Using Remote Sensing Techniques and Historical Records to Estimate Agricultural Area

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ABSTRACT

Reliable and timely information on agricultural land area, crop production, and land use are of great importance to planners and policy makers for efficient agricultural development. This study aims to estimate of agricultural area using remote sensing data and historical records from Agricultural Statistics Bulletin (ASB) during the period from 2001 to 2013. The results showed that, there is variability between the data from remote sensing and historical records especially when in studying the separated regions. The estimated agricultural area by remote sensing data is higher than historical records data from ASB in all regions inside Nile Valley (lower, middle, and upper Egypt regions), while outside valley region found agricultural area in satellite data lower than observed in historical records data from ASB. The remote sensing technique discussed in this paper provides several improvements. It covers large geographical areas, the assessment is updated monthly, it is easily obtained, and inexpensive.

Keywords: *Egypt, GIS, Linear regression, MODIS / terra satellite data, Remote sensing.*

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1. INTRODUCTION

The importance of agriculture sector for achieving food security demands that it's planning, management, and monitoring is based on sound evidence. The availability and quality of agricultural statistics have been declining in the developing and underdeveloped countries. Some of these countries even lack the capacity to produce a minimum set of data as evidenced by the poor response rates to Food and Agriculture Organization of the United Nations (FAO) questionnaires [1]. The possible links between poverty and crop yields, which depend upon a variety of factors such as cultivation practices, availability of irrigation and access to resources to buy agricultural inputs for adoption of new technology, cannot be fully understood without reliable estimates of crop area and yields [2]. The traditional methods (e.g. field surveys, literature reviews, map interpretation and collateral and ancillary data analysis) very important, however, are not effective to include all areas of vegetation covers because they are time consuming, date lagged and often too expensive, in addition to probability of human error. Since the introduction of objective method for estimation of crop statistics, steps have been taken from time to time for improvement of agricultural statistics in terms of coverage, scope, accuracy, standardisation and coordination [3]. The technology of remote sensing offers a practical and economical means to study vegetation cover changes, especially over large areas [4, 5]. The applications of information technology systems have been widely used and documented. There are many studies using remote sensing data for improving the estimates obtained from area sampling. GPS have also allowed data collection more accurate and consistent than estimating locations or area using paper maps and distance measurement. GIS on the other hand, has important applications which include monitoring of crops, management of precision farming practices and area frame survey support [6]. Remote sensing can obtain surface information macroscopically, periodicity and economically. It has many advantages in agricultural monitoring and survey. Governments has long been paid much attention to survey crop acreage and yield using remote sensing, and great success has been achieved [7-9]. Comparing the remote sensing and field survey technique during 2008/2009 winter and 2009 summer seasons with the conventional statistical method used by Ministry of Agricultural and Land Reclamation (MALR). The cultivated area of wheat was about 2.9 million feddans (4200 m^2) in 2008 depending on MALR statistics, while the area of wheat in the same year according to GIS and field survey was about 2.5 million feddans. There was about 13% difference between the two concerned methods (GIS + field survey) and MALR's conventional statistical method. However, the cultivated barley area in 2008 winter season was 148 thousand feddans according to GIS + field survey data, whilst the statistical data was 181 thousand feddans. The GIS + field survey data showed that the area of cotton were decreased sharply in the season of 2009 to 250 thousand feddans compared to 284 thousand feddans with the MALR's statistical method [10].

Cropland mapping through remote sensing could complement official statistics, generating annual cropland maps along with planted area estimates. The use of remote sensing for mapping land cover is well established in the literature, be it to evaluate natural vegetation cover, forest degradation and deforestation, cropland expansion, or land cover change [11-17].

The objective of the present study is to estimate agricultural area in Egypt using RS techniques and historical records.

2. MATERIALS AND METHODS

2.1. Dataset and Tools

Agricultural statistics data

Total of agricultural area for all governorates in Egypt were obtained from Agricultural Statistics Bulletin (ASB) –MALR – Egypt for the years from 2001 to 2013.

Remote sensing data

Total of agricultural area for all governorates in Egypt were obtained from the Normalized Difference Vegetation Index **NDVI**, 16 - day product (MOD13A1; 500 m; Version 5) which has been derived from Moderate Resolution Imaging Spector-radiometer (MODIS) instrument on the Terra satellite for the years from 2001 up to 2013.

Arc-GIS, ERDAS Imagine which is designed to handle remote sensing visualisation, manipulation and analysis of aerial and satellite images as well as geographic data records, and Microsoft excel are used in data processing, analysis and calculating the required area.

2.2. Methodological Approach

Collecting the total of cultivated area for all governorates in Egypt from tables of ASB and routine download of MODIS Terra 500-m NDVI every 16 days for the study period has been done from http://reverb.echo.nasa.gov website. The data are downloaded covering all Egypt.

2.2.1. Pre- Processing Satellite Data

Pre-processing steps have been done by using the most powerful commercially available ERDAS Imagine software package. All downloaded data are imported using "IMPORT" package to convert it from hdf format to img format, combined into one file covering the entire study area for each date using "MOSAIC" package, stacked images and converted it to monthly NDVI data [18, 19].

2.2.2. Processing and Analysis Satellite Data

Arc-GIS software was used to process and analyse satellite data as the following: Firstly the re-projected NDVI images had classified to "Water", "No vegetation", and "Vegetation" as show in Figure (1) according to the value of NDVI which is referred in MODIS VI (MOD13) C5 User's Guide [20].

Secondly, the reclassified data has been re-projected on Egypt (WGS_1984_UTM_Zone_36N) and exported into geo-database to calculate the area of each category during the study period. The agriculture area has been estimated over all Egypt as total number, in depth separately on each geographic zone, and governorates of the most variability zone.

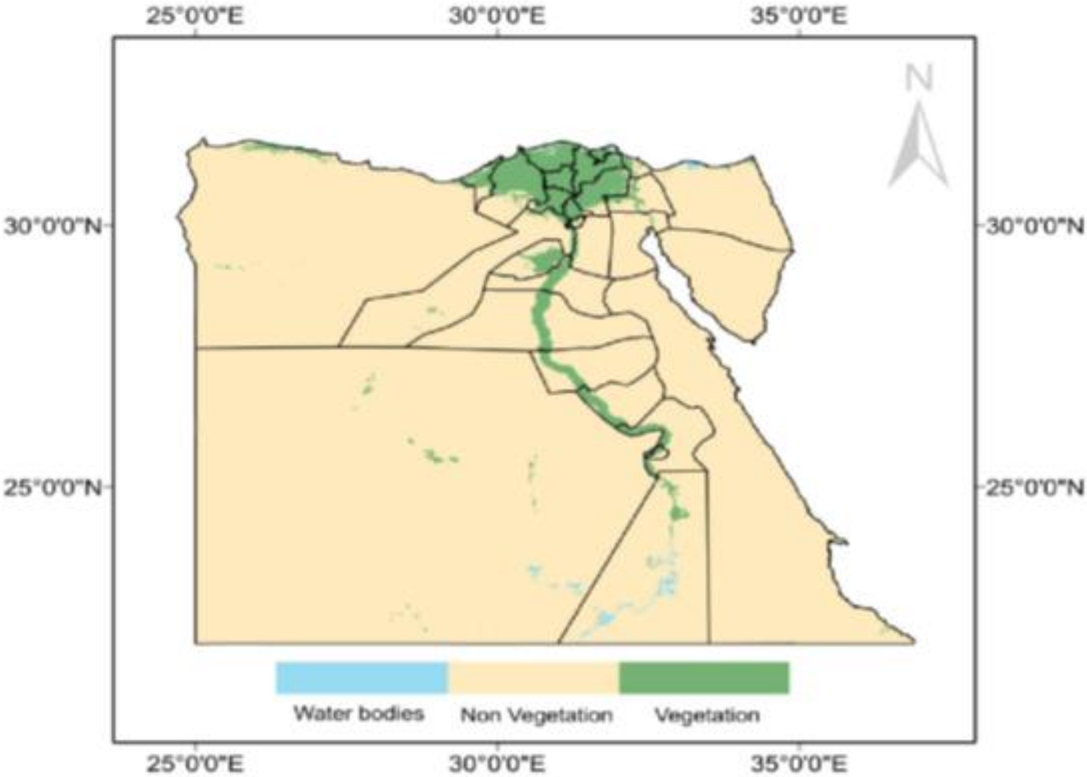


Figure-1. MODIS-Terra NDVI Classification.
Source: Agricultural Research Center, Central Laboratory for Agricultural Climate (CLAC)

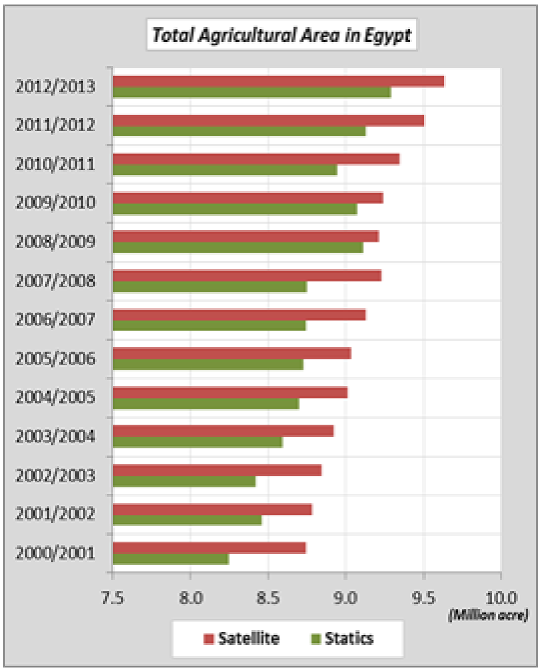


Figure-2. Total agricultural area in Egypt from satellite MODIS- NDVI data and records in ASB during the period from 2001 to 2013.
Source: Agricultural Research Center, Central Laboratory for Agricultural Climate (CLAC)

2.2.3. Descriptive Analysis

The study was conducted using secondary time series data of cultivated area in Egyptian regions from 2001 to 2013. Data were analysed in MINITAB software. The study relied on the use of descriptive analysis to characterise the problem, in addition to the quantitative analysis method using simple linear regression. Published and unpublished data were collected and used to achieve the study's objective.

3. RESULTS

Figure (2) shows the estimated total agricultural area in Egypt from satellite MODIS- NDVI data and that recorded in ASB during the period from 2000/2001 to 2012/2013 and it has been observed that, the satellite estimates agricultural area greater than ASB data, and the rate of increment was ranged from about 100.270 acres in 2008/2009 season to 495.320 acres in 2000/2001 season (by an average about 341.411 acres during the study period). Also the results indicated that the total agricultural area is in increasing trend during the study period in both data source.

The total agricultural area in Lower, Middle, Upper Egypt and outside valley regions have been also estimated separately to study if the increment in satellite data is caused by specific region, or it is a general observation in all regions.

The results found that, as shown in table (1), the estimated agricultural area by satellite data is higher than ASB data in all regions inside valley (Lower, Middle and Upper Egypt), while outside valley region, it was found that the agricultural area in satellite data lower than observed in ASB data, the equation 1 and 2 in table 2 showed that the total agricultural area inside valley and outside valley regions (satellite & ASB) had increased at annual statistical significant rate which reached 66.3 and 74.4 thousand acres respectively during the study period. The increment rate of inside valley region in satellite data has a wide variability range, and the highest range has been observed in Lower Egypt region, where its increment rate ranged from about 329,500 to 549,000 acres, the equation 3 and 4 in table 2 showed that the total agricultural area in Lower Egypt (satellite & ASB) had increased at annual statistical significant rate which reached 34.5 and 46.6 thousand acres respectively during the study period.

Middle Egypt, on the other hand, was the lowest range; where its increment rate ranged from about 53,300 to 138,800 acres, the equation 5 in table 2 showed that the total agricultural area in Middle Egypt (satellite) had increased at annual statistical significant rate which reached 4.5 thousand acres through the study period, whereas the equation 6 in table 2 showed that the total agricultural area in Middle Egypt (ASB) had increased at annual statistical- non significant rate during the period 2001- 2013.

Table-1. Total agricultural area in inside and outside valley regions in Egypt during the period from 2001- 2013

The agricultural area (Million acres)											
Lower Egypt			Middle Egypt			Upper Egypt			Outside valley		
Year	Satellite	ABS	Year	Satellite	ABS	Year	Satellite	ABS	Year	Satellite	ABS
2001	5.6	5.1	2001	1.5	1.4	2001	1.5	1.1	2001	0.1	0.6
2002	5.7	5.2	2002	1.5	1.5	2002	1.5	1.2	2002	0.1	0.6
2003	5.7	5.1	2003	1.5	1.5	2003	1.5	1.2	2003	0.1	0.6
2004	5.8	5.3	2004	1.5	1.5	2004	1.5	1.2	2004	0.1	0.6
2005	5.8	5.3	2005	1.5	1.5	2005	1.6	1.3	2005	0.1	0.6
2006	5.8	5.4	2006	1.5	1.5	2006	1.6	1.3	2006	0.1	0.6
2007	5.9	5.4	2007	1.6	1.5	2007	1.6	1.3	2007	0.1	0.6
2008	5.9	5.4	2008	1.6	1.5	2008	1.6	1.2	2008	0.1	0.6
2009	6.0	5.6	2009	1.5	1.5	2009	1.6	1.3	2009	0.1	0.7
2010	5.9	5.5	2010	1.5	1.4	2010	1.6	1.3	2010	0.2	0.8
2011	6.0	5.5	2011	1.6	1.5	2011	1.6	1.3	2011	0.2	0.6
2012	6.1	5.7	2012	1.6	1.5	2012	1.6	1.3	2012	0.2	0.7
2013	6.1	5.7	2013	1.6	1.5	2013	1.7	1.3	2013	0.3	0.8

Source: Calculated using the data taken from satellite MODIS- NDVI data and ASB, MALR

Table-2. General trend equations of agricultural area in inside and outside valley regions in Egypt during the period of 2001- 2013

Items	Equation	R^2	F	T	no
Egypt (in+ out Nile Delta) satellite	$\hat{Y}_i = 8328859 + 66337.8X_i$	0.97	357	18.9	**1**
Egypt (in+ out Nile Delta) ABS	$\hat{Y}_i = 7943394 + 74394.5\ X_i$	0.92	128.4	11.3	**2**
Lower Egypt satellite	$\hat{Y}_i = 5407024 + 34581.7\ X_i$	0.92	131	11.4	**3**
Lower Egypt ABS	$\hat{Y}_i = 4882963 + 46657.8\ X_i$	0.94	167.7	12.9	**4**
Middle Egypt satellite	$\hat{Y}_i = 1454412 + 4474.7X_i$	0.84	59.8	7.7	**5**
Middle Egypt ABS*	$\hat{Y}i = 1387344 + 2278Xi$	0.09	1.15	1.07	**6**
Upper Egypt satellite	$\hat{Y}_i = 1446709 + 11761X_i$	0.97	422	20.5	**7**
Upper Egypt ABS	$\hat{Y}_i = 1135645 + 11983X_i$	0.81	47.9	6.9	**8**
Out valley Egypt satellite	$\hat{Y}_i = 20578 + 15495X_i$	0.81	49.9	7	**9**
Out valley Egypt ABS	$\hat{Y}_i = 537441 + 13475X_i$	0.58	15.5	3.9	**10**

* Non Significant

Where:

$\hat{Y}_i$ = the estimated value for the dependent variable in the year i.

X_i = reflect time variable in the year i.

i = 1, 2, 3……13

R^2 = Determination coefficient.

F= F- Test, a statistical test in which the test statistic is based on the F-distribution under the null hypothesis.

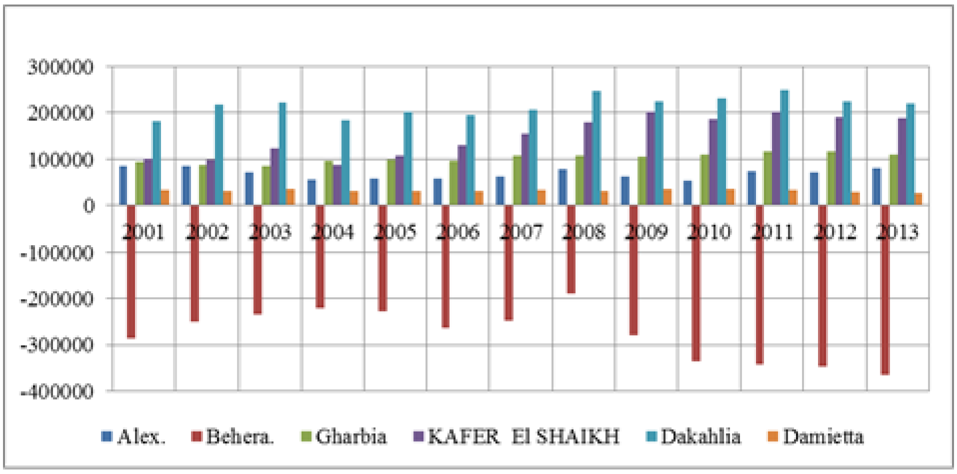
T = T- Test, test on individual regression coefficients

Source: Calculated using the data taken from table 1.

Moving to the Upper Egypt, the increment rate ranged between 267,000 and 371,000 acres, the equation 7 and 8 in table 2 showed that the total agricultural area in Upper Egypt (satellite & ASB) had increased at annual statistical significant rate reached 11.7 and 11.9 thousand acres respectively during the study period.

Also the increment rate of outside valley region in ASB data is a wider range than that observed in satellite data of any region of the inside valley, where its increment rate has been ranged from about 435,500 to 606,500 acres in ASB data, the equation 9 and 10 in table 2 showed that the total agricultural area in outside valley (satellite & ABS) had increased at annual statistical significant rate which reached 15.4 and 13.4 thousand acres respectively during the study period.

The high difference which is observed between agricultural area in Lower Egypt and outside valley regions data of satellite and ASB makes the study enter deeply into this regions by comparing their governorates data of satellite and ASB sources with each other to answer on the question "Whether the increment/ decrement in satellite data is caused by specific region or it is a general observation in all regions?". Estimating the agricultural area in Lower Egypt governorates indicated that the MODIS-NDVI data was not always greater than the ASB data as found in the total region result, where it was less than ASB records in Behera, Ismailia, Cairo, and Suez governorates as observed in figure (3) which shows the difference between the estimated agricultural area from MODIS and ASB records during the study period in this region, while estimating the agricultural area in outside valley governorates as shown in table (3) indicated that the MODIS-NDVI area was always lower than that recorded in ASB, and the decrement rate ranged from 530 to 365,500 acres among the studied governorates.



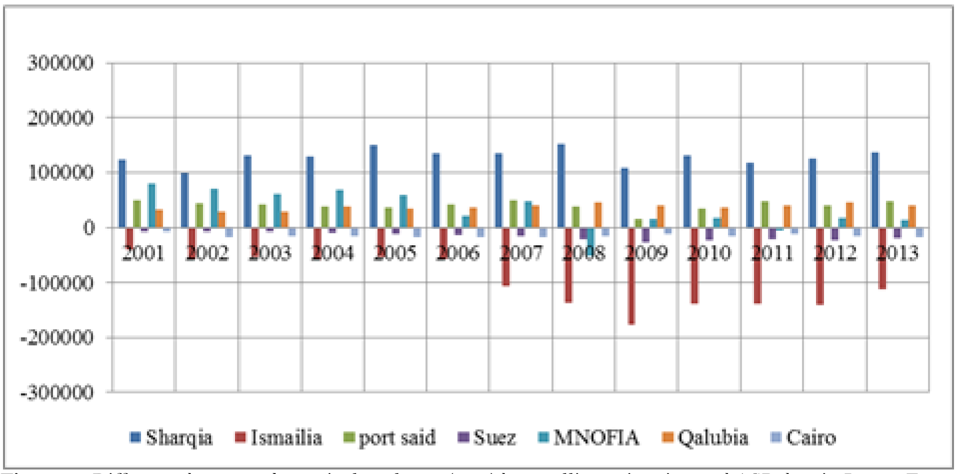


Figure-3. Difference between the agricultural area (acre) by satellite estimation and ASB data in Lower Egypt governorates [1]

Table-3. Difference between the agricultural area (acre) by satellite estimation and ASB data in outside valley governorates

South Sinai	North Sinai	Matruh	New Valley
-8450	-141039	-309303	-55803
-8299	-142614	-320067	-59403
-8453	-185747	-264211	-59732
-529	-179685	-265544	-77641
-10338	-171327	-283846	-83075
-10044	-122833	-299521	-67590
-10815	-148549	-294420	-67324
-11822	-158767	-264202	-80149
-13602	-190130	-290382	-96611
-14045	-189055	-365411	-20487
-14620	-127386	-197104	-79995
-18973	-131957	-254780	-45535
-26635	-154010	-267721	-30625

Figure (4) shows the variability between the agricultural areas from MODIS data and ASB data in Lower Egypt and outside valley governorates and it has been indicated that, Behera (in Lower Egypt) and Matruh (outside valley region) were the highest governorates representing agricultural area lower than that recorded in ASB data and their decrement rate were about 260,000 acres, while the lowest governorates were Cairo and South Sinai in

[1] Difference is equal satellite estimation minus ASB records

Lower Egypt and outside valley region respectively, and the decrement was about 12,000 acres. The highest governorates representing agricultural area higher than that recorded in ASB data were found in Lower Egypt region only, and observed in Dakahlia governorate where its increment rate was about 215,000 acres, while the lowest one was observed in Monufia, and its increment was about 30,000 acres.

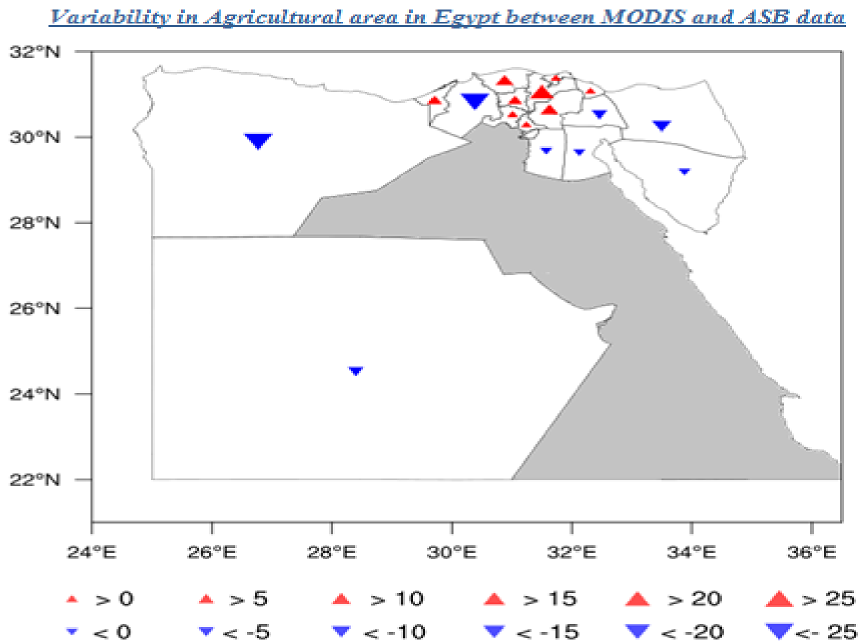


Figure-4. Average difference between agricultural areas (10000 acres) from MODIS data and ASB data in Lower Egypt and outside valley governorates during (2001-2013).

4. DISCUSSION

In recent times, much work has been done in the field of remote sensing for area estimation. Gallego [21] gave an overview of different ways to use satellite images for land cover area estimation. Carfagna and Gallego [22] discussed remote sensing as a valuable tool for agricultural statistics when area frames or multiple frames were used. Sahoo, et al. [23] developed an integrated approach based on remote sensing, GIS along with survey data for crop area estimation under paddy crop in the North-Eastern hilly regions of India. Sahoo, et al. [24] extended the integrated methodology in Jaintia Hills district of Meghalaya for estimation of acreage under paddy crop in India. Sahoo, et al. [25] developed methodology for generating cloud-free images, which can be used to provide reliable estimates of crop acreage and a methodology for estimating crop area directly from satellite images having cloud cover and shadows. Also Jinguji [26] introduced a new survey method known as the dot sampling method by combining a traditional attribute survey method with two current information technologies, namely Excel and Google Earth, to estimate rice planted area in Japan. Qinghan, et al. [27] using low resolution remote sensing data include the 16-day synthetic MODIS/NDVI data with spatial resolution of 250 m, produced by NASA (http://reverb.echo.nasa.gov/reverb, from January 1 to December 30th of 2013, with a total of 23 periods to estimate crop area in Kenya. Wardlow, et al. [28] and Ren, et al. [29] reported that the moderate resolution imaging spectroradiometer (MODIS) produces near-daily images with 250 m spatial resolution, suitable for identifying large crop fields in regions with widespread use of mechanised agriculture.

5. CONCLUSION

Generally, the results showed variability between the data from MODIS-NDVI and ASB specially when in studying the separated regions, and it was closest in middle Egypt, RS lower than that is recorded in ASB at parties of Lower Egypt and all the outside valley regions, and higher in heart of Lower Egypt regions. We realise that the current assessment of vegetation area relies on various methods of human manual estimating records, while such measurements can be quite accurate, they are difficult to obtain over a broad area, so they may fail to realise the changes in the pattern of vegetation across the parties of the landscapes and for this reason may RS data is higher in heart of Lower Egypt. Finally it's concluded from the study that, the estimations of remote sensing data should not be used as a direct and unique tool to estimate the agricultural area in Egypt, but, it's recommended to benefit from this technology and its application in agriculture after studying the certainty of it with the calibrated observations and determine the region that give highly confident results by this method, and exclude the low confident region results.

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