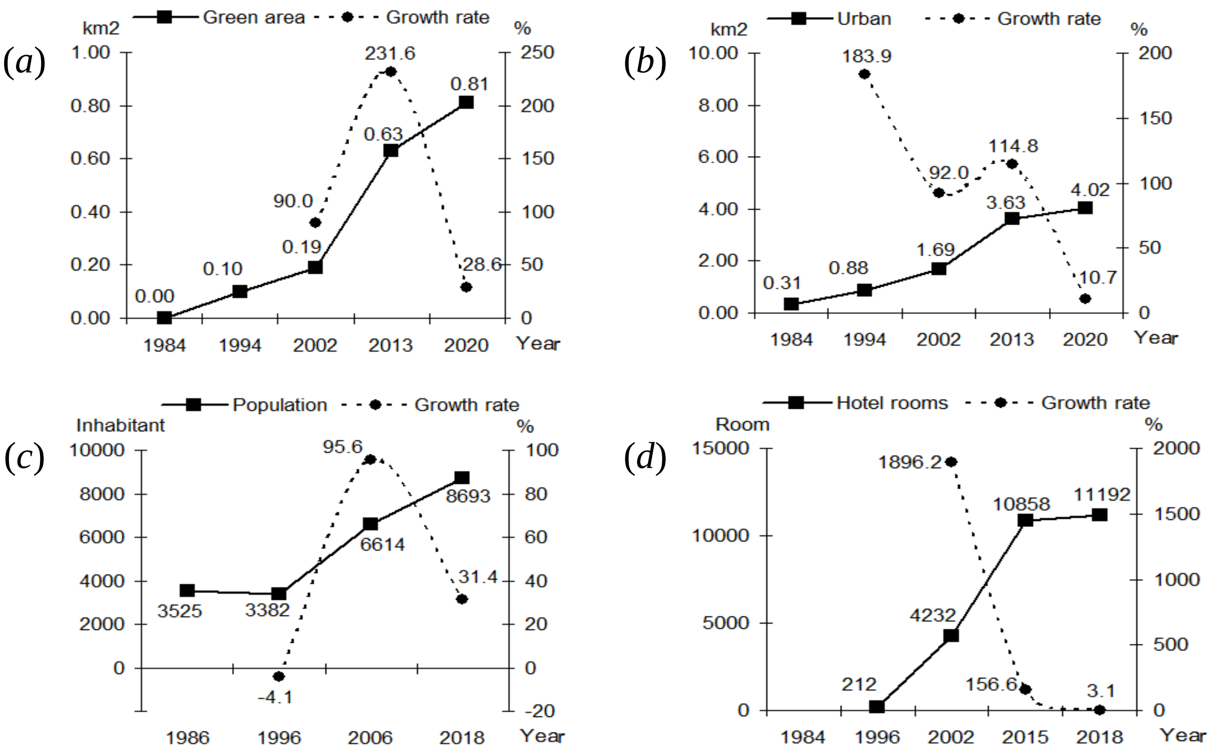

Fig. 3. Relative changes of some LULC and factors affecting urban growth in Marsa Alam, (*a*) green areas, (*b*) urban, (*c*) population growth and (*d*) hotel rooms.

Along the study period, the urban has increased from 0.31 to 4.02 km^2, which represent more than twelve times its primary area in 1984. From 1984 to 2020, the relative change of the urban was 1196 %, where the greatest increase was during the first interval by 183.87% (18.38% annual urban growth rate) and the least increase was during the fourth interval by 10.74 % (1.53% annual urban growth rate) (Fig. 3 (*b*)). During the first and second interval, the urban of Marsa Alam was increased by an area of 0.57 and 0.81 km^2 respectively. Then, it was increased by an area of 1.94 and 0.39 km^2 during the third and fourth interval respectively. Marsa Alam urban was increased by an average rate of 0.06, 0.10, 0.18 and 0.06 km^2 $year^{-1}$ during the first, second, third and fourth interval respectively, which are very small when compared with Hurghada city. The urban of Hurghada was increased from 0.96 to 12.82 km^2 during 1984-1997 (0.91 km^2 $year^{-1}$) (Dewidar, 2002, p 946). Marsa Alam urban areas were expanded mainly over areas covered by sand, basalt and gravel along the study period. Of the 3.71 km^2 of growth in urban (1984-2020), about 68.00% were converted from sand, 29.00% from sand and basalt and the remained 3.00% were converted from other LULC types.

3.3. Driving forces and constraints influencing the urban growth of Marsa Alam

Urban growth and expansion of a city are spatio-temporally influenced by a number of driving forces and constraints, which are different from a city to another. In their study for Hurghada, Kamh et al., 2012, discussed urban population growth, economic development, topographical and geological factors. For most RSCC, natural environment, social and economic factors are of utmost importance for the city planning and urbanization process.

3.3.1.Natural environment

Nature environment has provided Marsa Alam with unique geological and aquaculture features as well as other distinguished environmental conditions that made the city a valuable environmental and economic place for the development of the society. In general, the vital location and natural environment of Marsa Alam facilitate its function as a coastal city of touristic and mining-quarrying economic bases that are contribute well for the society and urban growth. In the same context, topographical and geological settings play major roles in directing and allocating the urban development of the city. Topography of Marsa Alam influenced its urban expansion directions, which tended to follow flat areas. Geologically, the planned coastal plain area has good potential for urban expansion to fulfil the residential, commercial and touristic needs. Further, all flood paths have been well known many years ago and many precautions are taken into consideration for most urban development areas (e.g., Gohar and Kondolf, 2020).

3.3.2.Population

At governorates level, RSG achieved one of the highest in-migration rates in 1996, and 2006 by 27.10 and 35.60 respectively, while it achieved the highest in-migration rates in 2017 by 8.20 %, which is an outcome of the increase in touristic projects and provision of job opportunities (Metwaly et al., 2018, pp 76-80). When comparing the population number of Marsa Alam with those of Hurghada, important outputs were obtained. The estimated population of Marsa Alam decreased from 3.525 in 1986 (CAPMAS, 1986) to 3.382 (CAPMAS, 1996), 6.614 (CAPMAS, 2006) and 8.693 inhabitant (CAPMAS, 2019) in 1996, 2006 and 2018 respectively, with growth rate of -4.06, 95.56 and 31.43 % during 1986-1996, 1996-2006 and 2006-2018 respectively (Fig. 3 (*c*)). Meanwhile, the population of Hurghada was increased from 21.504 (CAPMAS, 1986) to 60.085 (CAPMAS, 1996), 69.616 (CAPMAS, 2006) and 195.675 inhabitant (CAPMAS, 2019) in 1986, 1996, 2006 and 2018 respectively, with growth rate of 179.41, 15.86 and 181.08 % during 1986-1996, 1996-2006 and 2006-2018 respectively. The beginning of Hurghada (1986-1996) was very huge, while the beginning of Marsa Alam (1996-2006) was sensible. Furthermore, during 2006-2018, population growth of Hurghada was extremely rapid, while for Marsa Alam, it was about one-sixth the rate of Hurghada. Using the exact numbers, during 2006-2018, population numbers of 2.079 and 126.059 inhabitants were added to Marsa Alam and Hurghada respectively. This great difference in population growth between two cities related to the same remote region was mainly due to in-migration factor, which is greatly influenced by the differences in living conditions, opportunities and services. Compatibly, the limited population growth in Marsa Alam is a result of various administrative and services factors. According to Abdelkawi and Salama, 2018, Marsa Alam is suffering from unavailability of natural gas, shortages of sewage network and telecommunications coverage as well as limited medical and banking services.

From field work, it was noticed that there were no public clubs in the city. Furthermore, there were no commercial or recreational centres, which negatively affect the tourism sector and local community as well.

3.3.3. Economy

Economy of Marsa Alam is highly connected to its coastal and mining sectors as well as their related activities, which play major roles in the State and city economy. According to Red Sea Information Technology Unit RSITU, 2020, the number of hotel rooms of Marsa Alam increased from 212 to 4.232, 10.858 and 11.192 in 1996, 2002, 2015 and 2018 respectively (Fig. 3 (*d*)). When comparing the recent number of hotel rooms with each of the population number and the urban area of the city, it could be concluded that there are 11.192 hotel rooms per the 8.693 people (i.e. 1287 hotel rooms/1000 people). Further, there are 11.192 rooms per the 4.02 km^2 urban (i.e. 2784 rooms/ km^2 urban), which is very high percentages when compared to Hurghada capacity. Hurghada had 45.047 hotel rooms and a population number of 195.675 in 2018 (RSITU, 2020) (i.e. 230 rooms/1000 people). In addition, Abdelaal et al., 2021, mentioned that el-Sukari Gold Mine (SGM) is the largest gold mine in the Arabian-Nubian Shield.

3.3.4. Constraints to the urban expansion of Marsa Alam

The physical form of any city is compelled by some natural and/or artificial constraints. Natural constraints of Marsa Alam include Red Sea shoreline, flash flood paths and faults as well as the areas attached to SGM and Red Sea hills.

4. Conclusion

Marsa Alam was investigated using five Landsat images cover the period from 1984 to 2020. SAM classifier was very effective in classifying semi-arid coastal area like Marsa Alam, while PCC was very helpful in obtaining clear information of Marsa Alam LUCC during the investigated intervals. Along the studied period, the urban area of Marsa Alam was increased by 3.71 km^2 and the green areas were increased by 0.81 km^2. Adding housing, commercial and services areas to the city and encouraging private sector to participate and planning for future population growth are all essentials for Marsa Alam urban and population development.

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التغيرات في استخدامات-الغطاء الأرضي لمرسى علم، البحر الأحمر باستخدام الاستشعار عن بعد ونظم المعلومات الجغرافية

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المستخلص:
تعد المدن الساحلية للبحر الأحمر ذات أهمية كبري باعتبارها قاعدة اقتصادية سياحية وتعدينية هامة للدولة، والمجتمع والبيئة أيضًا وتعد مدينة مرسى علم اسما عالميا مشهورا، تشتهر ببيئتها البحرية الفريدة ومنجم ذهب السكري وهناك حاجة ملحة للحصول على معلومات واضحة عن وضع المدينة خلال الفترة الماضية من أجل ادارة المدينة ومواردها وتهدف هذه الدراسة الي استقصاء التغيرات في استخدامات- الغطاء الأرضي والتوسع العمراني لمدينة مرسى علم خلال الفترة من 1984 الي 2020. لهذا الغرض تم استخدام مُصنِّف (Spectral angle mapper) وتقنية (Post classification comparison) للكشف عن التغيرات لتحليل خمس مرئيات فضائية لاندسات تغطي فترة الدراسة وأظهرت النتائج زيادة في المناطق الحضرية والمساحات الخضراء. تم مناقشة العوامل المساعدة والمحددات التي تؤثر على التوسع العمراني والزيادة السكانية للمدينة. ويعد عدد سكان المدينة بعيدا جدا عن العدد المخطط /المطلوب ولا يعكس أهمية المدينة فيما يتعلق بالسياحة والتعدين، الأمر الذي يحتاج إلى مزيد من الجهود الحكومية لتشجيع الهجرة الداخلية إلى المدينة ودعم استثمارات القطاع الخاص. ولا تزال مخرجات الرصد التي يتم الحصول عليها من تكامل الاستشعار عن بعد ونظم المعلومات الجغرافية هامة جدا لتوفير معلومات أساسية قيمة لازمة لإدارة المدينة، ومواردها وأبحاثها. هناك حاجة إلى مزيد من أعمال الرصد على هذا المنوال لتغطية بقية المدن الساحلية للبحر الأحمر علي المستويين المحلي والاقليمي.

الكلمات الدالة:
البحر الأحمر، مرسى علم، مرئيات لاندسات، الاستشعار عن بعد، نظم المعلومات الجغرافية، التغيرات في استخدامات-الغطاء الأرضي.