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Reliability of Geomatics techniques in urban management and planning in Aqaba Governorate

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Abstract: Aqaba city is subjected to rapid development, economic growth and high rates of population growth over the past twenty years. This is due to its being changed into free trade zone and to the planning decision to improve its sea tourism potential. This region is characterized by the geographical location and the outstanding geological tectonic structure. Urban, industrial, commercial, and touristic developments are considered of high priority in the city but security and safety measures are always needed. In this work we are presenting the urban expansion of the city through the last years, and the appropriate plans to avoid the negative impacts of this expansion. In addition we present the natural risk in this city due to geological structure and the zones of danger as well as the security zones. All of the analysis is done using state of the art Geomatics techniques (GIS & RS). Geomatics techniques proved to be efficient in the field of urban management over time (1992 to 2009). For this purpose we used high resolution remotely sensed data over the study period in addition to geological and topographical maps. The urban expansions in 1992, 2001 and 2009 were mapped and the hazard zones were also identified. An optimal map for planning and managing the urban area in Aqaba zone was built to avoid the unstable zones. Moreover, the urban expansion over the 1992-2009 periods was analyzed and its impacts on Aqaba area environment were assessed. The expansion of urban growth was exceeding 71% and the expansion of transportation network was exceeding 30%, over the study period. A comparison to other similar studies for other cities with extra ordinary expansion rates such as Amman, Istanbul and Bangkok is presented. The comparison showed that Aqaba has the largest percent annual rate of urban expansion and vice versa the bigger impact and need for urban planning and optimal solutions.

Key words: GIS, remote sensing, urban growth, hazards zones, risk management.

INTRODUCTION

Aqaba historically was home to many nations because of its strategic location at the crossroads between Asia, Africa and Europe. It was one of the most important cities for the Nabateans and the Romans who expanded in the region and settled in. It was a conduit for international trade routes, and passage to the convoys coming from Al-Hijaz and the southern Arabian Peninsula heading to Egypt, Europe and Africa.

The south Jordanian city of Aqaba is located on the coast of the Red Sea in southern Jordan at 330 km from the Jordanian capital Amman. Aqaba city is the only maritime port of Jordan located at the head of the Gulf of Aqaba, branching from the Red Sea. The city is home to many important industrial facilities, and free trade zones. The population of the city is about 120.000 habitats.

The launch of Aqaba as Special Economic Zone was in 2001. This region covers an area of (375) km^2 and provides investment opportunities in the global business environment of world-class services ranging from tourism to recreational services, and professional services to various forms of logistics, and value-added industries to light manufacturing. The authority and the Government of Jordan launched the Aqaba Development Corporation in early 2004 to be the central development organization of the Aqaba Special Economic Zone. It owns the port and airport and plots strategy, as well as the development rights / performance of these assets and infrastructure and utilities. It has the power to develop the Aqaba Special Economic Zone and the construction of new infrastructure and advanced infrastructure or expansion of what exists in and finds anything that would help in the area of business, management / operation of facilities, and all that by maximizing attract developers and private sector operation. It is also responsible for the implementation of the master plan for the Aqaba Special Economic Zone a manner that ensures integrated development and transfer of Aqaba to the center for business and leisure in the Middle East**.** Understanding the growth and change brought on by urbanization is critical to those who study urban dynamics and those who must manage resources and provide services in these rapidly changing environments (Sanchez 2004; Yang 2002; Chen 2002; Aysan *et al*. 1997, Wright 1996; Clark and Jantz 1995).

Remote Sensing and GIS techniques are efficient in urban change detection and have been applied successfully in different urban planning studies (Lo and Yang 2002; Souleyrette and Anderson 1998; Cowen

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and Jensen 1998). Our work emphasizes the efficiency of RS and GIS techniques in detecting land use changes in Aqaba area over an extended period of time (17 years). The GIS Technology capabilities allowed the doing of all the necessary computations and the buffering of the geological hazard areas. The Remote Sensing technologies allowed to evaluate the change over time and to define the directions of urban expansion (Tapiador and Casanova 2003; Yang 2002, Madhavan *et al*. 2001; Ridd and Liu 1998; Jensen 1996).

Studies and analysis of the expansion of the cities is a very important issue as for each city a character and orientation depending on the times and periods. In the old days the rivers and seas derived the expansion of cities but new derivers and trends are created with time, each period is derived by something, this is what we are discovering every day.

Modern planning tries to create derivers and trends to orient expansion to the right places, while caring about the nature, people security and safety in addition to the best interest of the country. This is worldwide most of the expanding cities are analyzed or need to be analyses for optimal planning. Similar international studies were conducted to analyze the urban expansion for important cities such as: Istanbul in Turkey (Kaya and Curran, 2003), Bangkok in Thailand (Tachizuka *et al*. 2002), Atlanta in USA (Yang 2002), Kaoshiungin in Taiwan (Cheng-Ming 2002), ksar El Kebir and Khemisset in Marocco (Belaid 2003), Amman city (Al Rawashdeh and Saleh, 2006), and urban expansion in Jordanian cities using GIS. Our obtained results for Aqaba will be compared with those of Istanbul, Bangkok and Amman which are known for their extraordinary annual urban expansion rate.

An intensive geographical study was conducted through the existing and available bibliography. It included a description of physical conditions like climate, topography, soil, and Geology. The study focuses on urbanization encroachment, population/demography, and hazard mapping.

MATERIALS AND METHOD

Due to the scarcity of data for the previous periods, remotely sensed data was an excellent and important source of data which enabled the extraction of the land covers at different periods and the estimation of the annual rate of the urban expansion. RS and GIS technologies allowed carrying out the study at low cost and in no time. The GIS Technology capabilities allowed the doing of all the necessary computations and the buffering of the geological hazard areas. The Remote Sensing technologies allowed to evaluate the change over time and to define the directions of urban expansion.

Different types of data were used in this work such as:

(i) Aerial photographs acquired in 1992 (Fig.1) and 2009(Fig.2) obtained from Royal Jordanian Geographic centre (RJGC), (ii) Ikonos images acquired in 2002 ((Fig.3) obtained from Balqa Applied University (BAU), (iii) Topographic and administrative boundaries maps obtained from RJGC, (vi) Global Positioning System (GPS) coordinate points served as ground control points (GCP's) and (v) geological map obtained from Natural Authority resources in addition of other digital data obtained from previous works.

Fig. 1: Aerial photograph for Aqaba (1992),

Fig. 2: aerial photograph for Aqaba (2009)

Remotely sensed data acquired at different dates, by different satellite sensors were rectified geometrically, along with the GPS points into the same Jordan Transverse Mercator (JTM) coordinate system using remote sensing (RS) data. Moreover, the geological map was also image to image rectified using the rectified satellite image.The obtained remotely sensed images were spectrally enhanced to enhance the discrimination between features.

Change detection technique will be applied to detect change in urban area over time. To be noted that the change is usually detected by comparison between multi-date images in three methods of change detection:

a) Comparison between two land cover maps which are independently produced.
b) Change enhancement by integrating two images into a color composite or principal component image.
c) The differencing pixel by pixel Change Detection method.

In this study, the differencing pixel by pixel change detection method will be used. Figure (4) presents the flowchart of the methodology of data processing for all the remotely sensed data to extract the needed layers for our analysis.

Fig. 3: Ikonos Image for Aqaba (2001)

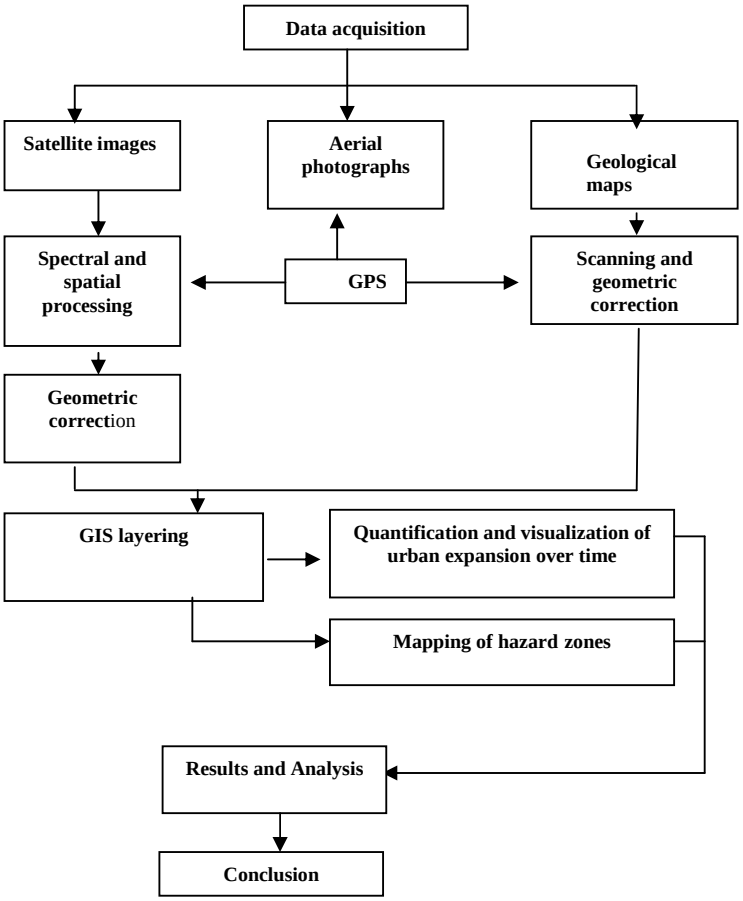

Fig. 4: the flowchart of the methodology of data processing

RESULTS AND DISCUSSION

The three previous rectified images were used to extract the urban area and other land covers classes for the three dates: 1992, 2002 and 2009. These three previous images were transformed to vector polygon layers using the latest version of GIS software (Fig. 5, 6 and 7). These layers were used by GIS software to do the necessary statistical works and to retrieve the necessary information to help for the analysis and the management of urban area in Aqaba. The obtained information was stored as spatial and attributes data in the database. The increase and decrease of land covers were evaluated using the change detection after overlaying the layers for the three dates.

Meanwhile, the faults were digitized from the rectified geological map. The activity of these faults was estimated from many data sources (The authority of Natural resources and previous studies) and considered as attribute information linked to the lines representing the digitized faults.

Figures (1, 2 and 3) present the main land covers of Aqaba area obtained from aerial photographs for the years: 1992 and 2009 and Ikonos image for the year (2002).Table (1) presents the change in urban expansion and green area in. This table shows that the urban area was about 4.628 km^2 in (1992), 5.179 km^2 in (2002) and 9.942 km^2 in (2009). No change in green area we believe it is due to the lack of rain water and being in a very arid zone. Figure 8 is a Histogram presents the expansion of the urban and green areas in Km^2 for the two mentioned periods.

Table (2) presents the percentage of the change in urban and green areas over the period of (1992-2002) and (2002-2009). The increase of urban areas over the periods (1992-2002) and (2002-2009) are about 1.449 km^2 and 4.763 km^2 respectively. This change represents 23% and 71.86% of the original value which reflects a rapid expansion of the urban areas especially in the second period where double increase was detected. Meanwhile, the increase of green areas was not important. They are evaluated at 0.52% and 4.19 % over the periods 1992to2002 and 2002 to 2009.Table 3 presents the roads and streets expansion (length) in Aqaba area at the fore mentioned periods of (1992, 2002 and 2009).

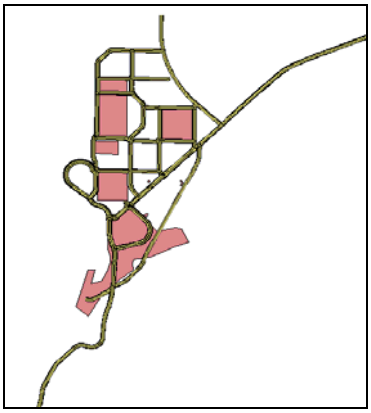

Fig. 5: Aqaba Urban expansion vector layer (1992)

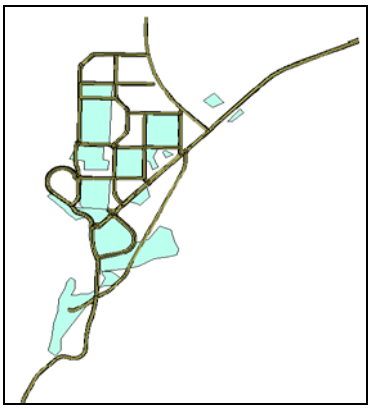

Figure 6: Aqaba Urban expansion vector layer (2002)

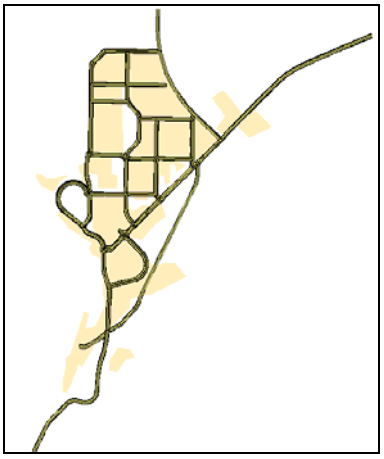

Fig. 7: Aqaba Urban expansion vector layer (1992)

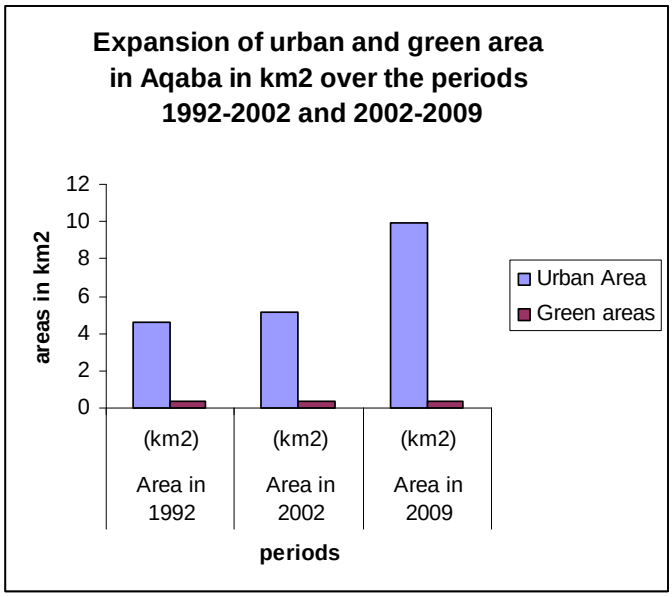

Fig. 8: Histogram for the expansion of the urban and green areas in Km^2.

Figure 9 presents a histogram of the change in roads length over the periods (1992-2002 and 2002-2009) as it was evaluated in Table (3).

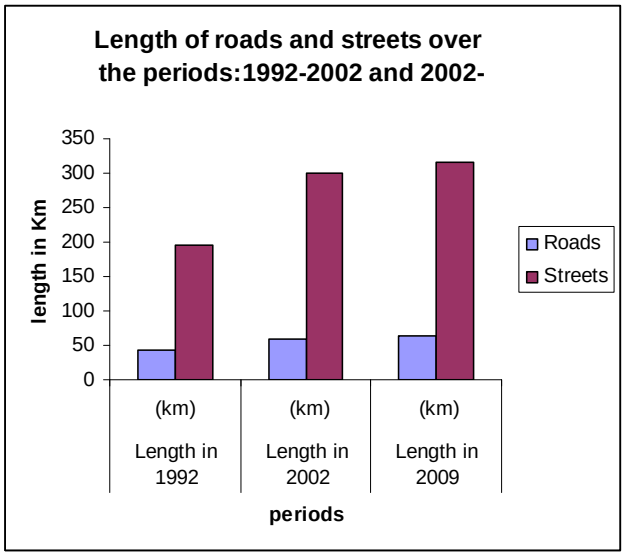

Fig. 9: Histogram for the expansion of the lengths of roads and streets in Km.

Table 4, presents the increase in length of the roads and streets over the periods (1992-2002 & 2002-2009). These are evaluated and found to be (16.099 & 5.002) km respectively. This change represents (37.71% and 11.72%). This shows the rapid increase of roads especially over the first period (1992-2002). Meanwhile, the increase of streets was evaluated at (104.268 km) to represent (53.30%) over the period of (1992-2002) and (16.099 km) to represent (8.23 %) over the period of (2002 and 2009). This shows a great increase of streets especially over the first period of (2002-2009) as divisions were added to the city and more streets and roads were needed. Figure (9) shows the important increase over time of the length of streets and roads. The analysis, tables and histogram reflect remarkable increase in urbanization and no increase in green areas. The final results for the expansion are presented in table 5, for the whole analyzed period starting in 1992 and ending in 2009. The activity and the expansion of the unique port of Jordan are remarkable and need to be well planned using informed decision making and modern Geomatics techniques.

Aqaba urbanization follows two major axes: (I) the first axis is oriented north-easterly and follows a major road passing through Wadi Araba and Dead Sea connecting Amman city. (II) The second axis is oriented towards the north and follows a major road which connects the city with Amman.

Mapping Hazard Zones Analysis:

A geological map and a recent digital data works were used to map the hazard zones which are mainly because of the activity and the presence of tectonic faults. Geological stability should be the base and the underneath driver of the expansion orientation especially in an area of special structure and tectonic faults. We felt the need for this type of analysis to complete our study. For this purpose, the geological map was first geometrically corrected (image to image) using the previous corrected remotely sensed images. Then, the available digital data about the activity of these faults was integrated in the data base after being added to the attribute tables of lines vector representing the faults in the area. A buffer zone of (50 m) for the non active zone and a buffer zone of (100 m) for the active zones were created. The obtained vector layer was overlaid with the layers of urban expansion for the year 2009 (Fig.10). Figure 10, shows an important fault is located in the urban area; fortunately this fault is not very active.

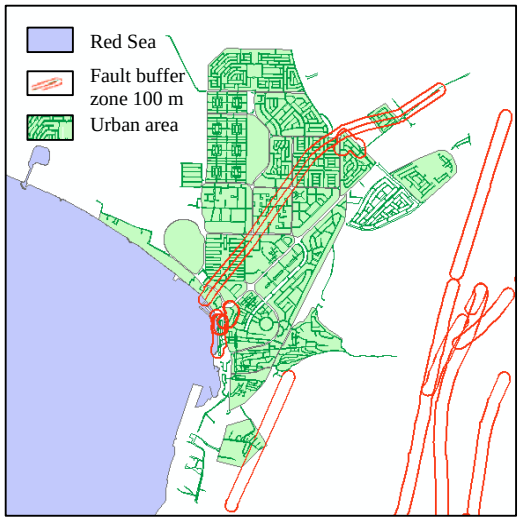

Fig. 10: layers of Aqaba urban expansion (2009) and buffers on tectonic faults (100m and 50m for active inactive and faults).

Comparison Between International Rates Of Urban Expansion At Other Cities Of Important Expansion Rates In The World:

Our obtained results were compared with those of Istanbul [1], Bangkok [2] and Amman [7] which are known for their extraordinary annual urban expansion (Table 3). The rate of the urban expansion for Istanbul over the period of (1987-2001) was 10km^2/yr, for Bangkok over the period of (1993-2002) was 42.7km^2/yr, for Amman over the period of (1983-2002) was 2.1km^2/yr and 0.36km^2/yr. Then the percent annual rate for urban expansion was calculated for the above mentioned cities. Aqaba showed the largest percent annual expansion rate (19.5%), in comparison with Istanbul and Bangkok.

Conclusion:

The planning schemes and patrons at the city of Aqaba:

Using Geomatics engineering techniques and the Remote Sensing in specific, to perform planning analyses and to define the existing trends in the expansion of Aqaba city over the years (Fig.11), we concluded the following:

1. During the period 1992-2002, the expansion was mainly near by the Red Sea cost. This explained by the nature of the city as it's surrounded by mountains in the east and the sea in the west, then it had to expand north and south which represent the sea shore area.
2. For the period of 1992-2002, the expansion of the city followed two main axes. The first axis is oriented toward the north direction and follows the road leading to the Desert high way. This is representing the industrial and services sector of the expansion in addition to some housing for the original inhabitants of the city and the employees of the hotels and the construction industries which is booming lately. The other axis is

oriented toward the East-west direction and parallel to the cost in this area the golf comes into the city and this is where the hotels, for rent buildings, sea clubs, resorts, restaurants and recreation areas expanded and Tala-bay area was created.

3. For the period of 2002-2009, new urban growth was noticed in the city and managed by the Municipality of Aqaba city. This axis had followed a major road which connects the new airport.

The unusual urban growth during this period was due to the immigration of people for work hunting and better job opportunities.

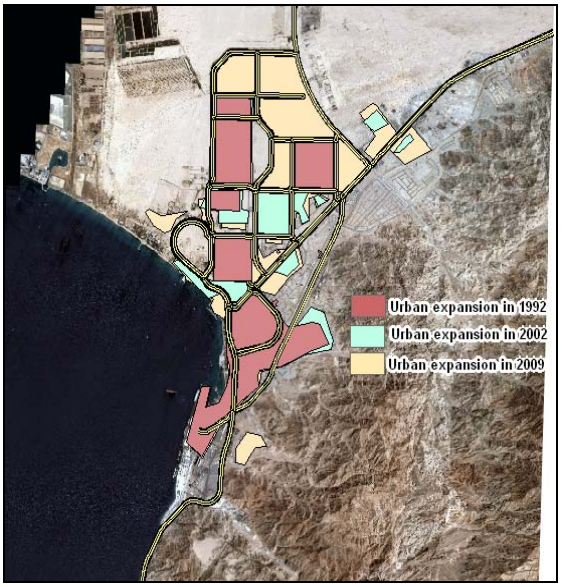

Fig. 11: Aqaba Urban expansion (1992, 2002 and 2009)

Table 1: Aqaba land use zones (km^2) over the period 1992-2009.

Item	Area (1992) (km^2)	Area (2002) ($km^{2)}$	Area (2009) (km^2)
Urban Area	4.628273	5.178894	9.941747
Green Area	0.363228	0.357855	0.315975

Table 2: The percentage change in urban and green areas.

Class name	1992-2002		2002-2009	
	km^2	%	km^2	%
Urban area	1.449379	23.05	4.762853	71.86
Green areas	0.00517	0. 52	0.04188	4.19

Table 3: Roads and streets expansion in Aqaba area

Item	(1992)Length In (km)	(2002) Length in (km)	(2009) Length in (km)
Roads	42.695	59.431	64.433
Streets	195.608	299.876	315.975

Table 4: The change in roads over the periods 1992-2002 and 2002-2009

Year	Building (m^2)	Blocks (m^2)	Roads (m)	Streets (m)	Green (m^2)
1992	2491360	12981757	42695	195608	363228
2009	6344165	18966840	64433	315975	315975
Diff.	3852805	5985083	21738	120367	241381

Table 5: Comparison in areas and lengths at Aqaba for 1992 and 2009

Class name	1992-2002		2002-2009	
	km	%	km	%
Roads	16.099	37.71	5.002	11.72
Streets	104.268	53.30	16.099	8.23

Finally, we believe if the urban expansion in Aqaba area will continue at this rate and without consideration and protection of all the rights of human, nature, sea and others, there will be great loss and disasters. Control on development should come into intention, industrializing, commercializing and transportation as well should be

calculated to control pollution and to safe keep our only sea shore. Keep in mind the wrights of people and the coming generation of better golf area.

We recommend to better plan the roads to decrease and divert pollution, on the other hand to enhance the sea side and old downtown streets in order to accommodate the increasing movement of people around the down town. We find laws of nature and public beaches protection should play a role in the development of the city. We think a master plan to include industrial, commercial and housing should be prepared while caring about pollution, economy, tourism and the future of the city.

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