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Change Detection Analysis using New Nano Satellite Imagery

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Abstract: Mapping Land use /Land cover (LULC), changes studies have become interesting over the past decades through using remote sensing. It is essential for a wide range of applications, including landslide, erosion, urban growth, agricultural expansion, land planning, global warming etc. In this study, LULC changes in a new Capital, North-East Cairo are investigated by using remote sensing images acquired by (Nano satellite / Planet Labs). For this purpose, firstly supervised classification technique is applied to Planet Labs images acquired in 21December, 2016 and 14 July, 2017. Image classification of four reflective bands of the two images is carried out by using maximum likelihood method with the aid of ground truth data obtained from topographic maps cover the studying area (25x21km). The second part concern is detecting land use land cover changes by using change detection comparison (Image Differencing Method). In the third part of the study, land cover changes are analyzed according to the different features by using ERDAS functions. The results indicate that land cover changes have occurred in the urban area were increased approximately by 1,847,790 sq. m and roads area by 245,385 sq. m while a decrease in bare soil areas by -2,093,175 sq. m. This occurred due to the rapid construction operation. It can be seen that the LULC changes were occurred by the rate of 1,395,450 sq. m. per year in the development area East side of the new Capital.

Keywords: Remote Sensing, Land Use / Land Cover (LULC), Change Detection, Supervised Classification.

I. INTRODUCTION

The earth's surface is changing as a result of natural phenomena or human activity, it plays a major role in the study of global change. The earth's surface changes are divided into two categories: land cover and land use. The Land cover at first describes the physical state of the land surface, which includes forests, agriculture land, wetlands etc. It has expanded in subsequent usage to contain human structures such as pavements, buildings and other aspects of the natural environment. The land use mentions the way in which human beings exploit the land and its resources including agriculture, urban development, pasture, logging mining etc. However, LULC are often used interchangeably because the two terms are interdependent and mostly related. Land use/land cover and human/natural development have largely resulted in deforestation, desert expansion biodiversity loss, global warming and increase of natural disaster-flooding. These phenomena problems are often related to LULC changes [4]. Therefore, the data on LULC changes can provide critical input to decision-maker of environmental management and planning of future [2].

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The increasing socio-economic necessities and growing population create a pressure on land use/land cover. This situation pressure results in mismanagement and uncontrolled changes in LULC. The LULC alterations are generally caused by unscheduled of agricultural, urban, range and forest lands which lead to terrible environmental problems such as landslides, floods etc. Remote sensing is powerful tools to gain accurate and timely information on the spatial dealing out of land use/land cover changes over large areas [4]. Past and present studies managed by organizations and institutions around the world, have mostly concerted on the application of LULC changes.

The aim of change detection process is to identify LULC changes on digital images for features of interest between two or more dates. In literature there are many ways to be used in such studies such as post classification comparison, standard image differentiation, using image ratio, image regression, and manual on-screen digitization of change principal components analysis and multi date image classification [4]. A variety of studies have directed that post-classification comparison was found to be the most precise procedure and presented the advantage of indicating the nature of the changes [2]. In this study, change detection comparison by Image Differencing Method technique was applied to the LULC maps derived from satellite imagery.

The aim of the study is to analyze LULC changes using Nano satellite / Planet Labs imagery ERDAS Imagine software for new Capital Province (North East Cairo). In order to achieve this objective, (Planet Labs) Imagery data acquired on 21December, 2016 and 14July, 2017 were used. Maximum likelihood classification and change detection comparison strategy was employed to identify LULC changes.

II. CHANGE DETECTION TECHNIQUES

In the past decade for extracting LULC change information, traditional methods and remote sensing technology were used. Traditional methods such as field surveys, map interpretation and data analysis are not effective to acquire LULC changes because they are time consuming, date-lagged and often costly. The remote sensing technology techniques include using aerial photographs, satellite images, spatial data set and other data [3] are a much more cost-effective and time-efficient means to study LULC changes, especially over regional or national areas in comparison with the classical methods. Now the detecting and analyzing LULC over large geographic areas as well as over regional areas have been spotlighted both in a method of separate long-time span and in consecutive time series with high temporal remote sensing satellites through a process often called.

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'Change detection'. Change detection has been defined as a "process of recognize differences. in the state of an object or phenomenon by observing it in different times"[4]. This is considered an important process in monitoring LULC because it gives quantitative analysis of the spatial distribution of the population of interest and this makes LULC study a subject of interest in remote sensing applications. Using remotely-sensed data to detect LULC changes, requires six main important steps as follows [5]:

1- Nature of Change Detection Problems.
2- Select of Remotely-Sensed Data.
3- Image Preprocessing.
4- Image Processing or Classification.
5- Selection of Change Detection Algorithms.
6- Evaluation of Change Detection Results.

A. Planet Labs Imagery:

Satellite Characteristics, Each Planet Labs satellite (10x10x30cm) is in the Cube Sat 3U form factor has characteristic as in table [1]. Planet Labs satellites are deployed over multiple launches during the year, each contributing to a larger constellation of satellites. On-orbit capacity will grow to a nominal constellation size of 120 satellites. With a full constellation of 150 or more satellites, the system will be able to image the entire Earth every day [1].

Table 1: Planet Labs System Mission Characteristics [1]

Mission Characteristic	Technical Specifications
Number of Satellites	++150
Equator Crossing Time	10:30 am ± 1.0 h
Orbit Altitude(reference)	475km
Sensor Kind	Frame imager with two-stripe NIR filter
Ground Sampling Rang (nadir)	3.7 m
Spectral Bands	Capable of capturing all of the following spectral bands (band name: spectral range): Blue: 455 – 515nm Green: 500 – 590nm Red: 590 – 670nm NIR: 780 – 860nm
Positional Accuracy	<20 m RMSE Today <10 m by the end of 2016
Revisit time	Daily at nadir
Swath Width	24.6 x 16 km (at reference altitude)
Data Availability	6h to 24h after collection
Imagery Capture Capacity	150 million km^2/day

B. Sensor Characteristics:

Planet Labs' satellites have a Charge-Coupled Device (CCD) camera provided with a Bayer mask style Color Filter Array (CFA). This means that at the time of image taken, each sensor will compute one of green, red, or blue wavelengths. These values are interpolated to specify a red, green, and blue value to each pixel. Time Delay Integration (TDI) is a technique prepared to increase the effective exposure time of images. TDI is a default designed for Planet Labs' image capture. It works by shifting the rows of pixels within the CCD at the same value as the ground motion of the scene. The TDI mode used to capture each scene is available in that scene's metadata.

C. Planet Labs Analytic Ortho Imagery Description/ Pre-Processing:

Planet labs Analytic imagery is orthorectified multispectral data from the operational mission-one constellation. This output is designed for a broad variety of applications that require imagery with a precise geolocation and cartographic projection. It has been treated to eliminates deformation and distortion caused by terrain and can be used for many data science and analytic applications. It removes the perspective effect on the ground (not on tall buildings), restoring the geometry of a vertical shot. The orthorectified visual imagery is optimal for value-added image processing including vegetation indicator, land cover classifications, in addition to the orthorectification, of imagery has radiometric corrections applied to rectify for any sensor artifacts and transformation to at-sensor radiance [1].

D. Satellites and Orbits:

They launch multiple groups of satellites per year, each contributing to a larger constellation of satellites. [1] Planet Labs provides high frequency, high-resolution imagery. Each satellite at the Cube Sat 3U form factor (10x10x30cm) as shown in Figure 1. On-orbit capacity is constantly under development, with technology development position at a rapid step. With a full constellation of 150-200 satellites as shown in Figure 2, it will be able to image the whole Earth every day.

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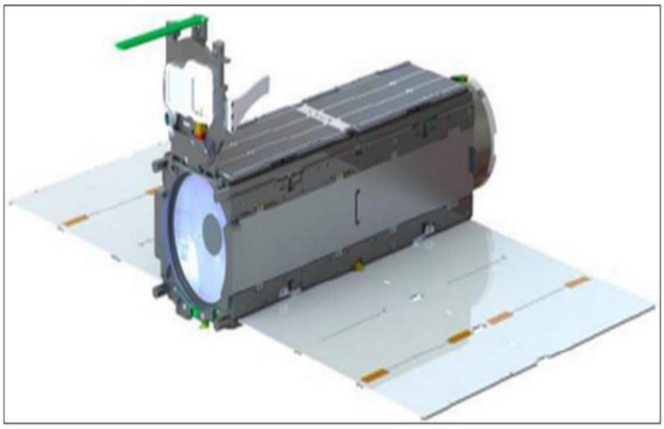

Figure (1) Nano Satellite Device

Figure (2) Constellation of Satellite

E. Study Area:

The study area in new Capital Province is located between 30 ° 08' 54.08'' and 30 ° 06'30.8'' N latitudes and 31 ° 36' 6.5'' and 31 ° 46' 3.5'' E longitudes North East of Cairo in Egypt. The area covers about 25X 21km. The study area is characterized by nearly leveled terrain as shown in Figure 3.

Subset:

Subset is generally carried out when the image has to be decreased in size or a sample portion of the image need to be used for performing analysis. The area covered lies within three satellite images and were provided by a commercial data provider. They were larger than the area of interest AOI. The part of the image AOI was extracted by using subset tool.

One of the advantages of carrying out the subset function is that after extracting the region of interest from the larger image, the classification process will be done just for the required area and the number of pixels for each class will be from the AOI only and not the whole images effective for recognizing and locating change and are easy to perform [3].

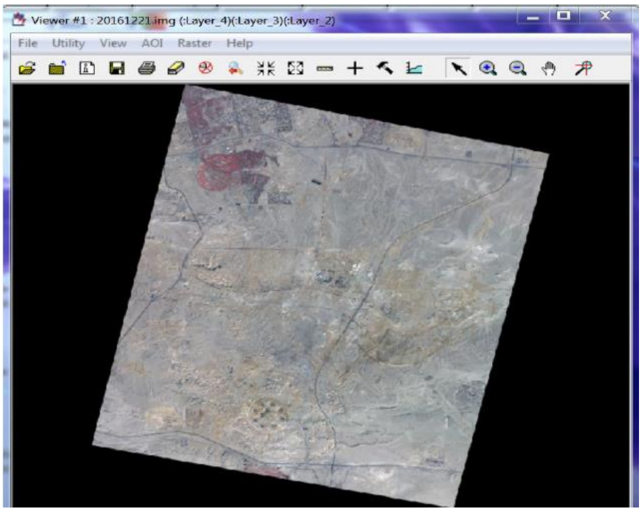

Figure (3) The AOI Subset From The Three Planet Labs Images

III. METHODOLOGY:

Data from, Nano satellite / Planet Labs images 21Desmber, 2016 and 14July, 2017 were used in this study. An area 25 X21 km of subset was used from these three Nano satellite / Planet Labs images with 3 m spatial resolution according to the information Image characteristics. All visible bands were included in the analysis. Remote sensing image processing was performed using ERDAS Imagine 9.2

A. Pre-classification Techniques:

The pre-classification techniques, known as double change or non-change data detecting techniques include various methods that directly use the two dates of satellite imagery to produce change and no change image. Several pre-classification methods have been used and matched to evaluate and recognize LULC changes such as, Image Differencing method (ID). The technique of change detection based on measuring the nature of changes, which means changes in the features of area of interest that will result changes in reflectance values [2]. The pre-classification techniques are identified as the most accurate change detection method because they are straight forward,

IV. CLASSIFICATION

In order to perform change detection, the image has to be classified into suitable classes first. Classification is the process of collect the pixels into different classes on LULC based on characteristics of the light reflected from each of the LULC type at the area that this image covers. At this study, total of, nine LULC classes were established as vegetation, grass, sand, building, bare soil, road, route, urban and water. The two dates images were compared using supervised classification method. Precise classifications are imperative to ensure accurate change-detection outcomes [4]. A Supervised classification method as shown in Figure 4 was carried out using training samples and test data for accuracy assessment. Maximum Likelihood method was performed to detect the land cover types in ERDAS IMAGINE (9.2). The end of classification outputs for both the images are shown in Figure 4. The image on the left is the classified result for image taken in 2016 and the image on the right is the classified result for image taken in 2017.

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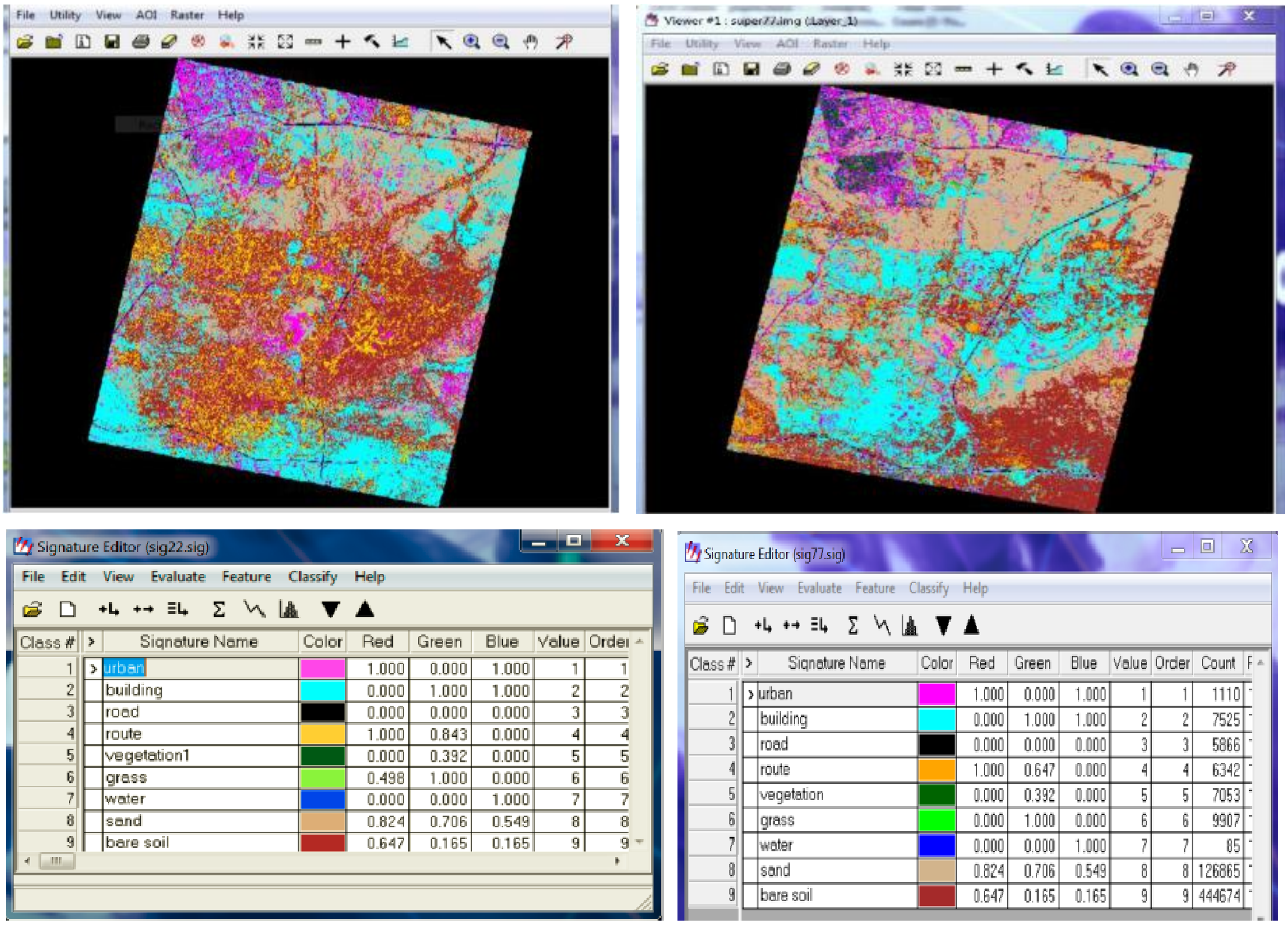

Figure (4) The Supervised Classification of Planet Labs Images Left 2016 and Right 2017

A. Assessment of Classification Accuracy:

The accuracy assessments of both techniques were made through an error matrix. The error matrix contains data about actual and predicted classifications done by a classification method. Table1and Table2. The pixel that has been categorised from the imagery was compared to the same place in the field. The final result of an accuracy assessment typically gives the users with an overall accuracy of the map and the accuracy for each class in the output map. The percentage of overall accuracy was calculated using the following form: [6]

$$\text{Overall accuracy} = \frac{\text{Total number of correct samples}}{\text{Total number of samples}} \%$$

Besides the overall accuracy, classification accuracy of single classes was calculated in similar manner. There are two approaches, producer's accuracy and user's accuracy. The producer's accuracy is derived by dividing the number of right pixels in one class by the gross number of pixels as derived from reference data. The producer's accuracy measures how well a certain area has been classified. It contains the error of omission which refers to the proportion of observed features on the ground that is not classified in the map. For now, user's accuracy is calculated by dividing the number of right classified pixels in each class by the total number of pixels that were classified in that class. The user's accuracy scales the commission error and shows the in all probability that a pixel classified into a given class represents really, that class on field. Producer's and user's accuracies are derived forms as following [6]

Producer's accuracy (%) = 100% - error of omission (%)

User's accuracy (%) = 100% - error of commission (%)

Tables [1] and [2] illustrate the producer's accuracy and user's accuracy for each class.

Table [1] Illustrate Accuracy Assessment of the (Planet Labs) Image Taken in 2016

Classified Data	Urban	Building	Road	Route	Vegetation	Grass	Water	Sand	Bare soil	Row Total	user's accuracy
urban	410	11	61	0	53	11	0	0	14	560	0.73
building	3	1286	0	118	0	0	0	88	307	1802	0.71

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road	53	0	2237	0	0	0	0	0	0	2290	0.97
route	0	5	0	11013	0	0	0	5	21466	32489	0.33
vegetation	9	0	0	0	2235	3	0	0	0	2247	0.99
grass	4	0	0	0	23	568	0	0	0	595	1.0
water	0	0	0	0	0	0	150	0	0	150	1.0
sand	0	11	0	38	0	0	0	17963	215	18227	0.99
bare soil	0	15	0	1422	0	0	0	182	51462	53081	0.96
Column Total	479	1328	2298	12591	2311	582	150	18238	73464	111441	
producer's accuracy	0.85	0.96	0.97	0.87	0.96	0.97	1.0	0.98	0.70		

Overall Accuracy image taken in 2016 = 0.783

Table [2] Illustrate Accuracy Assessment of the (Planet Labs) Image Taken in 2017

Classified Data	Urban	Building	Road	Route	Vegetation	Grass	Water	Sand	Bare soil	Row Total	User's Accuracy
urban	938	636	157	14	217	614	1	2040	30	4647	0.2
building	74	5693	0	157	41	107	0	1228	7503	14803	0.38
road	11	0	5620	0	14	178	0	0	0	5823	0.96
route	0	354	0	5340	12	0	0	222	11214	17142	0.31
vegetation	2	10	0	0	6684	33	10	0	36	6775	0.98
grass	12	34	89	0	7	8622	0	0	12	8776	0.98
water	2	93	0	0	75	0	74	0	0	244	0.3
sand	69	190	0	147	2	353	0	118506	13783	133050	0.89
bare soil	2	515	0	684	1	0	0	4869	412096	418167	0.98
Column Total	1110	7525	5866	6342	7053	9907	85	126865	444674	609427	
producer's accuracy	0.84	0.75	0.95	0.84	0.94	0.88	0.78	0.93	0.99		

Overall Accuracy image taken in 2017= 0.924

B. Chang Detection Analysis:

The LULC classification results are abstracted for the years 2016 and 2017 in Table 3. The changes occurred in three classes. For urban areas and roads, they increased by 1, 847, 790 sq. m (about 10.6 times the original) and 245,385 sq. m (about 2.5times the original) respectively. On the other hand, bare soil decreased by -2,093,175 sq. m (17.8%) The changes in bare soil in the time period is due to the changes of in population living areas in one year. These given data expressly state that the increase in urban and roads areas mostly resulted in from construction in the desert which means some bare soil areas were removed and converted to residential in that region.

Table [3] Change Detection Area Statistics for 2016 and 2017

			Area (Square Meters)		
	Urban	**Roads**	**Bare Soil**	**Row Total**	**Class Total**
Unclassified	0	0	0	0	0
urban	56124	0	1964385	2020509	2020509
roads	2052	0	243333	245385	245385
bare soil	114543	0	9528507	9643050	9643050
Class Total	172719	0	11736225	0	0
Class Changes	116595	0	2207718	0	0
Image Difference	1847790	245385	-2093175	0	0

Along with the increase in population, the area of new Capital Province was enlarged by the conversion of neighboring bare soil areas in to residential areas, because of the constructing pressure on Cairo region and its neighboring Capital Province area. The sand area which were converted in to residential areas changed the land nature and opened those places for housing shown in Figure5.

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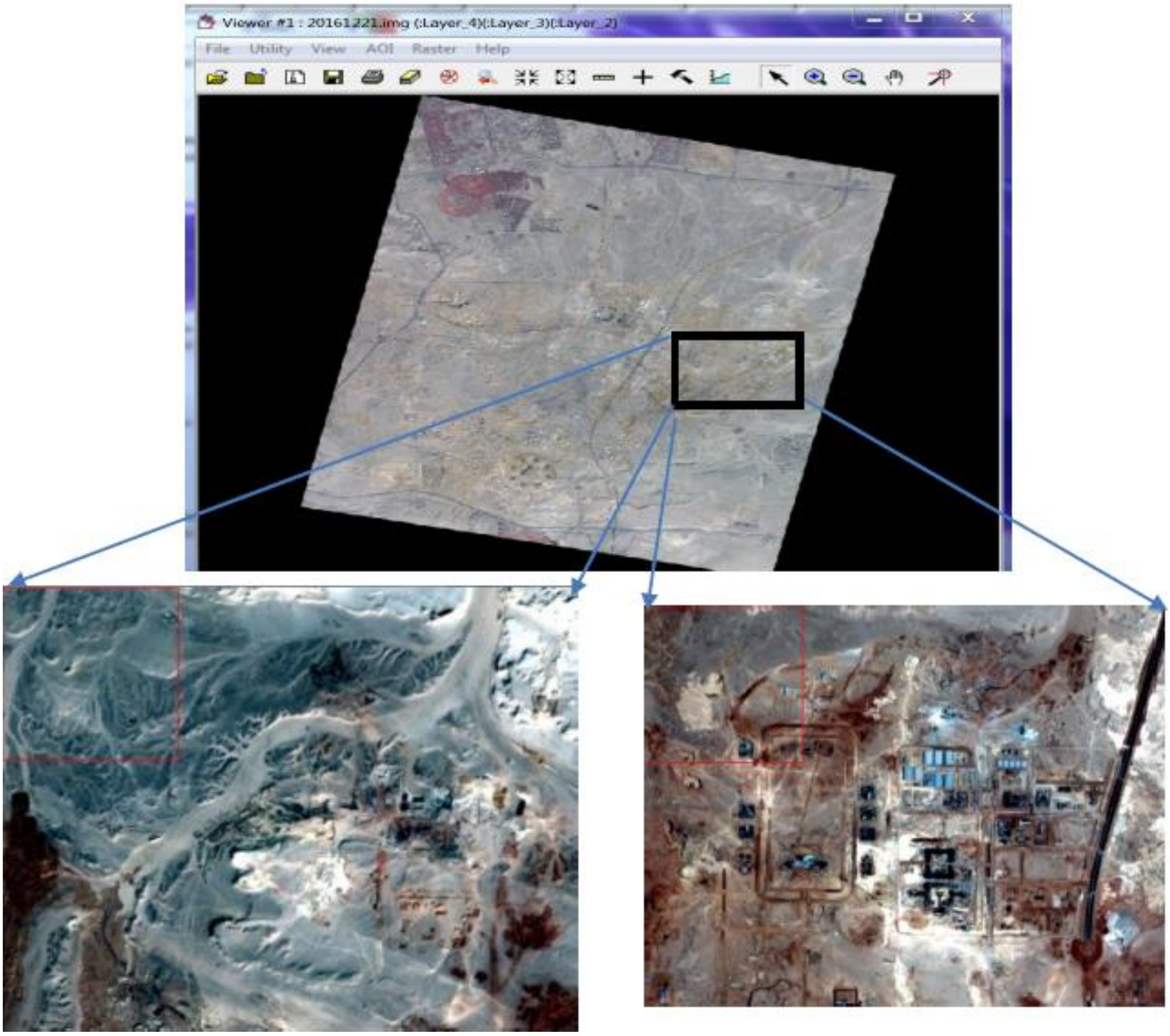

Figure (5) Illustrate Change Detection Planet Labs Images Left 2016 and the Right 2017

V. CONCLUSION

One of the most important uses of remote sensing is the production of Land Cover and Land Use maps. Land Use: refers to the purpose the land surveys: like the wildlife habitat, recreation, urban development, agriculture, and most areas affect by human activity. Land Cover: refers to the surface cover whether is water, urban development, bare soil, vegetation, or other. Identifying, delineating and mapping land cover are important for global observation studies, resource direct, and planning activities. Detecting and analyzing Land Cover and Land Use changes by using remote sensing satellites can be done through a process commonly called 'change detection'. This paper aims to investigate the changes occurred in new Capital Province between year 2016 and 2017 using remote sensing technique. The main change observed for that period was that the Urban area was increased approximately by1,847,790 sq. m (about 10.6 times the original) and roads area by245,385 sq. m (about 2.5times the original) while the decrease in bare soil areas was by -2,093,175 sq. m (17.8%). This occurred du to development operation. There is relatively fast rate of development in the new capital that may encourage and attract investors to invest in this promising area.

There were many researchers in the field of remote sensing are facing some difficulties in determining LULC due to some considerations about environmental characteristics in different remote sensing systems that must be satisfied. These include registration, geometric correction of multi-temporal images, atmospheric calibration and radiometric or normalization between them There is also need to consider the selection of the same spectral and spatial resolution images if possible as well as understanding the main steps of image processing to reduce errors, mistakes or uncertainties in each step. There for the advantage of this type of images (Planet Labs) can facilitated the above difficulties with reasonable spatial and spectral resolution of
(Nano satellite / Planet Labs) images:

- This product is prepared to be used for many purposes that demand imagery with a precise and accurate geolocation and cartographic projection. It has spatial resolution of 3meters.

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- The imagery is orthorectified and naturally colored imagery obtained from the operational mission-one constellation. A color curve can be applied that presents the imagery as natural color, (4bands).
- It has been processed to eliminate distortions caused by terrain and can be used for many applied analytic applications, cartographic mapping and visualization purposes.
- The imagery has orthorectified and radiometric corrections that applied to correct for using with any sensor artifacts and conversion to at-sensor radiance.
- The imagery has been processed to eliminate the perspective effect on the ground (not on tall buildings) return the geometry of a vertical shot.
- Nano satellite are designed to operate in harmony to continuously gather imagery of the sunlit part of the Earth's surface. At full constellation, Planet Labs' monitoring capability is expected to acquire approximately one complete global image dataset every day.
- It is recommended to employ these imageries for monitoring major projects.
- It will be helpful to follow up floods, hurricanes, storms and other environmental natural disasters

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