Integrating GIS and Remote Sensing Techniques in Kingdom of Bahrain 2010 Vegetation Survey

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ABSTRACT: The government of the Kingdom of Bahrain represented by the Information and e-Government Authority - iGA (formerly known as the Central Informatics Organization - CIO) conducted the 9th National Census on the 27th of April 2010. This has included Population, Housing, Buildings, Establishment and Agriculture, where the latter will be the prime theme of this paper.

As part of the move away from traditional census methods, GIS and remote sensing (RS) techniques were implemented to map the vegetation cover, i.e. by delineation of planted fields, type of crops in the fields, health of crops, area of cropped field, location of cultivated and patches of wild vegetation.

This project pursues the aim of providing the best services and outputs to the general public, as outlined by the government strategic vision. The project will be a valuable asset and lively addition to the services provided to the government as well as citizens which will have positive reflections in the progress of the Kingdom of Bahrain.

The paper will review the effectiveness of GIS and RS techniques in the measurement of vegetation cover, and discuss the main opportunities and challenges, including how some of the challenges were overcome, for example by integration of remote sensing, census and survey data.

The project resulted in a number of organisational benefits including improved coverage, cost savings and improved timeliness, as well as improvements in organisational know-how.

Finally the main paper discusses the potential for future RS projects, including agro directory and vegetation mapping, soil type and geological formation mapping, marine habitats and pollution mapping, land cover/use and change assessment mapping.

1. Introduction

The Government of Bahrain represented by the general Directorate for statistics of the Central Informatics Organization (CIO), which was later merged in 2015 with the e-Government Authority to form a new entity known as the Information and e-Government Authority (iGA) ; undertook in 2010 a general census in which part of it focused on vegetation and agriculture. (CIO, 2010).

As part of the census deliverables, statistical data and information pertaining to the vegetation cover in the kingdom of Bahrain were required. To meet this requirement a new approach was needed. A traditional method of data collection and analysis was actually ruled out due to the high costs associated with it and the extremely lengthy amount of time required to be carried out. A more robust and cost effect approach was adopted for the first time to utilize remote sensing techniques to map and measure the vegetation cover for entire area for the Kingdom of Bahrain of about 759 square Kilometers, inclusive of 4 Governorates, i.e. Capital, Muharraq, Northern and Southern, and to derive important statistical information (CIO, 2010).

The 2010 Vegetation Survey utilized high resolution (0.41 m) multi-spectral (near IR + BGR) imagery. The spectral reflectance is suitable for detecting vegetation, especially in the near Infra-Red range of the electromagnet spectrum (Xie *et al*, 2008). The study was executed in three phases. Phase I was a desk study of the subject matter, whilst phase II focused on the initial basic unsupervised vegetation classification, and last but not the least phase III encompassed the final supervised vegetation classification.

2. Phase I – Desk Study

This was the initial phase of the project in which the foundation of the project was laid out. It focused on the collection and review of existing information related to the project various phases, such as information of the different types of vegetation cultivated and indigenous to Bahrain.

Building on expertise and skills built within the GIS directorate in the fields of GIS and remote sensing, it was straight-forward to assimilate the various information and data and utilize them to plan and execute the vegetation survey.

The following organizations were contacted in search of relevant records for the project.

Table 1 organizations contributing with information and data pertaining to vegetation in Bahrain

Organization	Response
The Ministry of Municipalities Affairs and Urban Planning	Provided information regarding the land cover and land use.
Agriculture Affairs	Provided information regarding the vegetation type local to Bahrain.
Survey and Land Registration Bureau (SLRB)	Provided information regarding the topological features of Bahrain.

In addition, the websites for different Bahraini government agencies were accessed for additional relevant information.

Based on the collected information pertaining to topics of interest for this project, and drawing on the expertise within the GIS directorate, a clear view of the project requirements was reached. This view gave us an understanding of how to undertake the project as well as identify its requirements.

3. Phase II – Unsupervised Classification

An Unsupervised Classification is a remote sensing technique used to group/classify image pixels of similar values into clusters/classes, this grouping is done automatically without the user input and the resulting clusters/classes vary in number according to the user preference. This type of classification is usually done when no prior knowledge of the feature being investigated exists (GIS Geography).

This classification technique was employed in this Phase, which focuses on acquiring high resolution (0.41 m) multi-spectral (near IR + BGR) imagery and processing it in order to generate an initial vegetation classification map. This map was later used as the basis for generating the field survey maps used in phase III. This phase was made up of the following stages:

3.1 Imagery Acquisition and Processing

In this stage a high resolution GeoEye 1. (0.41m) multispectral (near IR + BGR) imagery (Digital Globe, 2010) was acquired in April 2010. The time of the acquisition was crucial, since it was extremely important to acquire the imagery in the same time as the planned field survey if possible, so as to minimize the amount of any likely errors in the classification. The imagery underwent a number of processes to deem it suitable for the initial unsupervised classification. The imagery was first corrected for atmospheric effects, later it was geo-rectified using aerial photographs and topological maps. The spatial reference used was 'AIN EL ABD 1970/UTM zone 39N'. Further, the imagery spectral bands (pixel values) were converted from DN values to spectral radiance and later to spectral reflectance (NASA). Figure 1 shows a sample of the satellite image.

Figure 1 A false color composite in the Red, Near Infra-Red and Green bands with vegetation shown in red color variations.

3.2 Normalized Difference Vegetation Index (NDVI)

In order to perform the unsupervised classification, the satellite imagery needed to be masked so that only vegetation based areas are classified. Normalized Difference Vegetation Index (NVDI) an index used to provide indications of the availability of live vegetation, as well as the general condition of the vegetation health (Weier, 2000), was used to identify vegetation areas in the satellite imagery. These areas were later used to create the vegetation mask. Figure 2 shows an example of an NDVI image of central western areas in Bahrain, where vegetation having light gray color indicate their good health.

Figure 2 Example of an NDVI image of central western areas in Bahrain.

3.3 Unsupervised Classification

The remote sensing application ERDAS Imagine was thereafter used to perform the unsupervised vegetation classification. In this classification, imagery pixel values of similar spectral reflectance are grouped together to form a class/cluster of similar homogeneous areas (GIS Geography) that represents an unknown feature. The vegetation mask derived from the NDVI imagery was used to select the vegetation areas. The selected areas were classified using the unsupervised classifier, with a maximum number of 90 classes. The resulting classification map as can be seen in figure 3 was used to prepare the field survey maps for in-situ investigations of the unknown vegetation clusters.

Figure 3 A sample of the unsupervised classified satellite imagery, showing vegetation classes of unknown types.

4. Phase III – Supervised Classification

A supervised classification is a type of classification in which image pixels are grouped together in clusters/classes based on ground truth data for a given feature (GIS Geography). This type of classification utilizes survey data collected from field survey visits as outlined in the following sections:

4.1 Field Survey

Based on the results of the unsupervised classification, 179 sites were randomly selected to be investigated. In-situ data pertaining to the vegetation was collected; such information included the vegetation type, Arabic and English names. A team of 5 GIS specialists conducted the field survey visits, with an average of 20 sites covered per day. High accuracy GPS receivers with the ability for data entry were used to collect the field survey data. The locations of the sites as well as the geospatial data were later converted into a GIS shape file. Figure 4, shows an example of the collected field survey data as a shape file ready for integration in the supervised classification workflow.

Figure 4 A map showing a sample of the collected field survey data.

4.2 Supervised Classification

This stage focused on the generation of a supervised vegetation classification map, through the utilization of the field survey data. The vegetation areas derived from the NVDI map was used to classify the high resolution – multi-spectral imagery, using a maximum likelihood supervised classifier. The field survey data was used as training sites for the classifier and in which the spectral signatures of the different vegetation are identified and used as a vegetation type indicator (Hexagon Geospatial).

The resulting supervised classification map contained 75 different vegetation types such as palm trees, mangroves, tomatoes, etc. The supervised classification map was further processed to remove any artifacts and later converted to a thematic vector map layer. Figure 5 shows an example of the vectorized classification map.

Statistical information obtained from the vectorized supervised vegetation classification map, included the total area for each vegetation type, and the percentages that each type covers with respect to the total land area. These results were published and assimilated in the Bahrain spatial data infrastructure (BSDI) geospatial repository.

Figure 5 An example of the vectorized vegetation classification map.

4.3 Accuracy Assessment

The accuracy of the supervised classification results were assessed through the utilization of the accuracy assessment tool in ERDAS (see Hexagon Geospatial). Moreover, Ground truth data for 110 randomly selected locations representing the various classes of vegetation were obtained using actual site visits. The data was fed to the system to measure the accuracy of the supervised classification. The measured accuracy was 87% accurate which according to international standards is quite an acceptable level.

Additionally, various statistical figures such as the total vegetation cover which was found to be 6121 hectares was compared to figures obtain from other government agencies, and it was found to be 6400 hectare, which is very close (Ministry of Municipalities Affairs & Agriculture, 2008) .

5. Results

As a result of using these techniques, the CIO was able to provide a range of statistical results from the Vegetation Survey. Many of these results were also produced as Thematic Maps, while some data was produced in tables. The main statistical results of the survey are shown in Appendix 1.

The Bahrain ‘Census Summary Result of 2010’ report released by the CIO, noted that the census of 2001 witnessed a turning point in using modern technology. Consequently, the 2010 census included the agriculture statistics, also adopted state of art technology – in this case, integrating remote sensing techniques with GIS technology. Suffice to say that the 2010 project was budgeted at 1.6 million Dinars, but could have cost 5 million if traditional methods had been used (CIO, 2010).

Overall, GIS and RS techniques proved to be an invaluable tool in the measurement of vegetation cover, which opened up new opportunities for future research and surveys. While challenges were encountered, they were handled and overcome by integration of remote sensing, census and survey data. Furthermore, several organizational benefits resulted including improved coverage, cost savings and improved timeliness, as well as improvements in organizational know-how.

6. Conclusions

The objective of the Kingdom of Bahrain vegetation survey was to map and measure the vegetation cover for the entire area of the Kingdom, using remote sensing classifications, standards and methodology. This survey conducted in 2010 was in response to the national agricultural census requirements.

Bahrain takes a pride in transitioning from conventional survey methods to satellite remote sensing, and conducting this national program for the first time. It is hoped that developing a standard national vegetation classification scheme and mapping protocols will not only facilitate effective resource management but will provide great flexibility in map design and production, data analysis, data management, and maintenance activities. From the initial desk study process and ground truth phase, it was quite clear that the new data collection and processing technologies now available could offer considerable improvements over traditional methods. From the business perspective CIO officials were more determined than ever (even compared with previous census experiences) that past traditional census data capture had become more expensive, took lot of time and was laborious. The significant project cost saving as highlighted in section (5) is also promising.

The 2010 vegetation survey results have been good, however there remains room for improvement. iGA is interested in expanding the vegetation research program to cover additional remote sensing projects and applications while expanding the models to include other inputs, such as weather and soils data. There are four new research areas that iGA hopes to move into the future.

These include 1) agro directory and vegetation mapping, 2) soil type and geological formation mapping, 3) marine habitats and pollution mapping, and 4) land cover/use and change assessment mapping. Looking to the future and coupled with the organizational “know-how and “know-what”, iGA expects to see more rapid development of remote sensing applications from research to operational status and hopes to excel and achieve organization benefits with reduced respondent burden.

Finally, the availability of commercial off-the-shelf software to perform the land classification and image manipulations has also advanced the remote sensing program at iGA. The addition of ERDAS Image remote sensing software and

Environmental Systems Research Institute's (ESRI) ArcGIS, have all played a critical part in enhancing processing capability and efficiency to reap benefits of using remote sensing techniques as a cost effective tool enabling vast area coverage. In short, Xie *et al*. 2008, contended that remote sensing technique has its own benefits if compared with other methods but not to neglect its limitations. Rapp *et al*. 2005 in (Xie *et al*. 2008), stated that when examining the results of vegetation mapping from remote sensing imagery, three questions should be raised: "how well the chosen classification system represents actual vegetation community composition, how effectively images from remote sensing capture the distinguishing features of each mapping unit within the classification and how well these mapping units are delineated by photo interpreters. Overall, limitations could be envisaged in terms more caution to be exercised to minimize ambiguity in derived results to achieve the right confidence level. Due to lack of time the team was not able to answer the questions posed by Rapp *et al*. 2005, which could well-considered in the next survey.

This paper has shown how the GIS Directorate of the Information and e-Government Authority – iGA was able to build and use the necessary GIS infrastructure in Bahrain and exploit the joint GIS and remote sensing analysis system for Bahrain to support agricultural statistics and likely crop monitoring activities.

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Appendices

Appendix 1

Key result* 1 - Total vegetation cover area

Key result** 2 - Total agricultural crops area

Table 2 Showing total vegetation cover and total agricultural crops areas.

Area	Dunum	Sq. Km	Hectare	% of Kingdom area
Total vegetation cover*	61216.250	61.216	6121.625	8.1
Total agricultural crops**	10922.365	10.922	1092.23	1.4

Key result 3 - A list of all vegetation types and their areas (the final classes; documenting 75 types inclusive of seasonal crops).

Table 3 shows a list of all vegetation types and their areas (the final types; documenting 75 types inclusive of seasonal crops).

Area in km^2	Types	
17.005	Date Palms	نخيل
0.978	Mixed Trees	أشجار متنوعة
1.644	Mixed Orchard	أشجارفواكه متنوعة
0.365	No translation	كنار
0.356	Almonds	لوز
0.006	Tangerine	ترنج
0.006	Orange	برتقال
0.003	Banana	موز
0.042	Lemon	ليمون
0.036	Mango	مانجو
0.229	Neem	شجر النيم
0.285	Sweet Tamarind	تمر هندي
0.056	Sour Tamarind	صبار حامض
0.129	Eucalyptus	شجر الكينا

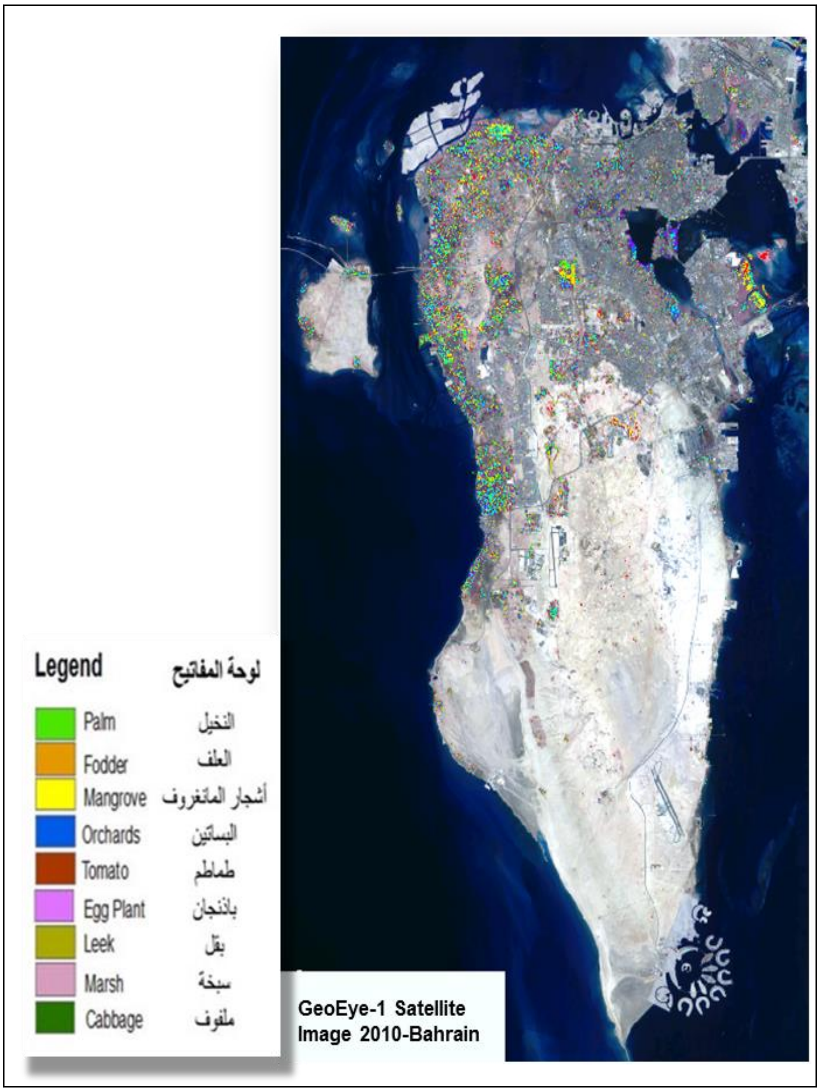
0.036	Sapodilla	جيكو
0.098	Papaya	باباي
0.300	Lasursa	بمبر
0.431	Arugula	جرجير
0.777	Barley	شعير
0.233	Beet Root	فجل
0.020	Bitter Gourd	قرع (صنف 1)
0.090	Bottle Gourd	قرع (صنف 2)
0.033	Broccoli	بروكلي
0.253	Cabbage	ملفوف
0.097	Carrot	جزر
0.303	Cauliflower	قرنابيط
0.175	Chard	سلك
0.005	Chilies	فلفل أخضر (حار)
0.110	Pepper	فلفل بارد (فليفلة)
0.179	Coriander	تابل (جلجلان)
0.072	Cucumber	خيار
0.019	Corn	ذرة
0.079	Dill	شبنت
0.242	Egg Plant	باذنجان
0.051	Leek	بقل
0.226	Beans	فاصوليا
0.296	Lettuce	خس
0.231	Marrow	قرع (صنف 3)
0.404	Basil Black	ريحان أسود
	Basil Green	مشموم
0.136	Mint	نعناع
0.274	Mixed vegetables	خضروات متنوعة
0.051	Mixed salad leaves	ورقيات متنوعة
0.460	Lady finger (Okra)	بامية
0.557	Onion	بصل
0.240	Parslane	بربير
0.133	Parsley	بقدونس
0.043	Potato	بطاطس
0.252	Pumpkin	بوبر
0.344	Radish	فجل
0.082	Radish seed pods	نبات بذرة الفجل
0.247	Snake cucumber	طروح
0.091	Spinach red	سبانخ أحمر
0.240	Spinach green	سبانخ أخضر
0.131	Sponge gourd	قرع (صنف 4)
0.127	Yellow squash	كوسا صفراء
	Small squash	كوسا
1.047	Tomato	طماطم

0.032	Turnip	شلغم
0.041	Water melon	جح
6.059	Gardens	حدائق
1.168	Fodder grass	علف
0.477	Alfa Alfa	جت
0.313	Mangrove plants Coverage-dense	نباتات استوائية كثيفة
0.065	Mangrove sparse	نباتات استوائية خفيفة
0.031	Mangrove dry	نباتات استوائية جافة
4.651	Marsh/sea algae	طحالب
0.570	Aquatic scrub	نباتات مائية
0.213	Long wild grass	عشب بري طويل
15.486	Scrub vegetation	فرك الغطاء النباتي
0.782	Grass	حشائش
0.021	Fallow ground (with young vegetation)	أرض بور
0.437	Shrub vegetation	شجيرة الغطاء النباتي
0.023	Dry vegetation (in agricultural fields)	غطاء نباتي جاف
0.493	Green house	البيوت الخضراء

http://www.cio.gov.bh/cio_ara/SubDetailed.aspx?subcatid=483

Key result 4 - A smart GIS location map of the various vegetation

Figure 6 shows a smart GIS location map of the various vegetation



Key result 5 - Information on the general health of the vegetation

Figure 7 shows the general health of agricultural crops