Development of a Fast and Cost Effective Geospatial Techniques to Monitor Real Estate Potential of Residential Manmade Islands in the Countries of the Gulf Cooperation Council

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Key words: Remote Sensing, Pansharpening, Thresholding, Realtors, Percentage of Development, Percentage of Development.

SUMMARY

Many GCC countries has adopted in the last two decades a policy of land reclamation as manmade artificial islands. The number of artificial islands intended mainly for luxurious and high standing residential purpose has significantly increased since then. Kingdom of Bahrain has four operational artificial islands and many under construction, the state of Qatar has one main one, while United Arab Emirates is a renowned for its Palm Islands. All of these Islands are built to play a significant role as recreational and touristic facilities. This study targeted the development of a quick, reliable and cost effective remote sensing based technique to evaluate the stage of development of artificial islands. In fact, while the cost of acquiring real estate properties in such islands is very high, many of them has not yet been fully occupied as construction work of new villas, apartment towers, hotels etc. Many realtors and real estate operators are clueless when it comes to assess and monitor the trend of development of such islands and where to advise potential buyers to invest. Landsat 8 OLI images was used to develop a quick and cost effective remote sensing based method to produce updated maps of status of development of five artificial island across the GCC. In Bahrain Amwaj Islands, Reef Island, Durrat Al Bahrain, Pearl Island in Qatar and Palm Jumeirah in UAE. The technique takes advantage of the nature of the land cover of artificial island which is uniform, homogeneous and very bright and therefore easily distinguishable even using Landsat-8 OLI imagery. A thresholding technique combined with pansharpening allowed to extract the percentage of development for each island as a whole and map providing crucial information where the development is full and complete, implying more comfort and quietness and where there is still empty parcels which means construction will soon start. Worldview-3 Image was used for validation over two islands in Bahrain (Durrat Al Bahrain and Amwaj Islands) and the accuracy of results obtained using Landsat 8 image with the described technique were proved 96% match. This study addressed each artificial island as a whole, which gives the contextual environment to perform a determination of the value for each specific properties. Geospatial techniques are a crucial element for a more holistic business intelligence model for the vibrant real estate market in the GCC countries.

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1. INTRODUCTION

The race for better spatial resolution for earth observation imagery is a continuous process which has witnessed the passage of ground sampling distance (GSD,) obtained from satellite imagery, in the last decades, from hundreds of meters to a fraction of a meter. Furthermore, this progress in GSD has been also accompanied by a tremendous improvement of revisiting time via constellation of the same satellite or the use of the same sensor onboard of various platforms. However, the generated data volume in term of computer memory as well as the computer processing capabilities of such data is not easily available neither practicable to many categories of users. Real estate sector is a very competitive sector where realtors strive to get up to date information and description of products on the market. Obtaining reliable, accurate, timely and affordable geomatics products is certainly a tremendous assets to any real estate agency aspiring to thrive. Here in the gulf cooperation countries and for the last two decades the policy of land reclamation is in the rise with manmade artificial islands as its main product. The number of artificial islands in the Kingdom of Bahrain has doubled in the last three years, passing from three operational artificial islands to six with many others under construction. The state of Qatar has one main one; the Pearl-Qatar while United Arab Emirates is a renowned for its Palm Islands and many more. All of these Islands are built to play a significant role as recreational and touristic facilities. Such mega projects do not are note merely intended to reflect an image of prosperity but also play a major role in the attempt of the counties in the region to diversify their economical income and raise the proportion of the tourism sector and real estate one in their respective GDP. In this study the effort is focusing to ascertain the ability of Landsat OLI imagery to produce reliable information on artificial islands (Elbattay, 2014). In fact, the technique used takes advantage of the nature of the land cover of artificial island which is uniform, homogeneous and very bright and therefore easily distinguishable even using Landsat-8 OLI imagery. Furthermore, in this study an investigation is done to confirm the inability of using high resolution data due to the high confusion created by the bright roofs with open areas in similar cases. The objectives of this study is (1) to determine the rate of development of selected artificial islands in Bahrain, Qatar and United Arab Emirates using Landsat OLI free images (2) to compare and validate this rate using worldview 3 resolution high resolution image, and (3) to monitor the rate of development in Amwaj Island (Bahrain) in 2014, 2015 and 2016.

2. METHODOLOGY

2.1. Study sites

In this study, five study sites were used to develop, test and extract the percentage of undeveloped versus developed area for five artificial islands across three countries of the GCC (Gulf Cooperation Council). Three of the sites are located in the Kingdom of Bahrain, while the remaining are respectively in Qatar and Unites Arab Emirates. Figure 1 depicts the location of the five study sites across the three countries. Kingdom of Bahrain is an archipelago of 33 islands, but with extensive land reclamation projects the number increased to 84 (as of 2008). Hence the total area went from 665 km^2 (257 sq mi) to 780 km^2 (300 sq mi). It is mainly a desert plain with the highest point at 134 m (440 ft). As per 2014, the population was estimated at 1,300,000 located in the Northern part of the main Island. As highlighted in yellow, green and blue in figure 1, the three artificial Islands projects covered in this study over Bahrain are located in Northern part, central and southern part of Bahrain main island.

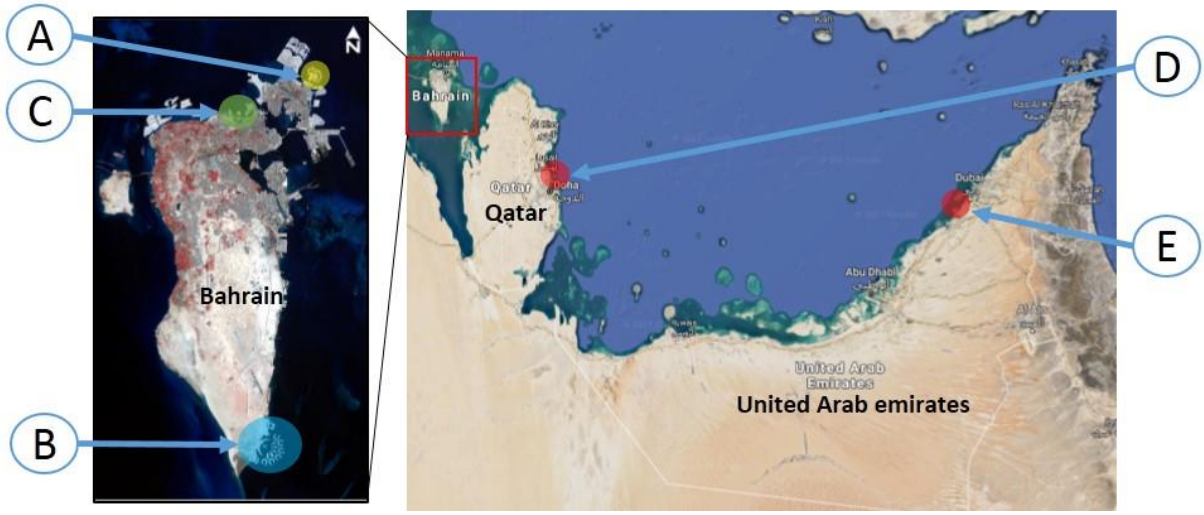
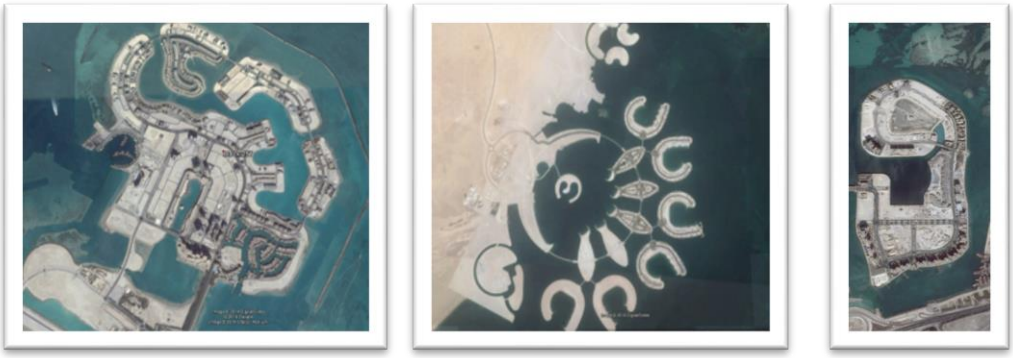


Figure 1: Locations of artificial Islands used in this study; (A) Amwaj Islands, (B) Durrat Al-Bahrain, (C) Reef Island, (D) The Pearl-Qatar and (E) The Palm Jumeirah

The three manmade islands projects selected in Bahrain are situated in different location over Bahrain main Island. They highly compete in terms of luxury and quality of life they offer. In terms of area, Reef Island is the smallest with only 0.579 Sq. Km, followed by Amwaj Islands with 4.1 Sq. Km and Durrat Al Bahrain is the biggest project of all three with an area of 21 Sq. Km. While Reef island might be considered as a mega residential compound with complimentary facilities and amenities, Durrat Al Bahrain is more a small city by its own. Amwaj Island is just in the middle as a neighborhood. Following is a description of each study site (artificial island) involved in this study, while figure 2 present an overview of each of them.

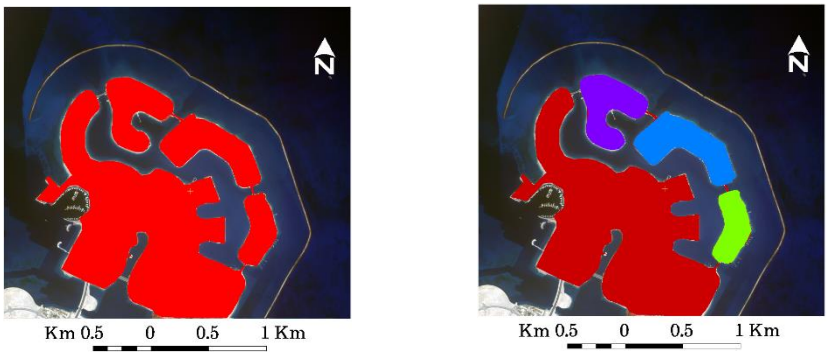


(a) (b) (c)

(d) (e)

Figure 2: Artificial Islands used in this study; (a) Amwaj Islands, (b) Durrat Al-Bahrain, (c) Reef Island, (d) The Pearl-Qatar and (e) The Palm Jumeirah

Amwaj Island's a six manmade islands, namely, Tala, Najmah, Asdaf, Murjan, Jood and LuLu, it has a total area of 4.1 sq. km and is expected to offer a truly enviable lifestyle for residents, with a choice of outstanding homes by the water, a vibrant and growing community and a relaxing, easy way of life just 10 minutes from the airport and 15 minutes from the capital, Manama (Amwaj, 2014). It is located in the North-West (Letter A and yellow circle in Figure 1). Figure 2 presents a zoom into Amwaj Islands where most of its different Islands can be seen. Figure 3 shows the mask created over the land area of Amwaj islands as well as four of its islands covered in this study; Tala (purple), Murjan (blue), Najmah (green) and Asdaf (marron).

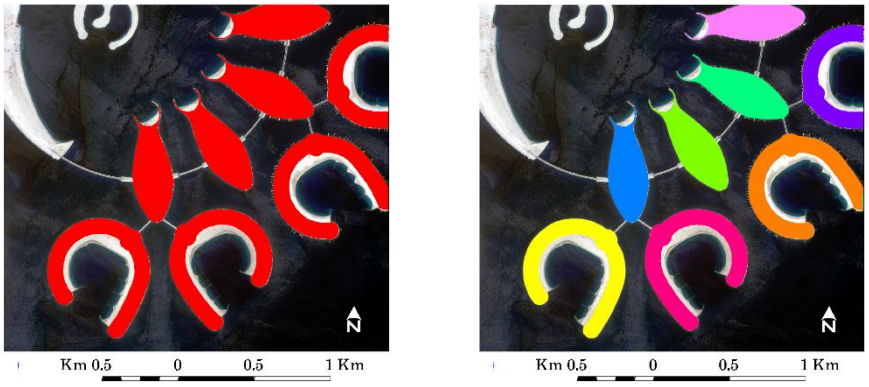


(a) (b)

Figure 3: Area of Amwaj Islands used in this study (a) the total area covered of Amwaj (b) four separate Islands of Amwaj: Tala (purple), Murjan (blue), Najmah (green) and Asdaf (marron)

Reef Island is located on Manama's northern shore, in the nearby of the new Bahrain Financial Harbour (Green circle in Figure 1). It is strategically situated in the heart of Manama, the Gulf's, and one of the worlds, fastest growing financial centres. Reef Island main marketing element is offering its residents, and guests, all the convenience of easy access to a bustling cosmopolitan city complimented with the tranquility of a tropical island getaway. it spreads over 0.579 Sq. Km (Reef, 2014). Because it is small, reef Island was considered as one entity and no subareas of it were used.

Durrat Al Bahrain, is located on the south coast of Bahrain (Blue circle in figure 1). It is a 21 sq. km where the master development has been created across a cluster of 15 spectacular islands. It will host, among its many kaleidoscopic offerings, over 2000 beautiful beachfront villas, 3600 executive apartments and offices, luxury hotels and spa resorts, parks and entertainment precincts, mosques and international schools, premier retail malls and restaurants, a 400-berth marina, and an Ernie Els designed 18-hole championship golf course. (Durrat, 2014). not all of the Durrat Al-Bahrain Island was used in this study, only the area designated by the red color in figure 3 was involved in this study. In fact, it consists of four atolls as “C” shape and four islands as “fish” shape, namely: Atol 3 (purple), Atol 4 (orange), Atol 5 (magneta), Atol 6 (yellow), petal 2 (pink), petal 3 (light blue), Petal 4 (pistachio) and Petal 5 (blue). From figure 3 it is clear that beaches were note included in the area of each island to avoid confusing them with the open areas.



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These three manmade islands projects, are situated in different location over Bahrain main Island. They highly compete in terms of luxury and quality of life they offer. In terms of area, Reef Island is the smallest with only 0.579 Sq. Km, followed by Amwaj Islands with 4.1 Sq. Km and Durrat Al Bahrain is the biggest project of all three with an area of 21 Sq. Km. While Reef island might be considered as a mega residential compound with complimentary facilities and amenities, Durrat Al Bahrain is more a small city by its own. Amwaj Island is just in the middle as a neighborhood.

The Pearl-Qatar is located 350 meters offshore of Doha's West Bay Lagoon area, Doha, Qatar. It covers around 5 sq. km. It is supposed to create over 32 kilometres of new coastline, for use as a residential estate with an expected more than 18 thousands dwellings and up to 45,000 residents when completed by 2018. The Residential development on the Pearl-Qatar island intends to incorporate many national and international themes, including aspects of Arabic, Mediterranean, and European culture. There are ten areas that make up The Pearl-Qatar Island. With more than 10 islands when construction is completed, where the llargest of them features a range of luxury villas, apartments, five-star hotels and over two million square meters of international retail, restaurants, cafes, and entertainment facilities. (The Pearl-Qatar, 2016)

Palm Jumeirah, It is located on the Jumeirah coastal area of the emirate of Dubai, in the United Arab Emirates (UAE) with a total area of about 10 sq. km. It looks like a stylized palm tree from space, was the first offshore development of its kind, and was originally billed as the Eighth Wonder of the World. Located at coordinates: 25°06′28″N 55°08′15″E, it consists of a tree trunk, a palm crown with 16 fronds, and a surrounding crescent island that forms an 11 kilometer-long breakwater. The island itself is five kilometers by five kilometers. It adds 78 kilometers to the Dubai coastline. More than 28 hotels are located in it with a vast selection of restaurants and other retails. It is also connected to Dubai metro and has its own monorail Monorail of about a 5-kilometre-long connecting the Atlantis Hotel to the Gateway Towers at the foot of the island (Palm Jumeirah, 2016).

2.2. Satellite Datasets

Five Landsat OLI images were used in this study covering Bahrain, Qatar and Dubai (UAE). Two Worldview-3 images were used for validation over selected area in the kingdom of Bahrain. Tables 1 and 2 present the datasets used accordingly to each study sites. The multispectral WV3 datasets consisted on blue, green, red and near infrared (Near_IR1). The GSD of these data was 2 meters. Landsat 8 OLI images were obtained from the USGS earth explorer portal, and consisted on five images with multispectral bands; blue, green, red, NIR, SWIR1, SWIR2 and Panchromatic ban.

Table 1: Satellite imagery for various study sites

Country/City	**Name of Artificial Island**	**OLI Images Used**	**WV3 Image Use**
Bahrain	Amwaj Island	OLI(1,2,3,4)	WV3 (1)
	Durrat Al Bahrain	OLI(1,2)	WV3 (2)
	Reef Island	OLI(1)	-
Qatar/Doha	The Pearl-Qatar	OLI (1)	-
United Arab Emirates/Dubai	The Palm Jumeirah	OLI(5)	-

Table 2: Description of Satellite Datasets used in this study

ID used in this study	Scene ID	Date of acquisition	Spectral Bands
OLI1	LC81630422014095LGN00	5 Apr. 2014	B2,B3,B4,B5,B6,B7,B8
OLI2	LC81630422014287LGN00	14 Oct. 2014	
OLI3	LC81630422015322LGN00	18 Nov. 2015	
OLI4	LC81630422016325LGN00	20 Nov. 2016	
OLI5	LC81630422013124LGN01	18 May 2014	
WV3(1)	14OCT15071745-M2AS_R1C1-054335560010_01_P001	14 Oct. 15	Blue, Green, Red and Near_IR1
WV3(2)	14OCT15071725-M2AS_R7C2-054335560010_01_P002	14 Oct. 15	Blue, Green, Red and Near_IR1

Figure 4 depicts the created subset from datasets described in table 1 and 2 for Amwaj Islands study sites. The false RGB color composite used to display these images is (NIR, Red, Green), where vegetation appears in red color while grey color indicates built up areas and bright color is the open areas.

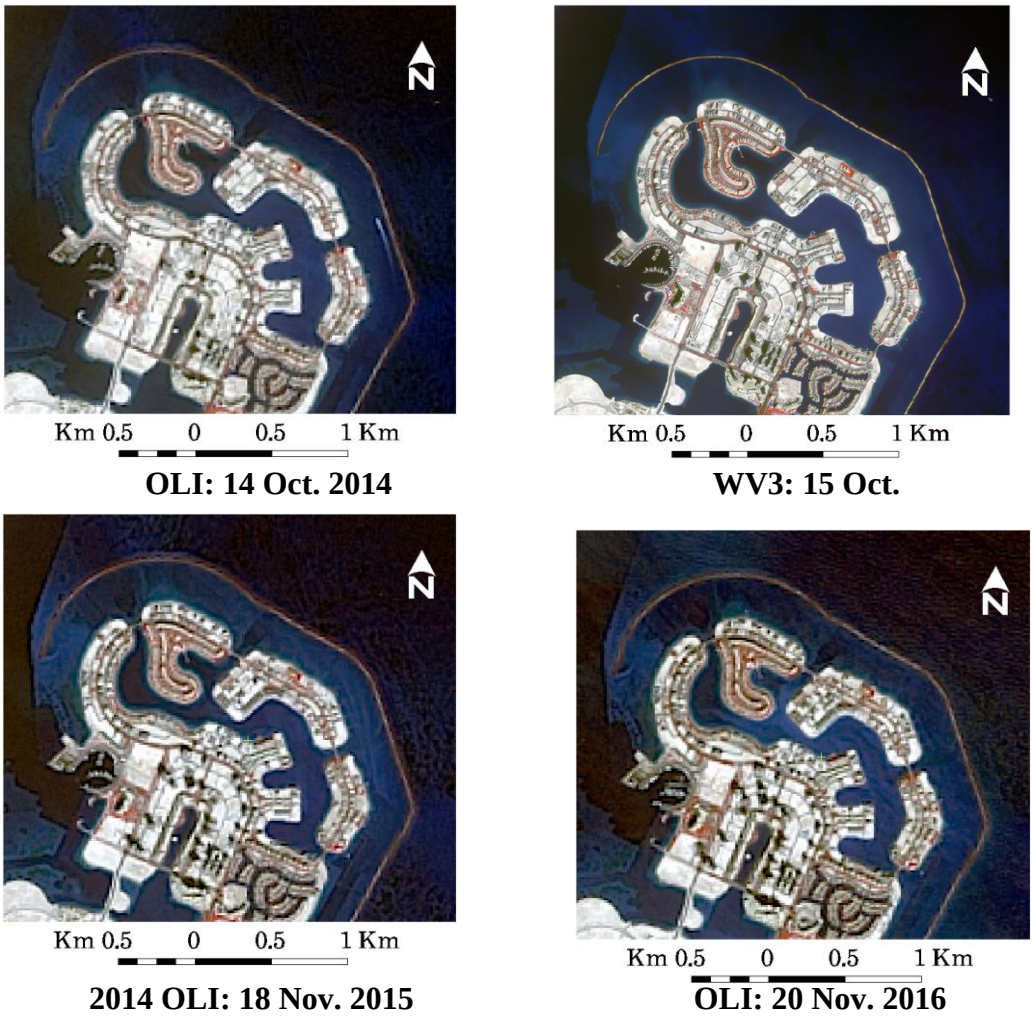
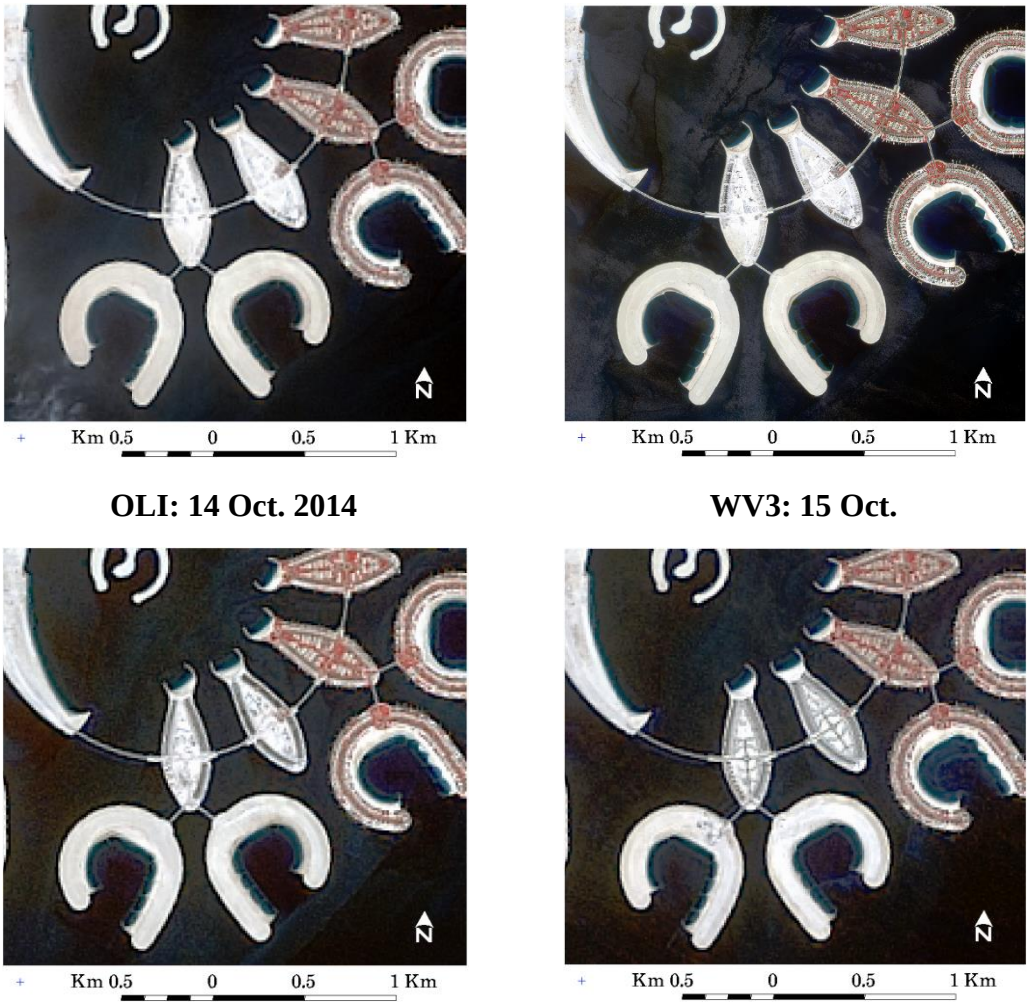


Figure 4: Subset of Landsat OLI and WV3 Images over Amwaj Islands (RGB =NIR,Red, GreeN)

Figure 5 depicts the created subset from datasets described in table 1 and 2 for Durat Al-Bahrain study sites. The false RGB color composite used to display these images is (NIR, Red, Green), where vegetation appears in red color while grey color indicates built up areas and bright color is the open areas. This site is very interesting because in 2014 two atoll islands and two petal ones were completely built up versus two atoll islands and two petal nearly untouched. The characterizing background soil brightness of the material used to build the whole project is very clear.



OLI: 14 Oct. 2014 **WV3: 15 Oct.**

2014 OLI: 18 Nov. 2015 **OLI: 20 Nov. 2016**

Figure 4: Subset of Landsat OLI and WV3 Images over Dural Al-Bahrain (RGB =NIR,Red, GreeN)

2.3. Processing

All OLI images were pansharpned using the high performance image fusion (PANSHARP2) using the commercial software Geomatica 2016. Although other image fusion techniques such as (IHS) and ImageLock Data Fusion can also be used, PANSHARP2 by Geomatica is meant to produce superior sharpening results while preserving the spectral characteristics of the original images (Geomatica, 2016). The green, red and near infrared multispectral bands with a radiometric resolution of 16-bit were used as reference for other bands and pansharpned with the OLI panchromatic Band 8. A full description of the pansharpening algorithm used in this function of Geomatica 2016 is described fully in (Zhang 2002, a and b). The resulting GSD is 15 meters for all

OLI images. On the other hand, the WV3 images has a nominal GSD of 2 meters and they were not panshaprned into 50 cm using its panchromatic band. Although the algorithm allows a fusion between raster of various origin, however merging Landsat 8 OLI data at a GSD of 30 meters with WV3 with a GSD of 2 meters is off the limit of this function for which a ratio of 1:5 is recommended (in this case 1:15). No atmospheric correction was applied to images, as the target is to develop a fast and simple methodology to use the raw images by yet to still get reliable results.

For both WV3 images over Amwaj Islands and Durrat Albahian Islands on 15 October 2014, unsupervised classification was performed. As known, unsupervised classification organizes image information into discrete classes of spectrally similar pixel values. As recommended, the maximum number of classes was set to 16, the minimum at 5 and the desired number of classes at 10. Hence aggregation can be performed to get the appropriate number classes. ISODATA method, classifier, which is similar in principle to the K-means procedure in the sense that cluster centers are iteratively determined sampled means (Geomatica, 2016, Tou, 1974). It represents a fairly comprehensive set of additional heuristic procedures which have been incorporated into an interactive scheme. For the dataset used in this study additional to described parameters the following one were used for the ISODATA classifier; 20 as maximum iterations, movement threshold at 1%, minimum threshold of 5, lumping threshold of 1, SD value at 10 and maximum lump pairs of 5. Once the clustering is run, a visual evaluation of clusters is performed to identify the ones representing open areas, and a bitmap is created to aggregate them. If necessary, raster editing by erasing or adding areas not classified is processed manually to assure the accuracy of classification. In fact, for both Amwaj and Durrat Al-Bahrain the site area is relatively small in term of area and such procedure is not time consuming, of course for the purpose of validation of OLI data only.

Using the histogram of various spectral band for OLI Images, and comparing with the density slicing of pseudo colors (figure 5). It was clear that the open areas in artificial islands have a distinctive high reflectance due to the material used in land reclamation. A cutoff DN value was selected based on the analysis of various dates and spectral band, and a threshold of 20,000 (DN based on 16-bit radiometry of the raster) was retained in the shortwave infrared SWIR1 ban for OLI images (indicated by the red arrow in the histogram figure 5). Therefore, when applying this threshold value to OLI images, all values overpassing the threshold are retained in a raster layer as open areas. The ratio of the area covered by this class to the overall land area of the study site is considered as the percentage of undeveloped proportion of the site.

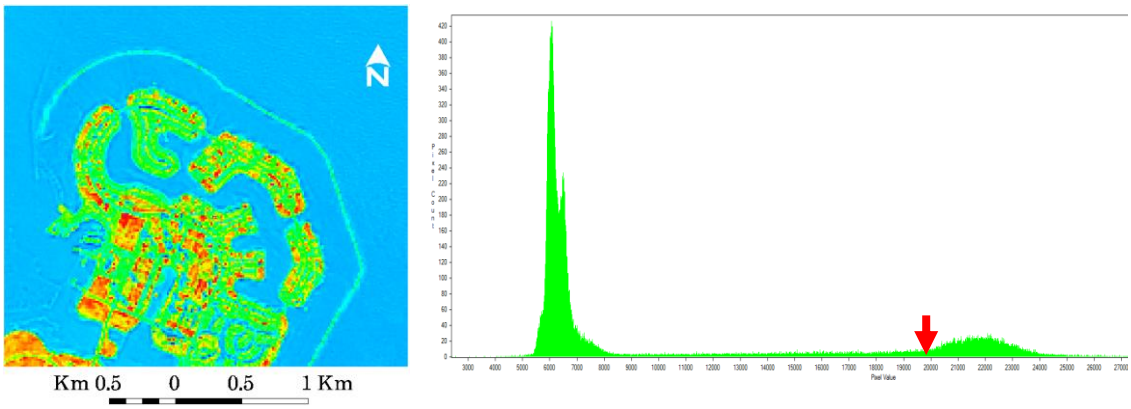


Figure 5: Pseudo colors representation of OLI SWIR1 on 14 Oct. 2014 aside of its DN histogram.

The subsequent methodology steps consisted first to compare the open areas proportions obtained from the classified WV3 image versus the values obtained from the simple thresholding technique. This was done using the available validation site at both Amwaj Islands and Durrat Al-Bahrain. If the correlation between this two methods is acceptable then a comparison in the same date between all five study sites is performed. Furthermore, for Amwaj and Durrat Al-Bahrain sites, a three years comparison is performed to monitor and determine the percentage of development of each of them.

3. RESULTS AND DISCUSSION

As described in the methodology above, the initial phase was to retrieve the percentage of development of Amwaj islands and Durrat Al-Bahrain from WV3 and OLI images on respectively 14 and 15 Oct. 2014. Figure 6 shows a visual comparison of the results obtained from the two various processes and datasets. The result obtained shows that using the process of unsupervised classification with aggregation of clusters and manual removal of building roofs it has led to 63.15 of developed area in Amwaw compared to 68.57% obtained with the simple thresholding technique from OLI image. Similarly, for Durrat Al-Bahrain 53% of development was obtained from WV3 image versus 48% from OLI Data. It is noticeable from figure 6 data the beach areas in both images and study sites was classified as open area. However, the mask used for the land area in both sites was excluding the beaches from the total area.

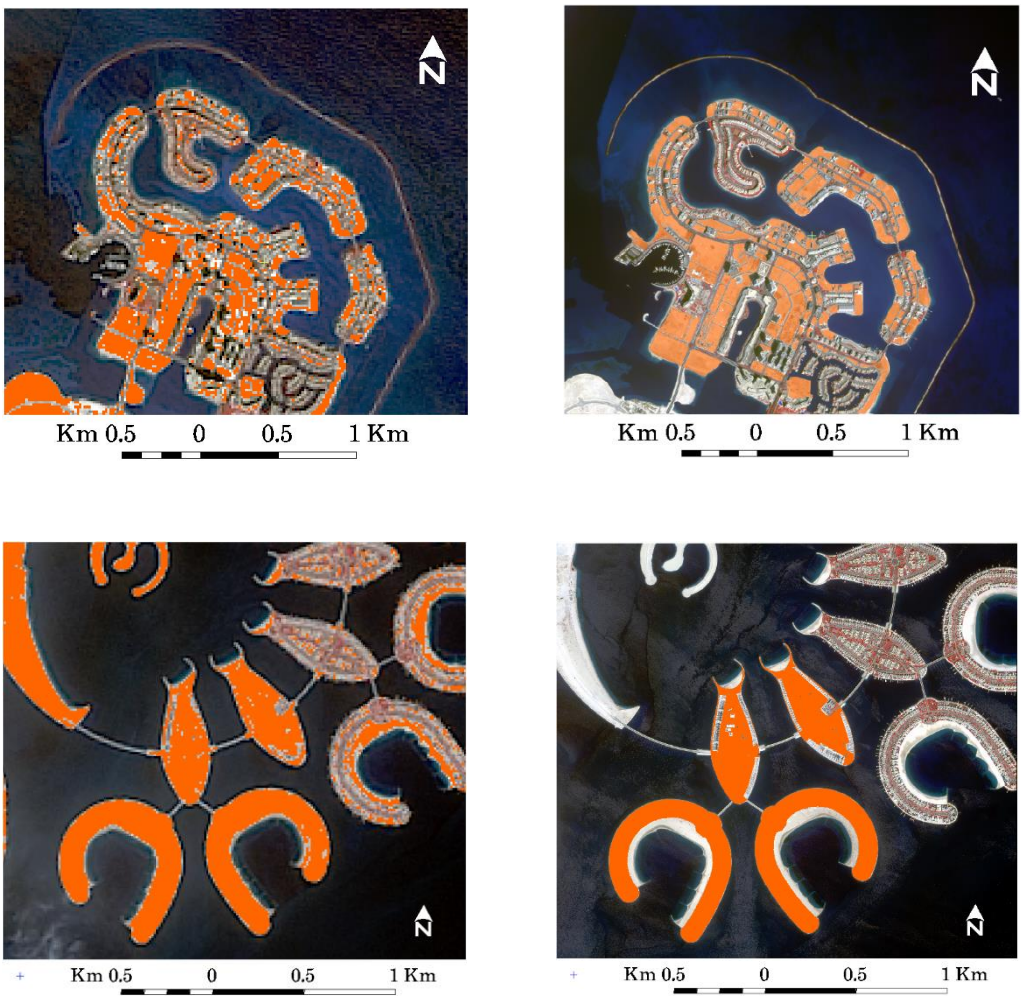


Figure 6: Comparison of percentage of development in Amwaj and Durrat Al-Bahrain and sub-islands using OLI (left) versus WV3 (right) in mid-October 2014.

To get more into details, for each sub-island of both study sites, the comparison between WV3 and OLI was performed. Figure 7 shows the results obtained and the correlation between the percentages of development retrieved by both processes gave a Pearson product moment correlation coefficient r=0.96. This is a good affirmation that the thresholding methodology based on pansharpned OLI image is reliable, simple and effective. In fact, using WV3 with a very performing classifier as ISODATA was not able to discriminate adequately the open areas versus rooftop of some buildings. It was necessary to go through a manual cleaning by visually determining the confusion and remediate to it. However, OLI image takes advantage of the low spatial resolution with a GSD of 15 meters. Hence, even if the rooftop of a building is bright but it will necessary be mixed with its surrounding context such as vegetation, roads or even shadow. Hence, from a very bright 2x2 meters pixel in WV3 image it will become less bright and letting only open area pixels appearing distinctively with a high brightness in OLI data.

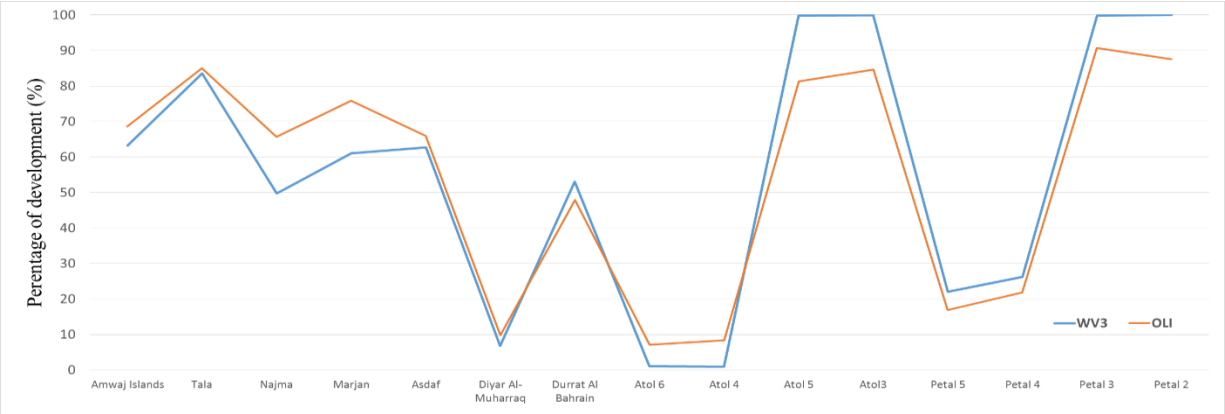
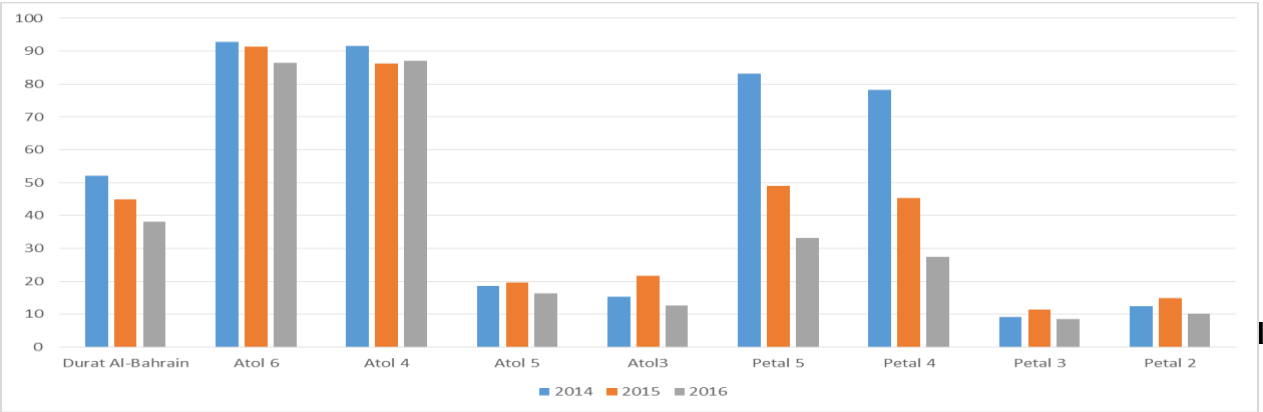


Figure 7: Comparison of percentage of development in Amwaj and Durrat Al-Bahrain and sub-islands using OLI versus WV3 images in mid-October 2014.

In annex 1 the results of thresholding from OLI images on 2015 and 2016 for both Amwaj and Durrat Albahrain are presented. In the same annex the Pearl-Qatar and Palm Jumeirah images and open areas from OLI images in April 2014 are presented.

Figure 8 depicts the changes in percentage of undeveloped areas in sub-islands of Durrat Al-Bahrain. This a clear example of how real-estate companies and agents may use such product to monitor overall progress of this type of artificial islands. In fact, if the island is fully developed this only means a more stable and quite neighborhood in term of acoustic pollution related to construction. In fact, for the example of Atol 6 and 4 in Durrat Al-Bahrain, these sub-islands have yet to be developed as the development rate is less than 15% in the years from 2014 to 2016 (figure 8). However, Petal 3, Petal 2, Atol 5 and Atol 3 has already a very high rate of development exceeding 80% and meaning the end if construction process. This information might not necessary be relevant if the developer of the project does not sell units in the project until the whole sub-island is built. However, in the case of Amwaj islands parcel of lands are sold separately and construction can start amid existing dwellings. Hence, Tala Island as a sub-island of Amwaj has a development rate exceeding 85% in 2014 and almost 95% in 2016 (figure 9).



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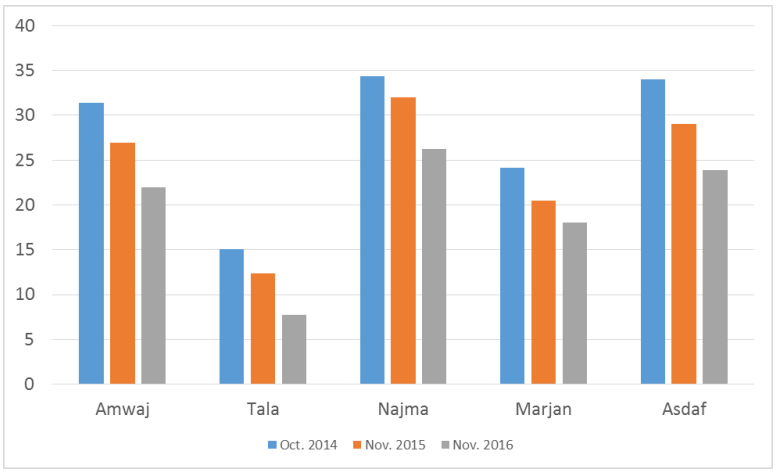

Figure 9: Percentage of undevelopment of study site in Amwaj Islands and its sub-islands from OLI images in 2014, 2015 and 2016

Real estate companies or potential investors can also be interested not only to now the rate of progress in time for various competitive artificial islands. They are also interested to compare all existing project at a given date or period. Figure 10 present the obtained results from OLI images for all the five study sites in April 2014 a cross three countries in the GCC. It is obvious that Palm Jumeirah at that time was the most developed artificial island among the five, with a development rate of 85%. In fact, 11 over the 14 main frond of its crown shaped main island were fully built. So although the technique used with OLI appears simplistic however it still gives very crucial information which is very hard to get from developer of these mega project.

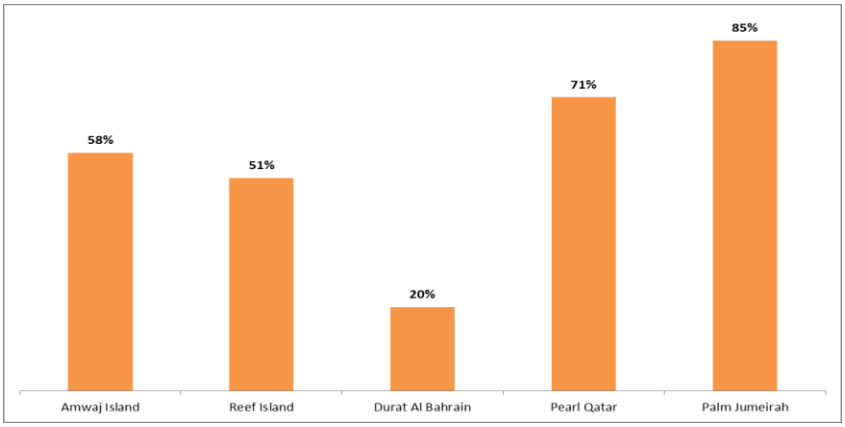

Figure 10: Percentage of development of all five study sites as per April 2014 using Landsat 8 OLI Images

4. CONCLUSIONS

Obtaining information on current status and temporal progress of artificial islands project in the GCC region is a crucial step for investors on home buyers. Being able to monitor the development of such mega projects and their sub-islands may be a first indicator of the high or low demand of various dwellings or high-rise products offered. It is not easy to obtain direct information from developer themselves as marketing consideration may bias the quality of the information. The technique developed in this study shows that with very basic processing on raw data from free available remote sensing images a considerable amount of information may still be retrieved. The open areas retrieval method used was validated using a more robust processing technique from WV3 images and still gave a correlation of 0.96. Furthermore, the main element of this technique relies on the fact that artificial islands are by definition spectrally homogenous due to the process of their construction. The very bright and typical spectral response in all spectral bands of OLI images make it easily distinguishable from any other target in the same area. The resolution of 15 meters has allowed the discrimination between the rooftop of buildings compared to open areas, due to the mixture with shadow, vegetation and adjacent roads. This study is a first step towards taking advantage of the open source available satellite imagery. with the release of Sentinel data and availability of Landsat series, and hopefully other data in the near future, combined the capabilities of cloud computing offered by e.g Google Engine or Amazon AWS combined with adequate API more spatially retrieved information on the real estate market related to artificial islands can be obtained.

5. ACKNOWLEDGEMENT

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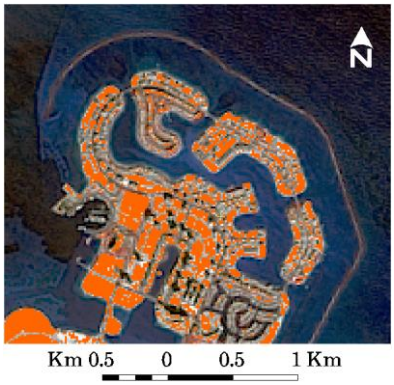
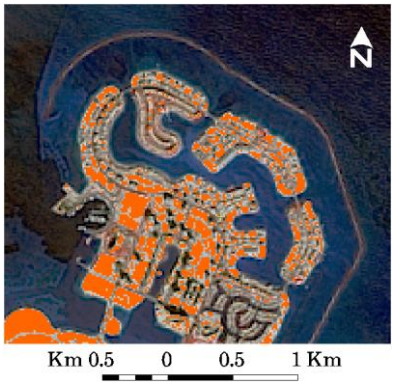
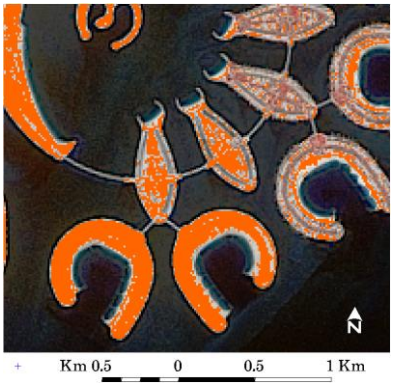
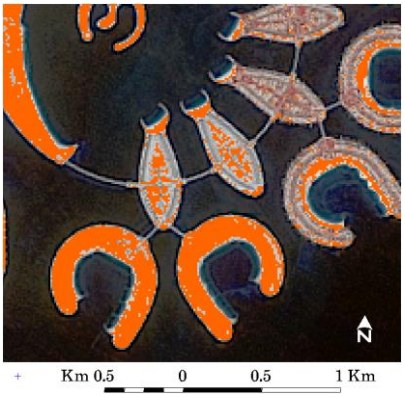
ANNEX 1



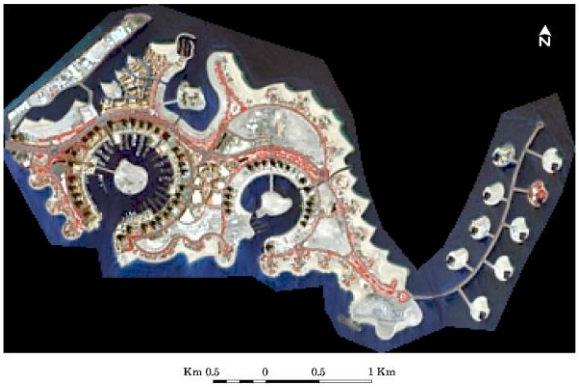


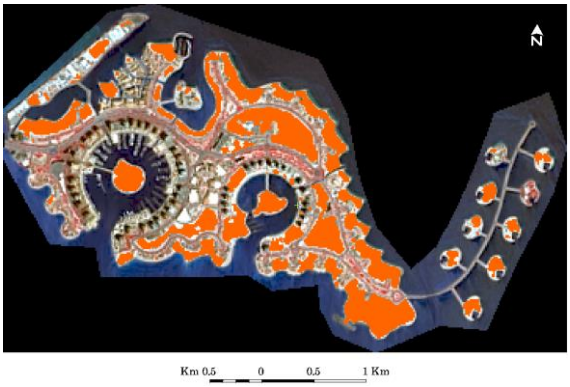
Amwaj open areas from OLI Nov. 2015 **Amwaj open areas from OLI Nov. 2016**



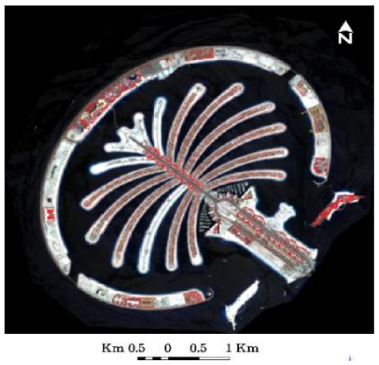


Durrat open areas from OLI Nov. 2015 **Durrat open areas from OLI Nov. 2016**

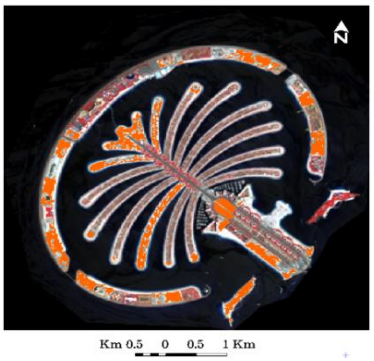




Pearl from OLI Apr. 2014 **Pearl open areas from OLI Apr. 2014**



Palm from OLI Apr. 2014



Palm open areas from OLI Apr. 2014