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# Monitering And Yield Estimation of Sugarcane Using Remote Sensing and GIS

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***ABSTRACT:*** *Earlier estimation of sugarcane yield is a main requirement for sugar production. Many operations of sugar production are based on yield estimation, such as planning for the season management including manpower, transportation, storage, marketing ...etc. In this study NDVI had been taken as means of the estimation of sugarcane yield in White Nile sugar factory. Therefore, the objectives of this study is to: (1) determine the ability of an in-season estimation of NDVI to predict sugarcane yield potential; and (2) determine optimum timing for predicting sugarcane in-season yield potential. The actual produced sugar quantities, for the same area and the same period of time, in the previous seasons had been compared with the NDVI results. The study, which had been applied in two successive seasons, had shown more effectiveness than the traditional direct field estimation. Due to the wide areas of the sugarcane fields (50-100) hectares, the height of the plants (1.5-2.00) meters, high cost of transportation together with the limitations of human eye limitations, direct ground field estimation has low precision and feasibility. The precision of estimation of the traditional method was 50% while of NDVI was 90%. In conclusion Geographic Information Systems (GIS), coupled with the remote sensing has proven to be successful in estimating crop yield using the NDVI. This estimation will help in the management of the season and decision for sugarcane farms right on time.*

***Keywords :*** *GIS, Remote Sensing, Sugarcane, Yield Estimation, (10 Italic)*

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## I. INTRODUCTION

Sugarcane (Saccharum officinarum) is a semi-perennial crop, which can be harvested annually up to five years without replanting; the first harvested crop is termed plant cane and stubble cane for each successive harvest which named as ratoon cycles. (R1-R4)Sugarcane growth season is varying from only nine months to more than 12 months in some places. The sugarcane growth season at Sudan consists of planting in October, and harvested during the winter months (Nov-Mach). During this growth season the sugarcane crop undergoes three distinct growth stages consisting of emergence (crop establishment) at first 3 months, tailoring, (vegetative growth) at next 6 months, and maturation at last 3 months prior to replanting. In recent decades, significant yield increases have been attributed to the addition of N fertilizer beyond any other agricultural input [2]. Nitrogen (N) is one of the most important crop growth factors, influencing both productivity and crop quality. Therefore, utilizing methods that can more accurately determine N rate recommendations is essential to maintain agronomic productivity [3].Above long growth cycles combined with the shorter growth period makes accurate N rate recommendations that optimize yields and minimize environmental impacts difficult. Worldwide N recommendations for sugarcane production are dependent on climate, crop age, length of growth cycle, plant characteristics, and soil characteristics [3]. However, currently for Sudan sugarcane projects N rate recommendations are dependent on crop cycle , either plant cane or stubble cane, and soil type, generalized as light or heavy textured soils and crop N demand [1]. These N rate recommendations are applied in a split application (half dose at the beginning of planting process) then another half at Unbarring period. Historically, soil sampling has been a technique utilized for determining N rate recommendations. Therefore, crop yield monitoring has become an important aspect of many N management schemes. A common method of incorporating crop yield into N rate recommendations is using yield goals specifically in crop production [5]. A yield goal is defined as yield per unit area we might expect. Many plant indices based on canopy spectral reflectance have shown the ability to accurately estimate crop physiological properties, including plant biomass and crop yield [10–12]. The NDVI value, which is a vegetative index that compares reflectance at the red and near infrared region, has also shown the ability to determine yield potential (YP) [13–15]. Yield potential differs from yield goal because it is a function of the environmental conditions of the current growing season and is defined as achievable yield with no additional N fertilizer [11]. Teal [14] reported that there was a strong relationship between NDVI and Crop yield in Cron using an exponential model. Raun [13] and Lukina [16] showed this relationship was improved when NDVI readings were adjusted using growing degree days (GDD), where NDVI was divided by GDD accumulated from planting to sensing, to create an in-season estimate of yield (INSEY). Raun [13].Several studies have suggested that growth stage, or time of sensing, were important in the ability to predict yield [13,14,16]. Raun [13] and Lukina.Several reports have shown that an estimate of yield alone is poorly correlated with optimum N rate [17]. However, Raun [11] showed the potential of utilizing a predicted YP as a component of N management scheme. This technology has shown the ability to improve N management decisions in many cropping systems across USA, Canada, Mexico, and other countries [18–20]. These reports suggest the potential of using yield prediction as an integral part of an N management decision tool to improve recommendations in crop production. Previous reports have documented the ability of NDVI to estimate sugarcane yield potential, however, most of these reports have been focused on satellite based platforms or passive sensors with few demonstrating the ability of an active ground-based remote sensor to estimate sugarcane yield [21–25]. Therefore, the objectives of this study were to: (1) determine the ability of an in-season estimation of NDVI to predict sugarcane yield potential; and (2) determine optimum timing for predicting sugarcane in-season yield potential.

## II. MATERIALS AND METHODS

### 2.1 **Study Area**

The study had been conducted in the White Nile sugar project which is in Sudan in the White Nile state near Aldoium city, It is about 180 Kilometre southern The Capital (Khartoum)and between the (1580650,428010 15) and (19192 461954) Coordinate system WGS_UTM_ZONE 36N It occupies a space (165000) Fadden (683000) Hectare.

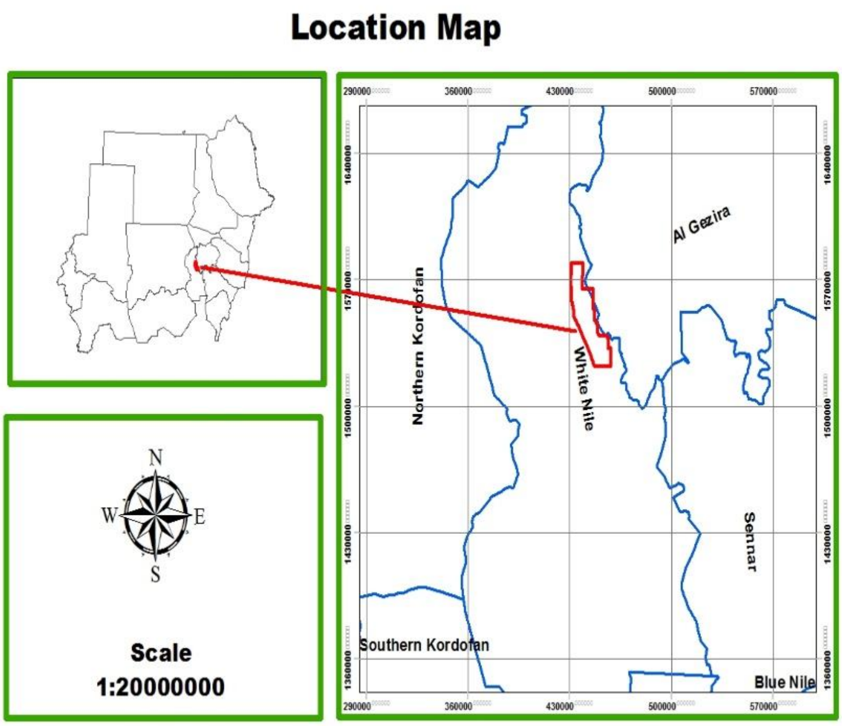


**FIG. 1:** The Study Area

## 2.2 Sources of Data

The green areas were obtained from the map of the project 2014, the tables of production for the previous years, and land sat 8 band 4 and 5.

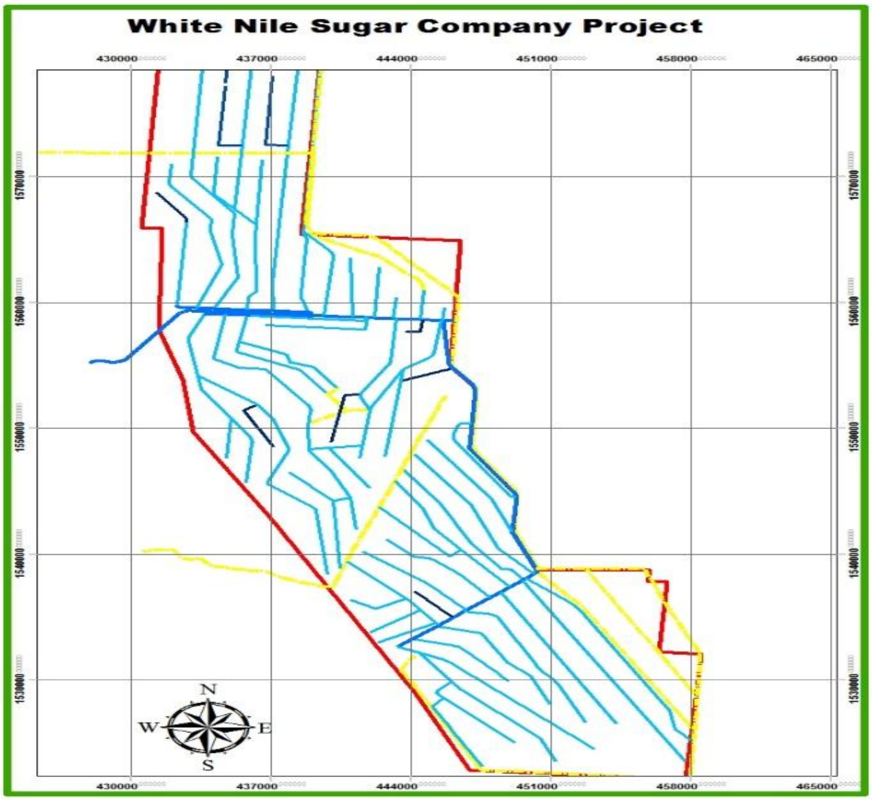


**Fig. 2:** White Nile Sugar Company Project

**Table 1: Season 2014 – 2015**

| Canal | Field | Crop Cycle | Varity | Area for Harvesting | Area harvested | Ton | TCF |
|---|---|---|---|---|---|---|---|
| P4SS | 13 | R2 | Co6806 | 41.3 | 41.2 | 1406 | 34.14 |
| P2SS | 15 | R1 | Co6806 | 30.8 | 30.8 | 1402 | 45.57 |
| P2SS | 16 | R1 | Co6806 | 36.7 | 36.7 | 1540 | 41.98 |
| P2SS | 17 | R1 | Co6806 | 35.6 | 35.6 | 1638 | 46.05 |
| P1SS | 7 | R1 | Co6806 | 25.2 | 25.2 | 1027 | 40.8 |
| P1SS | 8 | R1 | Co6806 | 44.7 | 44.7 | 1939 | 43.41 |

**Table 2:** Season 2015 – 2016

| Canal | Field | Crop Cycle | Varity | Area for Harvesting | Area harvested | Ton | TCF |
|---|---|---|---|---|---|---|---|
| Canal 9 | 1 | R6 | Co6806 | 110 | 68 | 2255.9 | 33.18 |
| P17AS | 3 | R2 | Mix | 10 | 10 | 327.8 | 32.78 |
| P20AS | 27A | R1 | Mix | 6 | 6 | 225.6 | 37.60 |
| Canal 2S | 15 | R2 | Co6806 | 30.7723 | 30.7723 | 1042.2 | 33.87 |
| Canal 2S | 16 | R2 | Co6806 | 36.6723 | 36.6723 | 1222.9 | 33.35 |
| P6WSS | 2 | P.C | TUC | 26.5 | 26.5 | 894.25 | 33.75 |

**Table 3:** Season 2016 – 2017

| Canal | Field | Crop Cycle | Varity | Area for Harvesting | Area harvested | Ton | TCF |
|---|---|---|---|---|---|---|---|
| Canal MJ3 | Field 13 | R1 | co6806 | 47 | 47 | 1425.9 | 30.34 |
| Canal MJ3 | Field 12 | R1 | TUC | 46 | 46 | 2601.82 | 56.56 |
| Canal MJ3 | Field 11 | R1 | TUC | 64 | 64 | 3359.36 | 52.49 |
| Canal MJ3 | Field 10 | R1 | 24 TUC / 19 R579 | 43 | 43 | 2134.53 | 49.64 |
| Canal MJ3 | Field 9 | R1 | 13 TUC /28.5 R579 | 41.5 | 41.5 | 1752.64 | 42.23 |
| Canal 11S | Field 8 | R2 | Co6806 | 128.772 | 128.772 | 4338.07 | 33.69 |

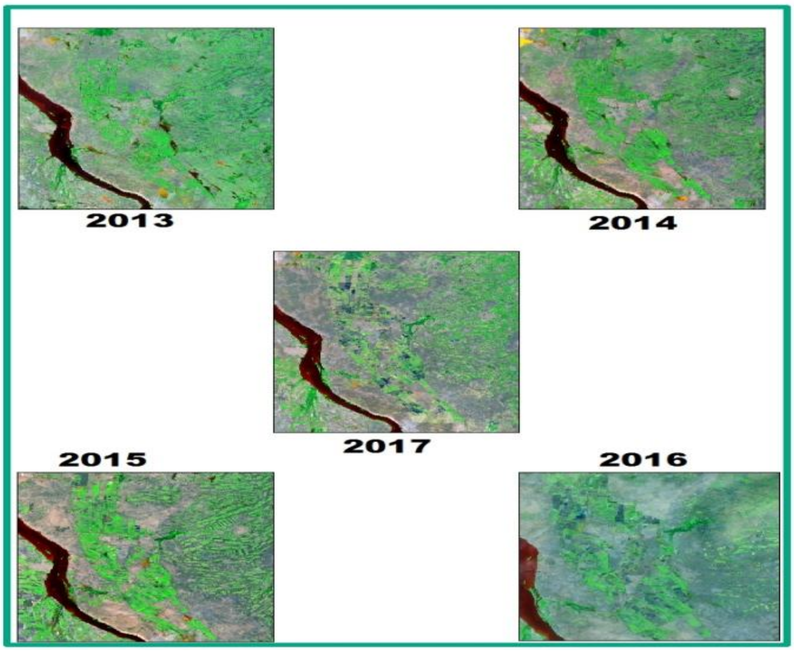


**Fig. 3**: Image of the area from Land Sat 8

### 3.3 Data Processing

The land sat 8 band 4 and 5 were used to give the NDVI using the GIS, the maps of the NDVI were converted into quantitative data using the global mapper which convert it into excel sheet.

the NDVI was calculated at different periods during the season starting from the planting till the cultivation in order to determine the best time for the estimation of the quantity of the harvest.

the produced quantity in the previous seasons were compared with the NDVI for the same period of time. for the farms that are planted for the first time the comparison was made with farms that has the same type of soil and the ratoon, when we used the NDVI of any farm initially regardless of the type of soil and the ratoon the prediction was less precise.

The following equation was used to estimate the production:

$$P = LP * \frac{NDVI}{NDVIp}$$

**Equation 1: The equation used to calculate productivity**

Where p is the estimated production.
LP: the production in the previous season
NDVI: the indicator of the current season
NDVIp: the indicator of the previous season for the same farm

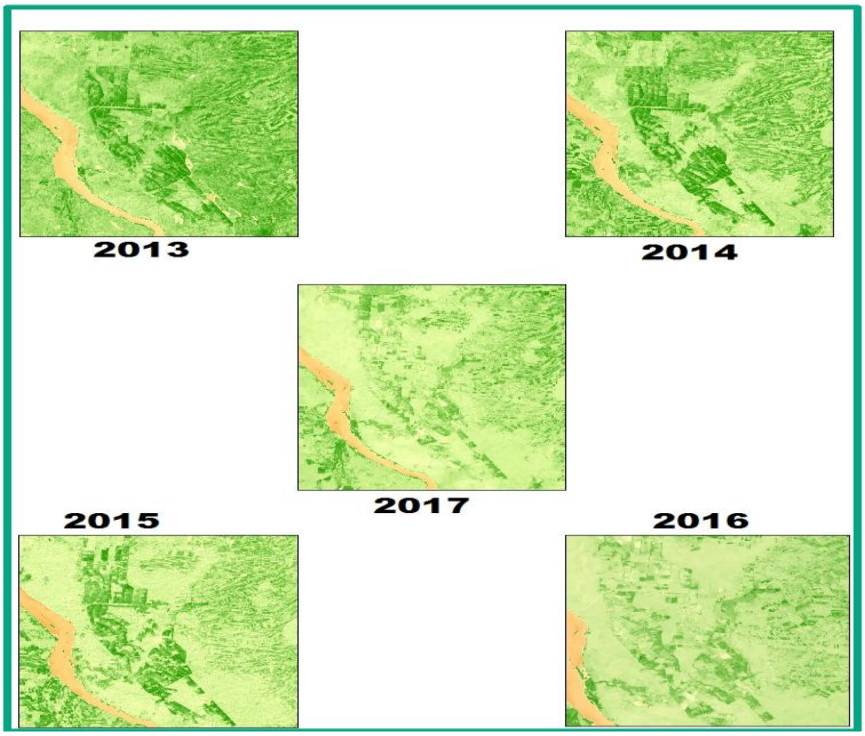


**Fig. 4:** Land Sat 8 Image NDVI Analysis

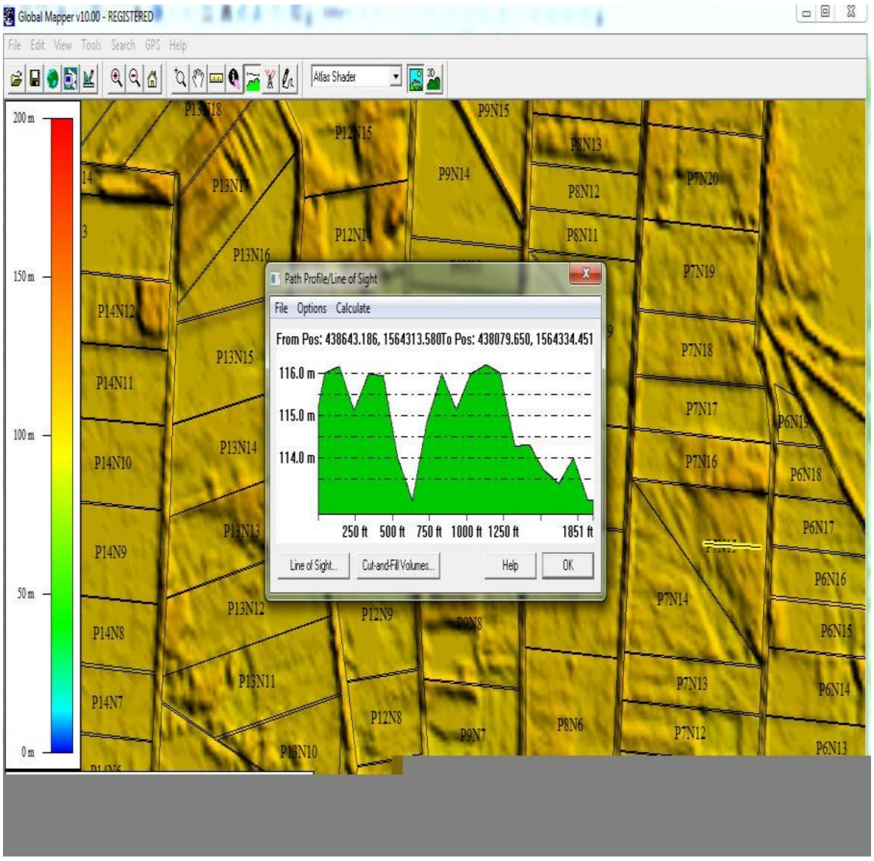


**Fig. 5:** Calculating NDVI value using Global Mapper Software

## III. RESULTS AND DISCUSSION

In the first season the precision for the previously planted farms was 95% and for the new farms was 85%. The estimation for the new farms

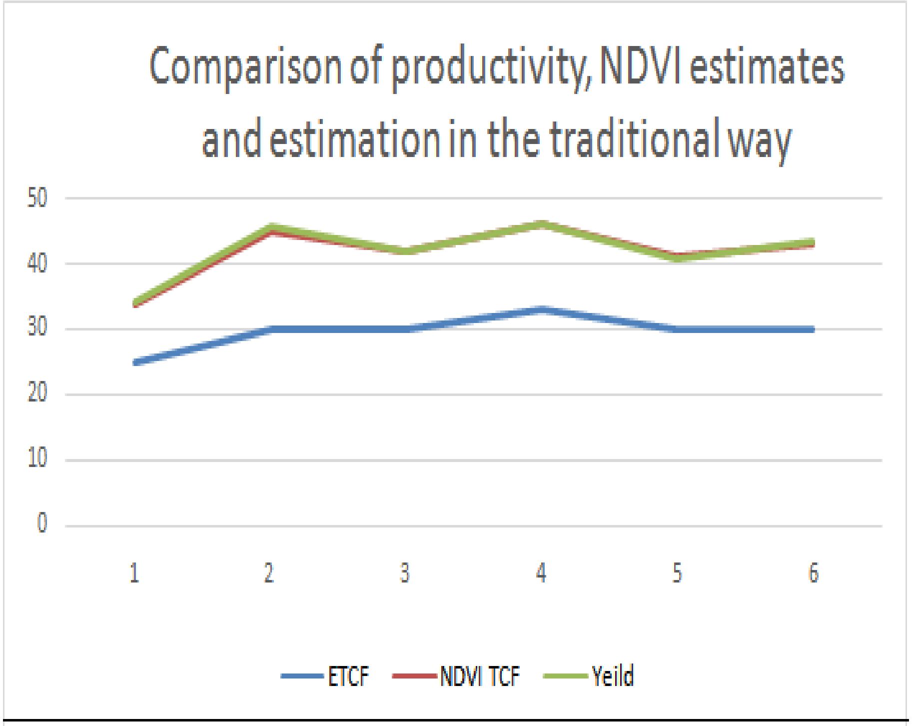


**Fig. 5:** Results of the 2014-2015 season

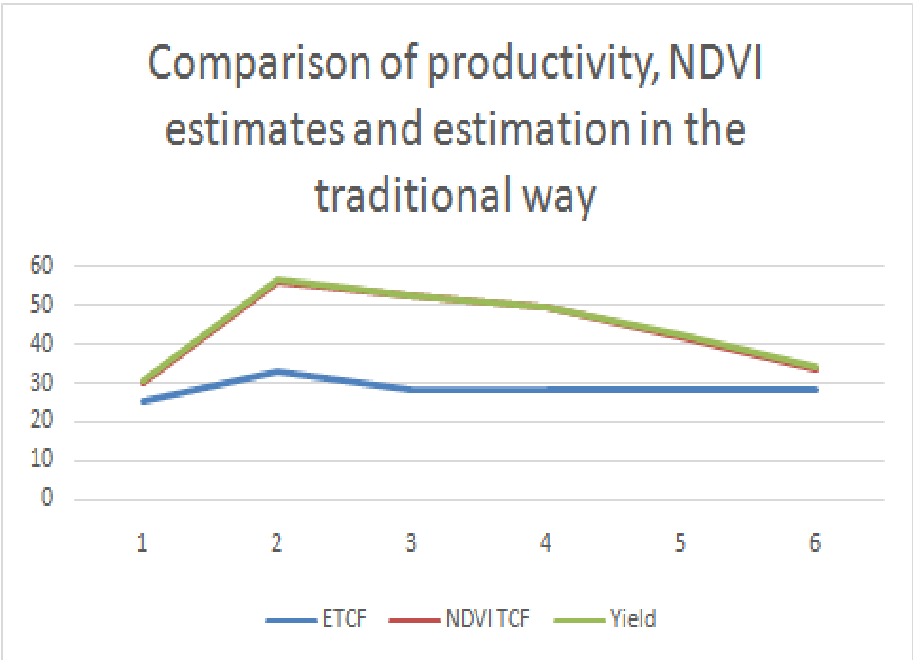


**Fig. 6**: Results of the 2015-2016 season

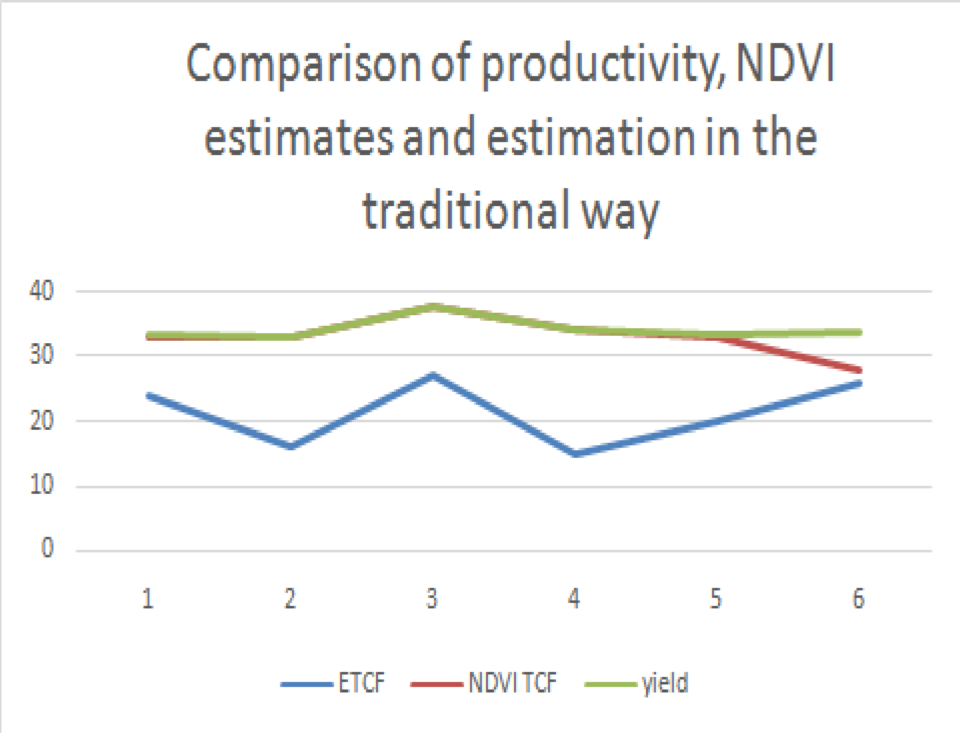


**Fig. 7**: Results of the 2016-2017 season

And it was improved in the following season by comparing the farm to a farm with the same type of soil and the same ratoon to reach 90%.

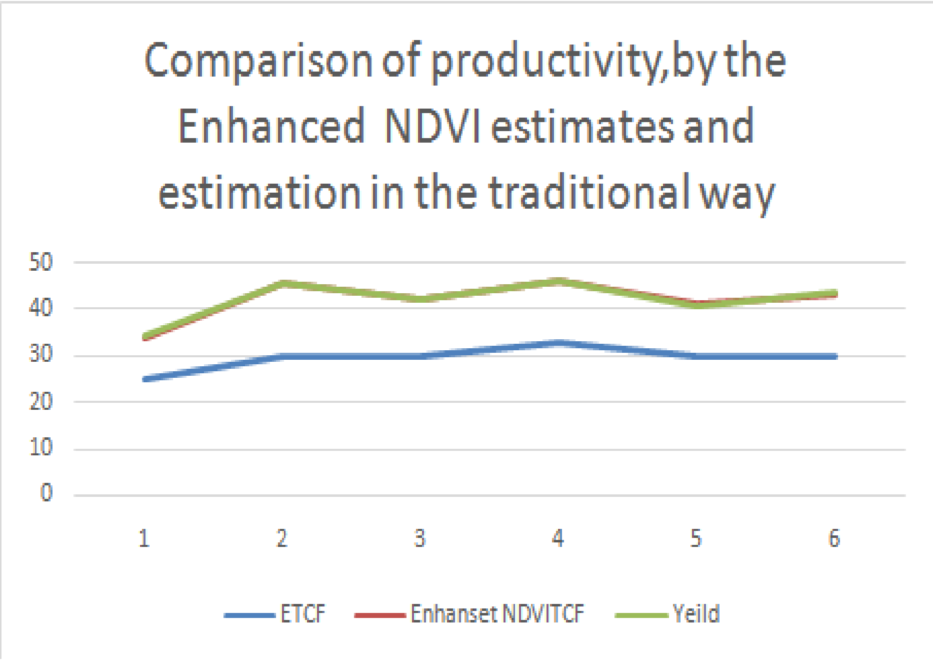


**Fig. 8**: Enhanced Results of the 2014-2015 season

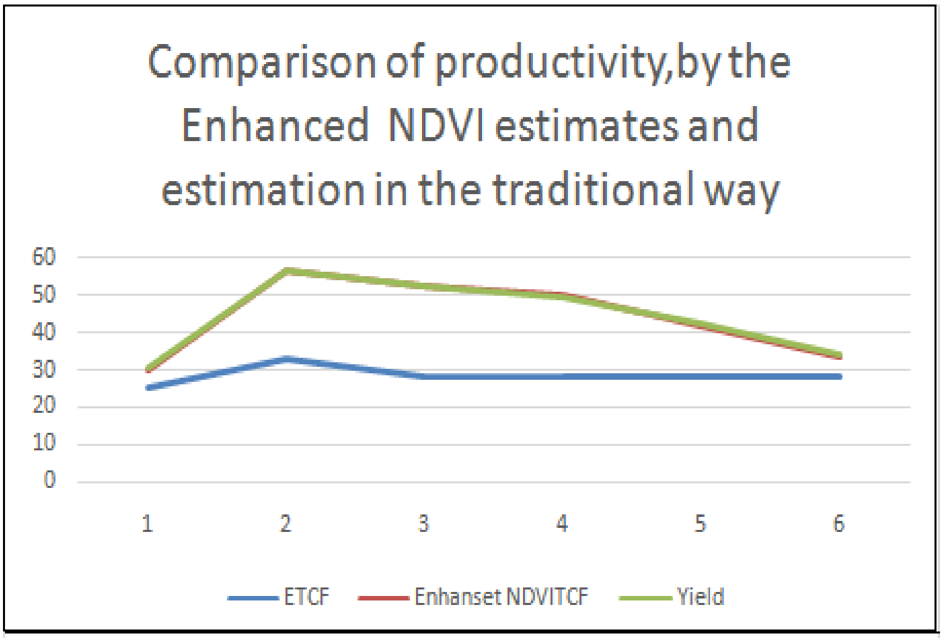


**Fig. 9:** Enhanced Results of the 2015-2016 season

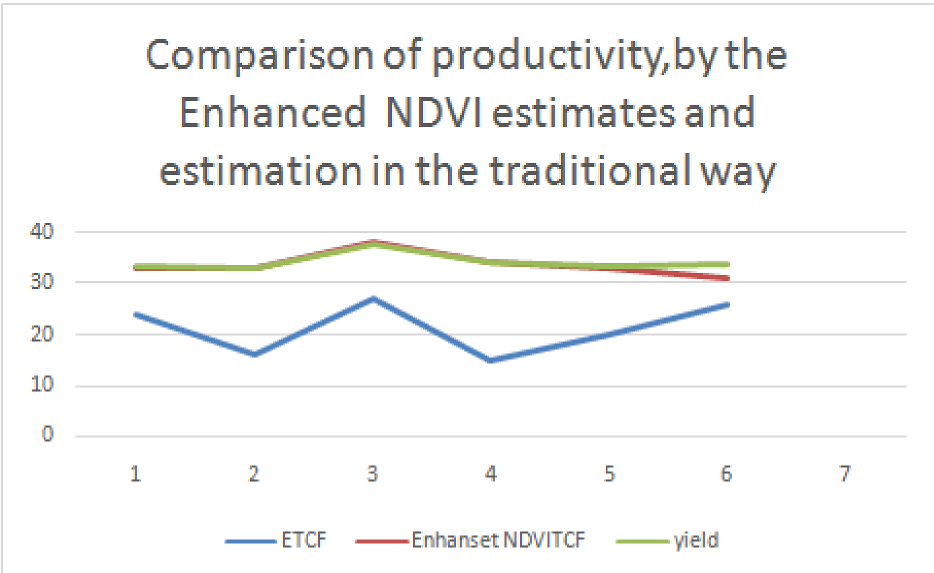


**Fig. 10:** Enhanced Results of the 2016-2017 season

The new method was tried in two seasons and proved to be more effective than the traditional method in which they calculate the quantity produced by certain area (e.g. 10 m2 and then estimate the production for the rest of the field based on it. The precision of the traditional method was 50%.

**Table 4:** Season 2014 – 2015 Estimations Results

| Canal | Field | Crop Cycle | Varity | ETCF | NDVI TCF | Enhanced NDVITCF | Yield |
|---|---|---|---|---|---|---|---|
| P4SS | 13 | R2 | Co6806 | 25 | 34 | 34 | 34.14 |
| P2SS | 15 | R1 | Co6806 | 30 | 45 | 45.5 | 45.57 |
| P2SS | 16 | R1 | Co6806 | 30 | 42 | 42 | 41.98 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P2SS | 17 | R1 | Co6806 | 33 | 46 | 46 | 46.05 |
| P1SS | 7 | R1 | Co6806 | 30 | 41 | 41 | 40.8 |
| P1SS | 8 | R1 | Co6806 | 30 | 43 | 43 | 43.41 |

**Table 5:** Season 2015 – 2016 Estimations Results

| Canal | Field | Crop Cycle | Varity | ETCF | NDVI TCF | Enhanced NDVITCF | Yield |
|---|---|---|---|---|---|---|---|
| Canal MJ3 | Field 13 | R1 | co6806 | 25 | 30 | 30 | 30.34 |
| Canal MJ3 | Field 12 | R1 | TUC | 33 | 56 | 56.5 | 56.56 |
| Canal MJ3 | Field 11 | R1 | TUC | 28 | 52.5 | 52.5 | 52.49 |
| Canal MJ3 | Field 10 | R1 | 24 TUC / 19 R579 | 28 | 49.5 | 50 | 49.64 |
| Canal MJ3 | Field 9 | R1 | 13 TUC /28.5 R579 | 28 | 42 | 42 | 42.23 |
| Canal 11S | Field 8 | R2 | Co6806 | 28 | 33.5 | 33.5 | 33.69 |

**Table 6:** Season 2016 – 2017 Estimations Results

| | Field | Crop Cycle | Varity | ETCF | NDVI TCF | Enhanced NDVITCF | Yield |
|---|---|---|---|---|---|---|---|
| Canal 9 | 1 | R6 | Co6806 | 24 | 33 | 33 | 33.18 |
| P17AS | 3 | R2 | Mix | 16 | 33 | 33 | 32.78 |
| P20AS | 27A | R1 | Mix | 27 | 37.5 | 38 | 37.6 |
| Canal 2S | 15 | R2 | Co6806 | 15 | 34 | 34 | 33.87 |
| Canal 2S | 16 | R2 | Co6806 | 20 | 33 | 33 | 33.35 |
| P6WSS | 2 | P.C | TUC | 26 | 28 | 31 | 33.75 |

## IV. CONCLUSION

Geographic Information Systems (GIS), coupled with the remote sensing has proven to be successful in the estimation of crop yield using the NDVI (90%). The achieved estimation percentage is appropriate for planning and managing the sugarcane production season properly.

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