Monitoring the Developments of Agriculture Projects using Remote Sensing: Cases Study White Nile Sugar agriculture Project in White-Nile Sub-Basin

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Abstract: Integrated automated application Water Resources Agriculture Spatial Indicators System (WRASIS) using remote sensing was developed to monitor and assess the agriculture projects developments, time series of remotely sensed data (Agriculture Moderate Resolution Imaging Spectro-radiometer MODIS NDVI–Rain-Fall Estimate RFE 2.0). Case study of White Nile Sugar Project (WNSP) as agriculture project which is located at White Nile sub-basin in Sudanis analyzed using this developed system. The developed system includes GIS-based procedures for computing water and agriculture spatial indicators. The data used is product derived from satellite images at different spatial and temporal resolution. These products were extended automatically and stored with analysis results in spatial database, which could be used with easy manner to obtain and compute statistical data for any other study area. The developed system WRASIS could be also facilitate data analysis and presentation in the form of statistical charts and classification maps.

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1. Introduction

Monitoring and assessment are an integral tools for managing and accessing the efficiency and effectiveness of investments in agricultural projects. However, monitoring and evaluation of agriculture projects developments have been a significant challenge due several reasons: First of all the large scale extent and high rate of growth in agricultural productivity, second variety of agriculture and vegetation patterns (seasonal activities), also agriculture climatic variables (e.g., rainfall, evaporation, temperature), and physical landscape conditions (e.g., soil type).

The development strategies for the Nile basin countries with increase intensity of agricultural productivity through large extent planned agriculture projects, wherever the agriculture activities increase the need to obtain information. Derivinga monitoring systems in which this production takes place become a must to evaluate the progress of these projects.

Remote sensing can be significantly contributed to provide a timely and accurate picture of the agricultural sector, as it is very suitable for gathering information over large extent areas with high re-visit frequency. The use of remote sensing techniques became a powerful tool to process that data in conjunction with information collected using traditional field techniques which helps to overcome traditional data volume constraints. Remotely sensed data permits the preparation of base, terrain evaluation, land use classification and land degradation maps.

MODIS data products offer a magnificent opportunity for land-cover and land-use change studies due to their characteristics of moderate spatial resolution, frequent observations, enhanced spectral resolution and improved atmospheric calibration (Zhang et al., 2003). And being free to download to the end user. Moreover, the MODIS Land Science Team provides a suite of standard MODIS data products to users, including 16-day composited MODIS – product MOD 13Q1 (250 m resolution).

Most of the available satellite image analysis and GIS software packages do not have specified procedure setup that can handle time series analysis of images, and are not optimized for the needs of the agriculture monitoring activities (A. Jagadeesh Babu1, 2004).

The objective of this paper is to evaluate agriculture activities WNSP as agriculture project in White Nile sub-basin in Sudan using time-series MODIS NDVI (MOD13 -Q1) data. In addition to monitor the rainfall behavior. The classification map of different crop types was validated by both statistical data and fine resolution remote sensing data to evaluate the noise reduction and the classification method.

2. Study Area And Data

2.1. Study Area

The study area of WNSP is located at White Nile (WN) sub-basin in White Nile state; with about 50 km long and 28 km wide Figure (1), with an estimated area about 165.000 Feddan, bordered to the east side by the El Gezira irrigation scheme and to the west by Khartoum Rabak highway. The expected Capital investment of the WNS P project is about 1.1 billion USD as mentioned by Kenana Engineering Technical Services (KETS) the owner of WNSP.

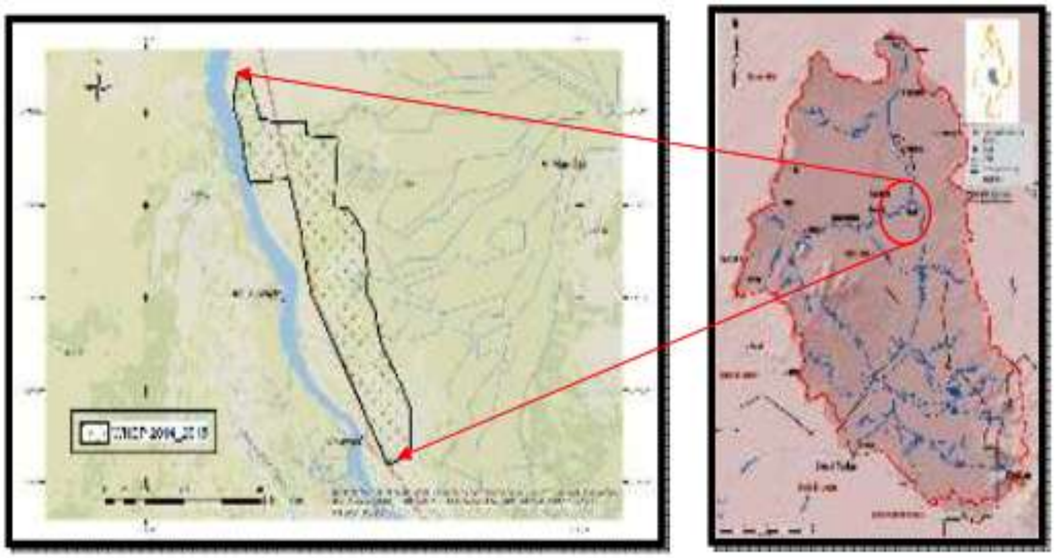

Figure (1) Location of study area (WNSP)

The WNSP consists of a sugar refinery in addition to ethanol plant, feed plant and a cane farm, covering a total area of 165,000 Feddan WNSP began commercial operation in 2012 and aims to produce 450,000 tons of sugar, 100,000 tons of fodder, 45 million litter of ethanol and 115 megawatt per year (KETS).

The planned area of WNSP project was designed to be 165.000 Feddan, this area was verified using Google Earth Pro (year 2012) the follow-up of the project boundaries in study years (2004-2015) showed that the boundary of the project area of the was extended to be about 240.000 feddans (year 2014).

The WNSP monitoring was executed for two time phases according to project boundaries as follows:

1. The first phase (2004-2013) with project area 165.000 Feddansas shown in Figure (2).
2. The second phase (2014-2015) with project area 240.000 Feddans as shown in Figure (3).

Figure (2) WNSP boundaries (2004-2013)

Figure (3) WNSP boundaries (2014-2015)

2.2. Data Description

2.2.1. Rain-Fall Estimate 2.0 (RFE 2.0)

RFE2.0 data description

Input data used for operational rainfall estimates are from four sources; (1) Daily GTS rain gauge data for up to 1000stations (2) AM SU microwave satellite precipitation estimates up to 4 times per day (3) SSM /I satellite rainfall estimates up to 4 times per day (4) GPI cloud-top IR temperature precipitation estimates on a half-hour basis. The three satellite estimates are first combined linearly using predetermined weighting coefficients, then are merged with station data to determine the final African rainfall. Daily binary and graphical output files are produced at approximately 3pm EST with a resolution of 0.1° and spatial extent from 40°S-40°N and 20°W-55°E. Additional data sets of 10 -day, monthly, and seasonal rainfall totals are created by accumulating daily data. Seven other daily binary output fields are produced using various combinations of input data, but these are not considered operational and will be discussed later. Resources needed for the algorithm to function include the four data source files (Nicholas S. Novella, 2013). Table (1) shows the data sources and used techniques and coverage extent for RFE2.0.

Table (1) RFE2.0 data sources and used techniques and coverage extent

Category	Used technique	Extent
Gauge	GPCC - atoll	Land – atoll
IR	GPI	40°South- 40° North
MW (Scattering)	Grody	Global land ocean
MW (Emission)	Chang	Global ocean
Model	ECMWF	Global land ocean

RFE2.0 Algorithm

Each input source of the four data sources mentioned before is considered to be incomplete in spatial coverage and contains non negligible random error and systematic bias. The method used to combine data improves these aspects significantly. The first step involved in the merging process is to reduce random error of the satellite precipitation estimates. This is done by linearly combining GPI, SSM/I, and AMSU data through a maximum m likelihood estimation method (Pingping Xie, 1996) Using the equation:

Where: Wi= weighting coefficient, F2 = random error

$$W_i = \frac{\sigma_i^{-2}}{\sum_{i=1}^{3} \sigma_i^{-2}}$$

The RFE2.0 data source is NOAA-CPC with daily time interval and 8 km spatial resolution (Nicholas S. Novella, 2013).

2.2.2. Normalized Difference Vegetation Index MODIS - (NDVI-13Q1)

The NDVI gives a measure of the vegetative cover over the land surface over wide areas. Dense vegetation shows up very strongly in the imagery, and areas with little or no vegetation are also clearly identified. NDVI also identifies water and ice.

Vegetation differs from other land surfaces because it tends to absorb strongly the red wavelengths of sunlight and reflect in the near-infrared wavelengths. National Oceanic and Atmospheric Administration (NOAA) satellites measure the intensity of the reflection from the Earth's surface in both these wavelength ranges. The NDVI is measure the difference in reflectance between these wavelength ranges. NDVI takes values between -1 and 1, with values 0.5 that indicating thedense of vegetation and values <0 indicating no vegetation. NDVI data may be used for characterizing land surface biophysical properties and processes, including primary production and land cover conversion.

MODIS data represent huge opportunity for land cover and land use. The classifications researches due to their properties are moderate spatial resolution, reliable time series frequent observations, and also the enhancement of their spectral resolution, improve atmospheric correction and calibration and finally being free to download for any user (Xiao X, 2003).

Global MOD13-Q1 data are provided every 16 days at 250m spatial resolution as a gridded product in the Sinusoidal projection.

- **(MOD-13Q1) Algorithm**

The NDVI algorithm operates per-pixel basis and requires multiple observations for the same spot (days) in order to generate a composited NDVI. Due to satellite orbit overlaps, multiple observations may exist for one day with maximum number four observations per day that could be collected. Theoretically this will result in a maximum of 64 observations over a 16-day period, however, due to the clouds presence and actual sensor spatial coverage, the observations number will range between (64-0) with decreasing observations from polar to equatorial latitudes. The MOD13-Q1 algorithm separates these observations according to their orbits providing a means to further filter the input pixels data (Ramon Solano, 2010).

- **(MOD-13Q1) data characteristics**

The NDVI MOD-13Q1 data is represented in HDF data set file format containing 12 different bands with different characteristics as shown in Table (2).

Table (2) MOD13-Q1 data characteristics

Science Data Set (250m -16 days)	Sub-dataset ID	Units	Data type	Valid Range	Scale factor
NDVI	0	NDVI	int16	-2000, 10000	0.0001
EVI	1	EVI	int16	-2000, 10000	0.0001
VI Quality detailed QA	2	Bits	uint16	0, 65534	NA
Red reflectance (Band 1)	3	Reflectance	int16	0, 10000	0.0001
NIR reflectance (Band 2)	4	Reflectance	int16	0, 10000	0.0001
Blue reflectance (Band 3)	5	Reflectance	int16	0, 10000	0.0001
MIR reflectance (Band 7)	6	Reflectance	int16	0, 10000	0.0001
View zenith angle	7	Degree	int16	-9000, 9000	0.01
Sun zenith angle	8	Degree	int16	-9000, 9000	0.01
Relative azimuth angle	9	Degree	int16	-3600, 3600	0.1
Composite day of the year	10	Day of year	int16	1, 366	NA
Pixel reliability summary QA	11	Rank	int8	0, 3	NA

3. Methodology

- The data analysis procedure was planned to be run first manually to manipulate project study area data through series of steps using ARC-GIS package and Erdas Imagine software. Themanual procedure was planned first as preliminary stage just for testing and verifying data and results for one year.
- Due to big sized data either for Rainfall RFE 2.0 or Vegetation NDVI which will be highly time consuming especially that the proposed assessment and monitoring procedure that was designed to deal with the variant study area boundaries and through several years of study.
- For all the previous mentioned reasons an automated system (Water Resources Agriculture Spatial Indicators System) WRASIS was developed after the previous stage to be applied on any study area and for several years of study in order to set analysis and monitoring system for these projects to illustrate the efficiency and effectiveness of investments in these agricultural projects.

WRASIS was designed to be run on three main phases: (1) Data-base preparation, 2) Model Calculation (data analysis), and finally (3) System Tools and Outputs as shown in Figure (4)

Each stage from the three stages mentioned above goes into workflow through the WRASIS. Figure (5) illustrates the system workflow.

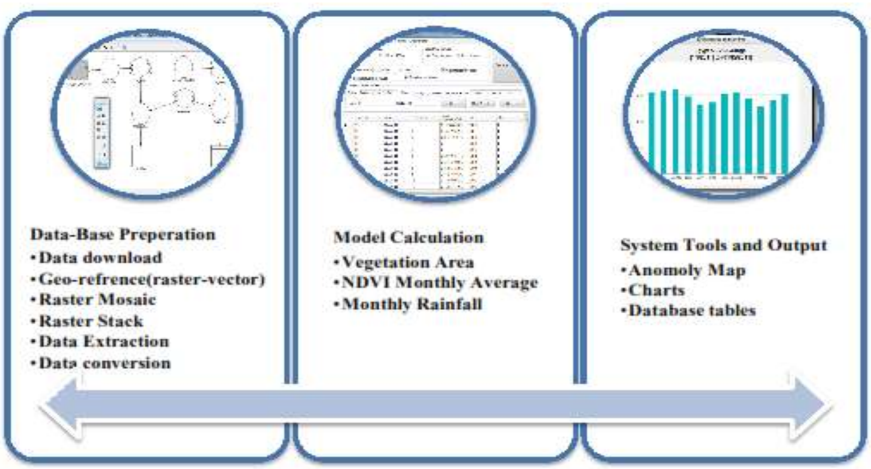

Figure (4) Main phases of WRASIS

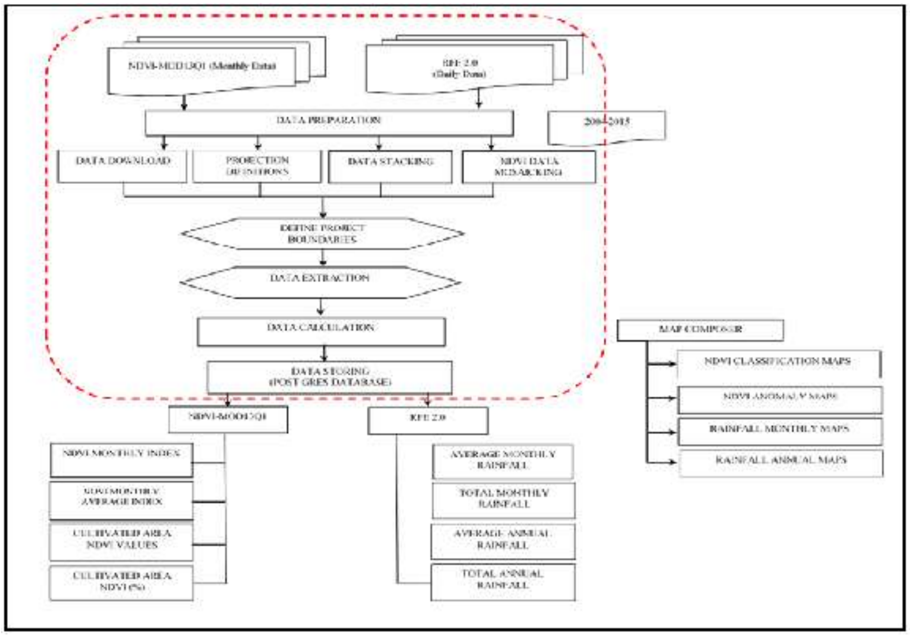

Figure 5: WRASIS schematic workflow

3.2. Data-Base Preparation:

This phase involve several processes by which the data would be ready for the analysis phase. This phase includes the following processes, these processes include:

3.2.1 Data Download:

This phase involve Download time series monthly agriculture data for NDVI (MOD-13Q1) from (NASA-USGS, 2004) website as well as the daily RFE 2.0 data from (USGS, 2001) website with for the study area for WNSP for the study years (2004-2015).

3.2.2 Data projection (or re-projection):

NDVI MOD13-Q1 data be re-projected from Sinusoidal projection to UTM Zone 36 projection and the RFE2.0 Data will be projected as well to the same projection system UTM Zone 36.

3.2.3. Data stack:

Data stacking is the process of creating a single raster dataset from multiple bands and can also create a raster dataset using only a subset of bands. Data stacking was applied on the RFE2.0 in order to convert daily data to monthly data rainfall data and also for NDVI-MOD-13Q1 order to convert the two images for each month to on image monthly data.

3.2.4. Data mosaic:

The process of combining or merging multiple images covering certain to manipulate single image. And since the NDVI MOD13-Q1 data is downloaded in tiles, then the mosaicking process was applied on the NDVI data that cover the WNSP project area.

3.2.5. Data Extraction:

Data extraction process define the cells of a satellite image that is correspond to the areas defined by a study area boundaries. Data extraction was applied on the RFE2.0 rainfall data and NDVI-13Q1.

3.2.6. Data analysis (Indicators calculations):

The WRASIS was adjusted to calculate the agriculture and rainfall indicators through the study area years for the boundary area of WNSP project and variant charts and graphs were driven as system outputs. These outputs are either basic indicators (include one indicator for one time step) or Advanced indicators (combination of more than one basic indicator Rainfall RFE2.0 or Agriculture NDVI (MOD13-Q1)

3.2.7. Data output (Indicators calculations):

Indicators were computed for the WNSP and on monthly basis for the study years (2004-2013) for the preliminary extended boundary of the project, and the outputs include tabular data and charts and classification maps.

3.2.8. NDVI-MOD13-Q1 Classification Procedure:

Using NDVI-MOD13-Q1 mapped the reflectance from chlorophyll and distinguished varying amounts of vegetation per pixel level. NVDVI uses the Red and Near-Infera Red bands to distinguish between vegetation and non-vegetation lands according to equation (1).

$$NDVI = (NIR - RED)/ (NIR + RED) \quad (1)$$

The calculated NDVI values is stored in NDVI-MOD13-Q1 in separate band (band 0) with scale factor (0.0001) as shown in equation (2). In this study The NDVI values were classified according to average monthly values ranging from (-1 to 1) where the cultivated area have NDVI values starting from 0.3 to 1

NDVI = (Band 0) *0.0001 (2)

Classification according to average monthly NDVI values and cumulative cultivated areas the WRASIS adapt classification and recognition of the WNSP area based on the NDVI.

4. Results and Discussion

WRASIS results show that through time series data representing NDVI values and corresponding rainfall values it could be define the growth profile and vegetation density (cultivated area) for study area WNSP. In addition, the results represent the effect of rainfall on the NDVI signal of crops, with a decrease in rainfall having a dipping effect on the NDVI and vice versa.

4.1. Rain-Fall (RFE2.0)

The rainy season for WNSP area begins in April and then begins to increase until it reaches its maximum value in July or August and then starts to decrease until October and is almost out of November till March then the cycle is repeated again from April. Figure (6) shows the total monthly rainfa ll (Mm3) for WNSP for the study years (2004-2015).

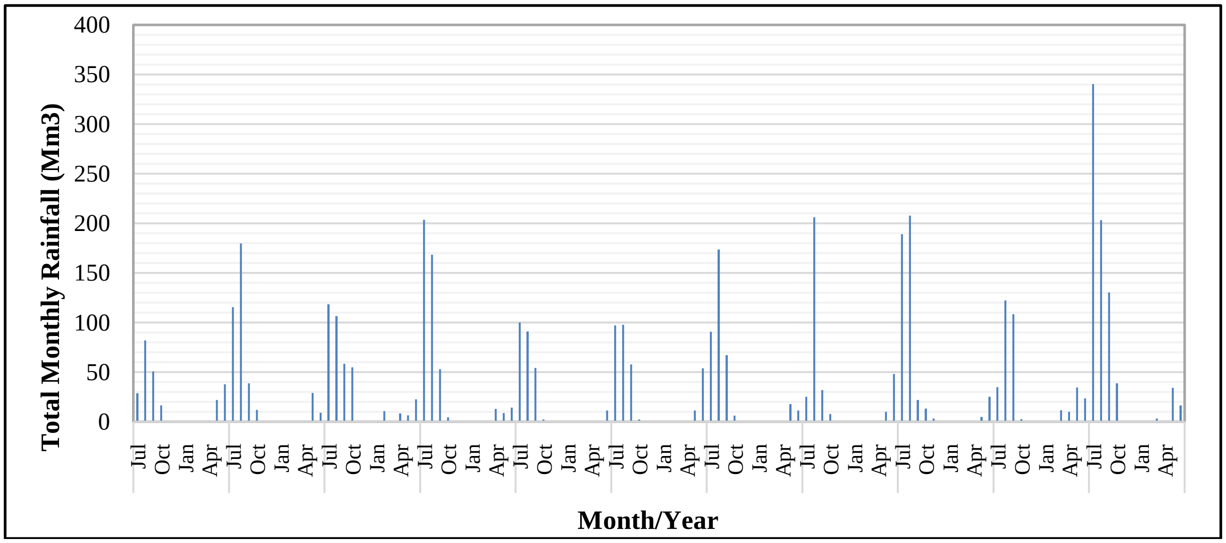

Figure (6) Total monthly rainfall for WNSP for the years (2004-2015)

Figure (7) shows the average of total monthly rainfall for WNSP study years (2004-2015), the Figure shows that the maximum value rainfall for the average monthly occurs in August with an amount of 148.9 million m3.

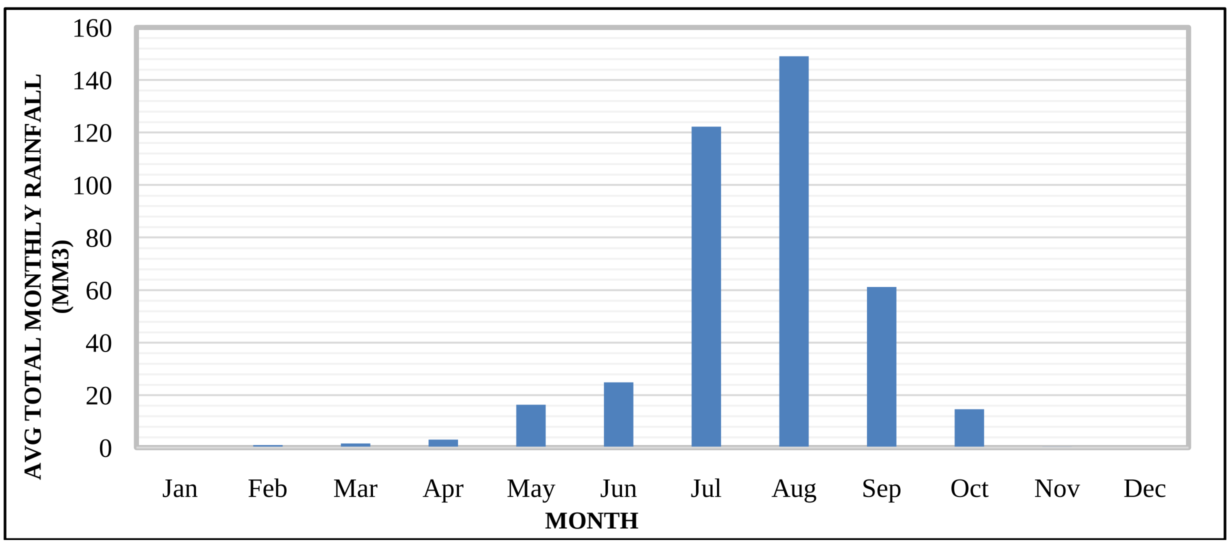

Figure (7) Average total monthly rainfall for WNSP for the years (2004-2015).

The average of the total annual rainfall for WNSP project during the study periodis estimated with 417.8million m3 while maximum value was in year 2014with total amount reached 793.28 million m3 and the lowest value in year 2009 with an amount reached 266.88 million m3. Figure (8) show the distribution of the total rainfall for the study years (2004-2015).

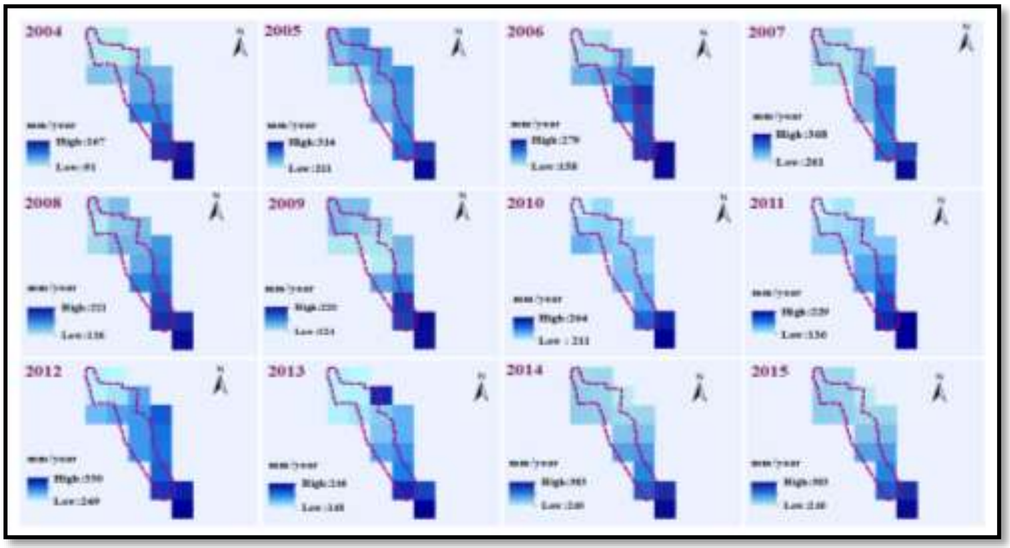

Figure (8) Total annual rainfall distribution for WNSP for the years (2004-2015)

4.2. NDVI (MOD 13-Q1)

Average monthly NDVI index value for WNSP area is presented as shown in Figure (9) for the study period,. The value of NDVI index ranges differ through study period.

The Figure also shows that the NDVI patterns of green vegetation for average monthly values for the study years ranges between (0.28-0.42) in January decreasing slightly till April to reach (0.26-0.32) however it increases gradually to reach the maximum value in September reaching (0.64-0.78).

The trend of vegetation intensity of WNSP project area is the same for along study years (2004-2015) but analyzing the pattern shows that the NDVI values increased in year 2015 for all months.

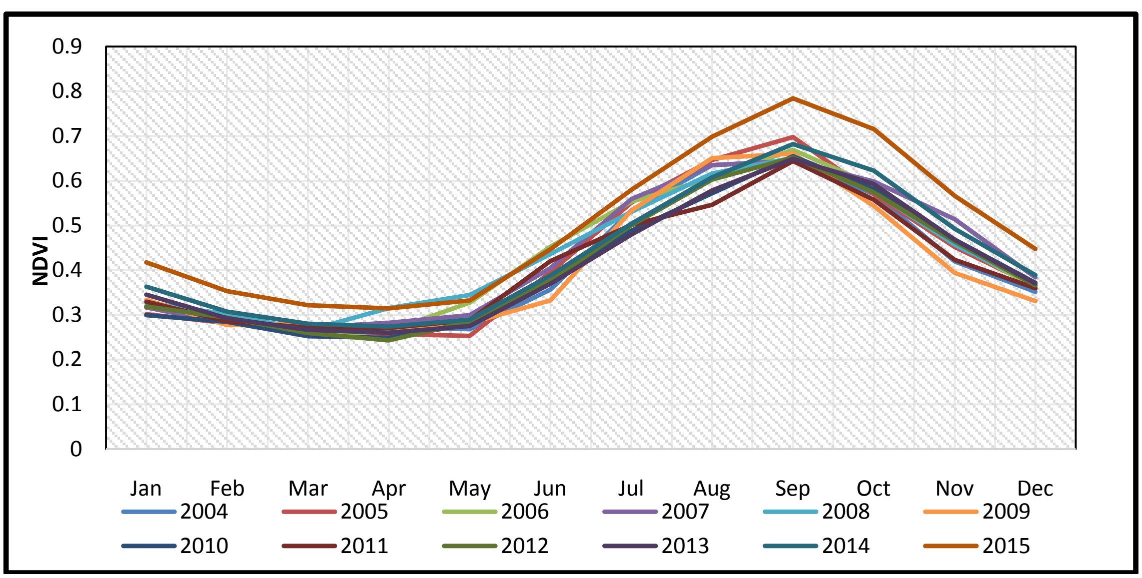

Figure (1) Average monthly NDVI values for WNSP (2004 -2015)

The percentage of the cultivated area of WNSP project presents in Figure (10). The connected line reflects the monthly average of the maximum cultivated area from (2004/2005) to (2014/2015), the columns represent the proportion of the cultivated area per month in (2014-2015) and the dotted line represents the monthly average of the minimum cultivated area from (2004/2005) to (2014/2015). The data shown in the Figure reflect that year 2014/2015 (where the cultivated area is about 40-80% over the months) is higher in cultivated areathan of all study years 2011 / 2102-2013 / 2014 (which is the percentage of cultivated area since the actual planting of the project (30-70%) as well as in the years (2004 / 2005-2010 / 2011) since the start of the project planning, which amounted to about (0-55%) the average in way in which we can conclude that the project cultivated area is increasing with time.

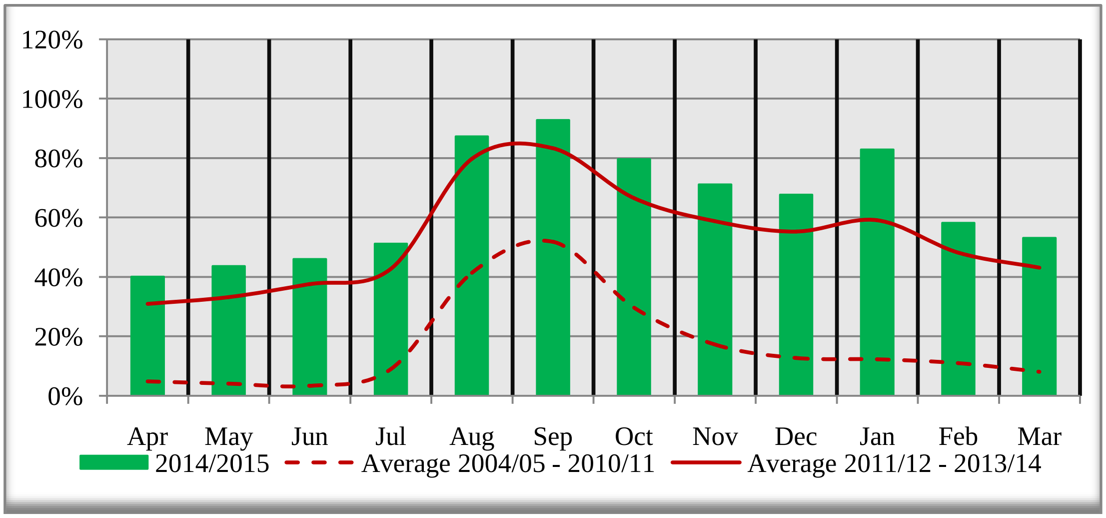

Figure (10) Average monthly NDVI values for WNSP (2004 -2015

The classification of monthly NDVI values for year 2015 (follow-up maps) as shown in Figure (11). The Figure also show that the NDVI patterns of green vegetation starting to increase from January to April reaching the maximum value in September then decreasing slightly till January.

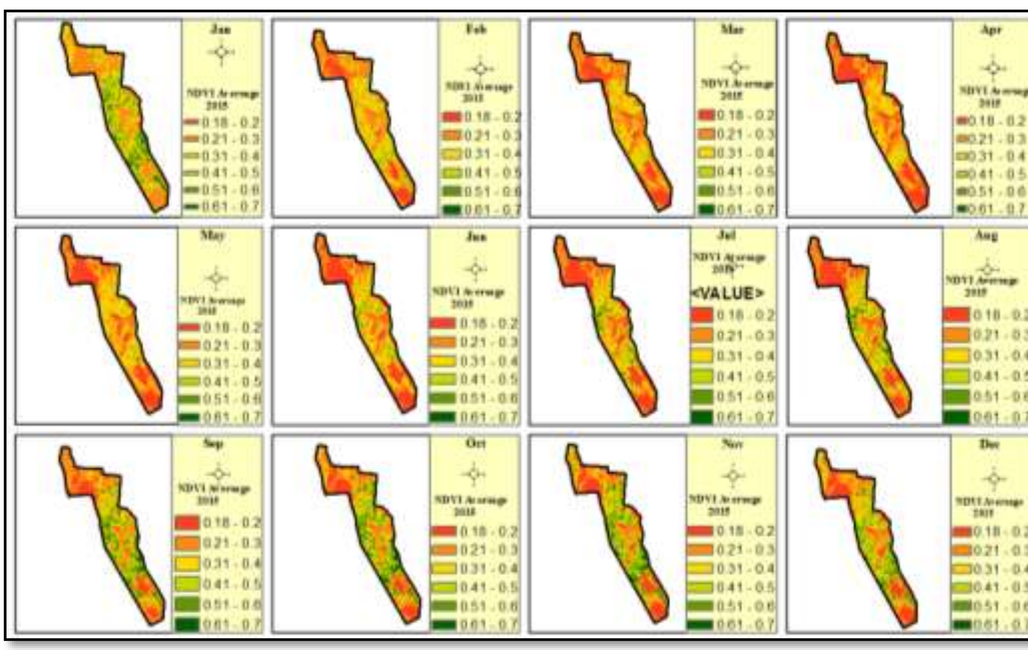

Figure (11) Classification of monthly NDVI for WNSP for year (2015)

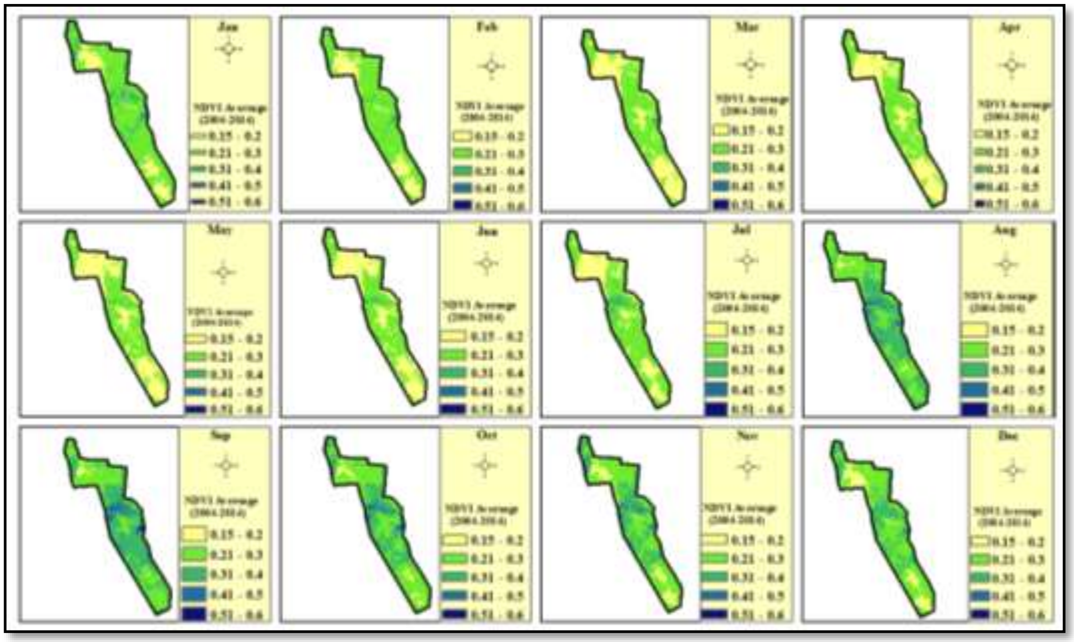

Figure (12) Classification of average monthly NDVI values for WNSP for years (2004-2014)

Figure (12) shows the classification of Average monthly NDVI values for years (2004-2014). The NDVI patterns of green vegetation starting the same as in the last year 2015.

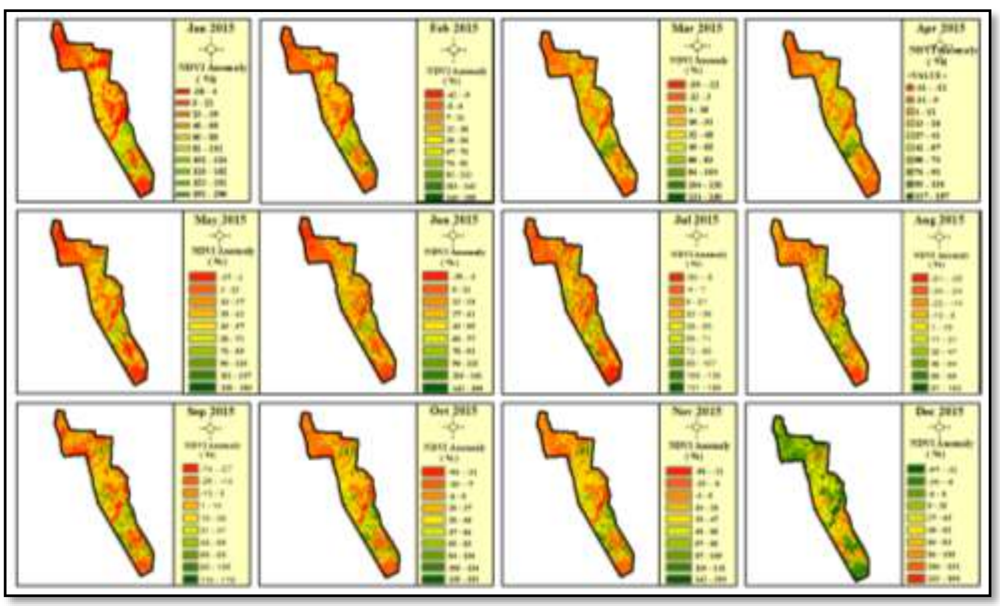

Figure (13) Classification of anomaly NDVI monthly values for WNSP for years (2004-2014)

Figure (13) represents the percentage of change in the value of vegetation cover in year 2015 from the average per unit of survey (250m x 250 m) in each month for the years (2004-2014).

The percentage of variability in vegetation density between the month of follow-up and the average of the same month in the years 2004/2005 to 2014/2015 is called anomaly maps. Anomaly maps positive values represent the height ratio of the vegetation index, either by increasing the density of the vegetation cover from the average or by cultivating new areas that these areas were not previously planted, while the negative values represent the decline in the value of the vegetation cover from the average or the cultivation of previous crops.

4.3. NDVI (MOD 13-Q1) with Rainfall (RFE2.0)

Figure (14) illustrates the development of WNSP monthly cultivated area with total monthly rainfall. rom 2010/2011 to 2014/2015, it could be noticed the effect of supplementary irrigation on the percentage and pattern of cultivated area, where the cultivated area is not less than 40% of the total area of the project, while reaching 100% in August and September.

By comparing the percentages of agricultural areas during the reporting period (October - November - December) with the average cultivated area during the years 2011/2012 - 2015/2016, the increase in the proportion of the area disturbed during the agricultural season and stability at a value of up to 70%.

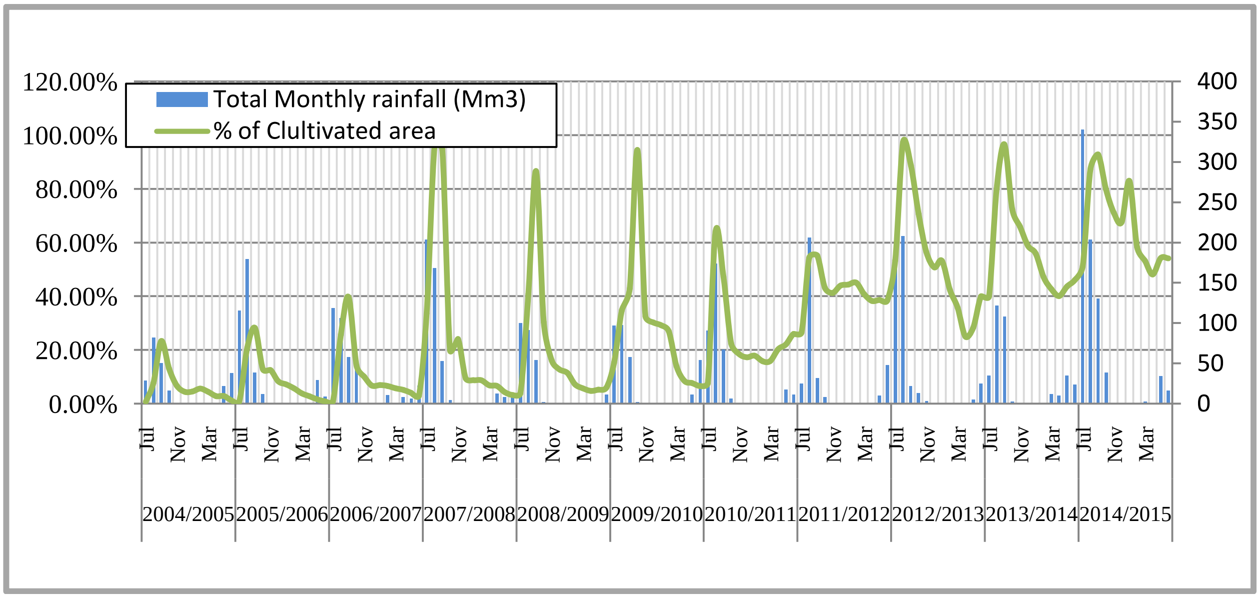

Figure (14) Development of WNSP Cultivated area with total monthly rainfall (2004/2005 - 2014/2015)

5. Conclusion and Recommendation

- WRASIS was developed to be applied on WNSP in Sudan (or any project study area) for several years of study in order to set analysis and monitoring system for these projects to illustrate the efficiency and effectiveness of investments in these agricultural projects using remotely sensed data.
- The results of WNSP show that the trend of vegetation intensity of the project area is the same for along study years (2004-2015) but analyzing the pattern shows that the NDVI values increased in year 2015 for all months.
- The density cultivated area of WNSP in the recent years of the study (2011/2012-2014/2015) compared to the early study years (2004/2005-2010/2011) indicted that the agriculture behavior of the WNSP changed from being completely relaying on rainfall season to use supplementary irrigation.
- Further satellite images (Land Sat. 7, Land Sat. 8, Sentinel 2, etc.) And satellite images products (The Tropical Rainfall Measuring Mission TRMM, The Africa Rainfall Climatology ARC) with higher resolution could be added to the WRASIS in order to enhance results.
- Further advanced analysis methods could be included in the WRASIS such as defining crop patterns and adding crops spectral signatures into software libraries to identify crop types and then relate these to the projects in order to produce crop maps.

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