

An Empirical Investigation of the Declining Sucrose Content in South African Sugar Cane

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Abstract: This study is aimed at investigating the declining sucrose levels in South African sugar cane using principal component analysis. The agricultural production of sugar cane has been one of the major sources of income to the South African economy. Sucrose has been classified in the analysis of Brix percentage of sugarcane juice as one of the most important parameters of sugar composition, due to its usefulness, among the components in sugar cane which are needed for farmers to generate income within the economy. However, data indicates that the sucrose content decline which began in 2014 is still ongoing, representing great loss to the farmers. To investigate this trend, this study has regressed the sucrose percentage in cane as a dependent variable against the ratio in Tons of cane to 1 Ton of sugar, tons of cane crushed, tons of sugar made, and yields per hectare of harvested cane. The study used correlation matrices, summary statistics and principal component analysis as tools in carrying out its investigation. From the regression result, the proportional composition value of sucrose which stands at 0.6059 - the highest compared to others in the model - indicates that it is an essential component in the chain of sugar production. However, when the maximum value of sucrose (14.24000) is compared with its minimum (12.92000), a remarkable decline is observed. Since a remarkable difference is also observed when the mean value of 13.55353 is compared with the standard deviation value of 0.378318, the study can conclude that the percentage level of sucrose is low compared to other explanatory variables. This typically signifies a decline in the value of sucrose when compared with other variables under investigation.

Keywords: *Sucrose, Sugar Cane, Principal Component Analysis*

1. Introduction

Dated back to 1970's, the deterioration of sucrose content in cane under South African conditions has been investigated by (Wood, 1973). Similarly, Robillard, Vawda and Lionnet (1990) have indicated that for the deterioration of whole stalk sugar cane, ethanol could be adopted as a chemical index. Ethanol extract concentrations are now being adopted at the industrial level in the monitoring of cane delays. However, one essential part which appears not to have been covered concerns the application of the concentration of ethanol to evaluate the quantity of losses in sucrose as a result of the post-harvest deterioration process. It is important to note that apart from the aspect of sugar recovery, as a result of lower purities at the factory, the destruction of sucrose in the stalk represents a direct loss to the farmer who delivers the cane (Robillard, Vawda, and Lionnet, 1990). Among the raw materials rich in sucrose that produce sugar all over the world, sugar extraction from sugarcane makes up 70% (Butterfield et al., 2001). Due to its ability and peculiarity in the phenomenal dry matter production, it is also being adopted as a bioenergy crop. In fact, the crop is gaining great significance in the biofuel industry (Chohan et al., 2014). Again, as a result of the consistent increase in population, the demand for bio-energy, sucrose and white sugar is increasing day by day. Due to low production, however, the present production of sucrose requirement is not enough to meet the increasing demand needed for man's consumption (Cheema, and Mahmood, 2005). Low sugar yields, low sucrose, low rate of adoption of the available varieties and high cane are some of the sugarcane yield productions limiting factors, amongst others (Chohan et al., 2007; Ong'ala, Mwanga, and Nuani, 2016).

Again, in terms of global sucrose and cane production, current global production is in the average of 1450 million tons of cane from 22 million hectares worldwide, thus making sugar cane the world's primary sugar crop. Brazil and India are currently the two major sugar cane producing countries in the world, with the global production accounting for about 60% in addition to its impacts in the food industry, while South Africa is the highest cane producing country in Africa. For instance, Brazil, dedicates 48% of her sugar cane production capacity to the production of ethanol, while 52% is allocated to meeting the sugar production requirements in the country. Whereas, in Asia, nations such as China, India, Philippines, Thailand, and Pakistan have already taken biofuel crop for ethanol production as main output resulting from their ambitious plans in the use of sugar cane. It is expected that such a production capacity will be able to meet up

with fuel mixture requirements. For instance, among other fuel requirements, these countries have been able to adopt 10% of E10 with the fuel of ethanol and 90% is gasoline. Basically, more than a hundred countries under temperate tropical, subtropical conditions grow sugar cane. This is because sugar cane, whose yield is affected significantly by temperature, is basically a crop of tropical climates, relative humidity and solar radiation. Likewise, grand growth period favors stalk development the relative humidity ranges between 55 – 85%, while the optimum mean daily temperature range is 14 to 35°C. The optimal solar radiation requirement is 18 – 36 MJ/m² (Total annual: 6350 MJ/m²). With daylight in the range of 10 – 14 hours, stalk growth increases.

With special attention to the South African sugar industry, the industry produces an approximate 2.3 million tons of sugar rich in sucrose annually (Anon, 2014a), 75% of which is marketed and sold within the Southern African Customs Union (SACU), and the remaining 25% in other parts of Africa, the USA, and Asia. It has thus continued to rank among the top fifteen sugar producing countries in the world. However, a consistent decline in production has been observed over the past two decades peaking in the recent past planting season, with various factors speculated as being responsible. Some of those factors are weakening yields and a reduction in sugar-cane production area according to the Bureau for Food and Agricultural Policy (BFAP) in Anon (2014b); rising input costs and a lack of cohesion and economies of scale (Anon, 2014b; Stainbank, 2011); a growing culture of minimum reinvestment into farm infrastructure (especially among commercial farmers) due to the threat of land claims, poor soil health, and replanting (Anon, 2014b; Harris, 2016). There is an ongoing debate in the literature on the possible reasons for the decline in sucrose ratio to overall sugar cane. This study is out to investigate with empirical evidence the reality/veracity of the purported decline of sucrose in the South African sugar industry, and then propose suggestive corrective measures to the current low level of sucrose in sugar cane. This is because growing a crop with high sucrose quality is of great relevance for maximum profitability. In some certain cases, nutrients rich in sucrose that could move sugarcane quality forward, has the tendency of also enhancing the sugar quality and content of the harvested cane crop. Again, since sucrose improvement in sugarcane enhances the market value, the sucrose content of cane remains the primary driver of on-farm profitability both to the individual and to the national GDP growth. This is partly because the logistical cost of harvesting and transporting large volumes of cane with a low sucrose content is prohibitive, and also because sucrose is the primary component of the RV payment system (Robert, 2017).

2. Literature Review

The Empirical Approach: Ftwi, Mekbib and Abraha (2016) adopted principal component analysis to achieve their study's objectives, which aimed at assessing the inter-relationships among traits considered and the phenotypic nexus among 49 sugarcane genotypes. The demonstrated cluster analysis indicated that the 49 sugarcane genotypes under investigation were highly different for Pol in juice and were made to clustered into nine groups as indicated by milleable stalk population (ha-1), the cane yield (tons ha-1m-1), number of tillers (ha-1), and purity percentage. It was noted that the relationship among sugarcane genotypes was not dependent on geographic origin, indicating a variation in the large proportion of complete genetic which was retained within the origin groups. Where active genetic exchange was found, milleable stalk diameter and milleable stalk height had been seen to be greatly associated with sugar yield while there is weak correlation between sugar yield and quality traits. On the other hand, multiple regression analysis and path indicated that recoverable sucrose percentage (%), cane yield, and Pol impact closely to the variability of sugar yield; these traits are very vital for high sugar yield, and may be put into consideration in sugarcane breeding programs. More importantly, milleable stalk population and milleable stalk height through Brix and cane yield, purity, Pol, together with the number of internodes via recoverable sucrose % had large indirect impacts on sugar yield indicating that such traits could be given consideration during sugar yield high selection. Generally, adequate and similar information was provided following the adoption of cluster, linear discriminant, principal component, multiple regression analyses, and path coefficient. The adoption of multivariate analyses led to positive results, and the outcomes of the study were highly adequate for offering concrete recommendation.

Again, (Zhou, 2014) data gathered from the variety testing final stage estimated by adopting the SAS mixed method to analyze cultivar least square means. The objectives of the research were to investigate which

trends determine genetic gains for sucrose content, cane yield, and sugar yield for cultivars that germinates in the sandy and humid soils of the Midlands region, so as also determine the characteristics of the cultivar and the soil types. Quality over time and trends in yield and were examined by adopting simple linear regression analysis. There were significant and consistent increase in cane sugar yield with year of release, implying remarkable achievement in the genetic gains. When comparing sugar yield and higher cane with that of older cultivars, the currently released cultivars produced more significantly, showing that there will be significantly increased profitability through the adoption of new cultivars. Gains in sucrose content were limited, showing the necessity to promote breeding for sucrose content. The negative association between sucrose content and cane yield was found by the use of principal component analysis, implying that there exist the main variables that grouped the cultivars. Specifically, cultivars generating low level sucrose content (for instance N31) appear not to be suitable for the humid soils, while cultivars generating low cane yield (for instance N37) appear not to be suitable for planting in the sandy soils. Consequently, breeding cultivars generating high cane yield for the sandy soils and high sucrose content for the humid soils would increase genetic gains for sugar yield. Hence, increasing planted area to current cultivars is expected to enhance sugar yield by 7-20%.

Sugar yield is obtained from cane yield and sucrose content (Terzi et al., 2009) and therefore, cane yield and sucrose content and their interaction are important parameters for developing superior genotypes (Zhu et al., 2000; Chohan et al., 2007). Several reports clarify the relationship between cane yield components and cane yield and cane quality traits. For example, Ahmed et al. (2010) reported positive correlation between cane yield and its components (number of milleable stalks/m², milleable stalk height internodes/stalk and single weight) but negative association with milleable stalk diameter, Pol in juice and purity. Similarly, Tyagi and Lai (2007) reported that the weight of milleable stalks contributed high direct effect on cane yield followed by milleable stalk, height, number and thickness. Ei-Shafi and Ismail (2006) used a multiple regression model and reported that the main contributors for sugar yield were cane yield, sugar recovery percentage and milleable stalk diameter. Generally, the results of different studies showed discrepancies to the level of sugar yield and cane yield. This phenomenon necessitates successive studies to be conducted to determine the relationship and association of the traits to increase the efficiency of selection.

Barnes, Meyer and Schmidt (2000) offer an alternative method of reducing the delay in the harvest to crush of sugar cane through the instrumentality of sugar cane. It has been discovered that the main source of losses in sucrose and deterioration of cane quality and other sugar cane components in the sugar cane processing industry is the long-time delay between the period of harvest and the crushing. Data were collected from the Sezela mill area using simulation model, well developed strategies for reducing harvest-to-crush delays were adopted, such as implementation of harvesting groups and altered burning and delivery schedules were examined for the mill area. Major sources of data collection came from hauler and extension growers and personnel, interviews with mill personnel by means of surveys of transport systems and harvesting were used in the area. Previous simulation model of the Sezela mill-yard were derived from analytic data on mill-yard operations while further time studies were carried out in the mill-yard. The software with which to develop the mode was chosen from the Arena Simulation System. The outcome of simulation modelling application to the analysis of delays in harvest-to-crush in the harvesting of sugarcane and transport system could be said to be a successful investigation. The modelling of what is known as complex system became easy through the application of simulation modelling and this complex task which would have been somehow complex to be accurately represented by adopting other related analytical techniques such as scheduling algorithms, queuing theory or linear programming.

Harris (2016) investigated the post- harvest deterioration in the south African sugar-cane supply chain where temperature and burn harvest to crush time are seen as two major determinants of sugar-cane deterioration. The study undertook analytical work on Maid-stone Mill where various delivery data were gathered for 2015/16 season and robust correlations were derived from spreadsheet based model for regression analysis. The result indicated that if 12 hours reduction for the current 2016/17 season could be achieved, R9694352 would be saved as a result of the combined efforts in reduction of losses incurred from post- harvest deterioration and mill extraction improvement and recovery in the boiling house. Singh (2013), taking Uttar Pradesh and four districts as a focus point to analyze economies of sugar-cane base farming because this product is a very important cash crop with domineering impacts in the farming system. Data collection were sourced mainly from both primary and secondary sources. The suggestion spanning from the outcome of the

research has shown that simultaneous planting of two heterogeneous products such as wheat and sugar-cane would reduce cultivation cost where attention is to be given to yields, production and technology of plantation.

Again, one of the earliest works carried on sugar cane extraction is that of Buchanan (1976) who attempted to study the impacts of sugar cane quality on the performance of the processing factory. Twenty-five annual quality trends in cane sugar content were correlated. Understandably with level of consternation, the trend was viewed from some quarters especially when forecasts are postulated based on past trends. When the observation is compounded, it is noted that purity in mixed juice decline at a rate of 0,038 per annum. It is However required that some compensation could be achieved from the fact that the percentage in fiber cane has declined at the average rate of 0,053 per annum particularly when recent addition of suspended solid is corrected. The trend is considered from the perspective of time trend in yield and age, and the following summary conclusion were made from the research: statistical trends in yields and the quality of cane must be economic supported for yields to continue to increase, otherwise, there must be decline in cane quality. It is certain that the cane quality on its own must not be maximized at the expense of yield, particularly, the rates in relation to which the variation in the two variables are to be closely screened. There should be exclusion of the unnecessary aspect of cane quality as this form part of the above conclusions. However, in certain situations the non-leaf part of the tops can be processed to the advantage of the economy. These areas should be subjected to more investigation in details.

3. Methodology

To ascertain the decline of sucrose in the production process through the cleaner production strategies in the sugar milling industry, this model built on the work of (Zhou, 2014; Ong'ala, Mwanga, and Nuani, 2016). Hence, from the foregoing:

$$\text{Suc} = f(\text{LOGTS}, \text{LOGTC}, \text{LOGYP})$$

$$\text{Suc} = \alpha_1 + \alpha_2 \text{LOGTS} + \alpha_3 \text{LOGTC} + \alpha_4 \text{LOGYP} + \mu$$

The model transformation is based on time series data analysis, hence:

$$\text{Suc}_t = \alpha_{1t} + \alpha_2 \text{LOGTS}_t + \alpha_3 \text{LOGTC}_t + \alpha_4 \text{LOGYP}_t + \mu_t$$

Suc implies sucrose percentage in cane; LOGTS implies Tons of cane to 1 Ton of sugar; LOGTC implies Tons of cane crushed; YP implies Tons of sugar made; Tons implies yields per hectare of harvested cane. This section wants to establish with empirical evidence that there is consistent decline of sucrose in the sugar cane production is South Africa in the recent years. The stages shall include: Data source, stationarity test, descriptive statistics, correlation Matrix and principal component analysis.

Data Source: Data on sucrose percentage in cane (Suc); Tons of cane to 1 Ton of sugar (LOGTS); implies Tons of cane crushed (LOGTC); Tons of sugar made (YP); yields per hectare of harvested cane (Tons) are adopted to enable us establish this fact was on SASA statistical Bulletin, 2016/2017 session.

Test stationary: Tests for unit root for all the variables in the data set had been conducted to determine the form of model to adopt in this study. This process has been achieved by testing the unit root with three method alternatives offered by robust versions of Augmented Dickey Fuller, Phillip Peron and Dickey Fuller.

Table 1: Results from Augmented Dickey Fuller, Phillip Peron and Dickey Fuller Tests for Unit Root

Augmented Dickey Fuller			Phillip Peron		
Variables	Order of Integration	P-Value	Order of Integration	P-Value	Order of Integration
SUC	I(0)	0.0077	I(0)	0.0048	I(0)
LOGTS	I(1)	0.0043	1(1)	0.0002	1(1)
LOGT_C	I(1)	0.0229	I(1)	0.0000	I(1)
Y_P	I(1)	0.0360	I(1)	0.0000	I(1)
TONS	I(0)	0.0066	I(0)	0.0027	I(0)

Source: Author's Computation, 2017***, ** and * represent statistical significance at 1%, 5%, and 10%, respectively.

4. Results

Suc implies sucrose percentage in cane; LOGTS implies Tons of cane to 1 Ton of sugar; LOGTC implies Tons of cane crushed; YP implies Tons of sugar made; Tons implies yields per hectare of harvested cane. The study identifies the integration order for all variables in first differences and levels it tested for the presence of unit roots. Several approaches had been engaged to compare, test, and validate the findings in the results so as to further ascertain consistency. The unit root test results are reported in Table 1. The result as indicated showed that none of the variables is of I (2). Again, Table 1 showed that LOGTS, LOGTC and YP have unit root and are thus integrated at I (1), thereby becoming stationary at 1% level of significance. However, yields per hectare of harvested cane (Tons) and sucrose percentage in cane are all devoid of unit root, and thus, integrated at I (0). This unit root test offers mixed outcome because part of the variables was found stationary at order one while others were stationary at levels.

Table 2: The result of correlation Matrix on the series Suc (dependent variable), LOGTS; LOGTC and YP Tons

	Ordinary correlations:				
	SUC	LOGTS	LOGT_C	Y_P	TONS
SUC	1.000000				
LOGTS	0.037980	1.000000			
LOGT_C	-0.170939	0.976405	1.000000		
Y_P	-0.074525	0.841162	0.853532	1.000000	
TONS	-0.837841	-0.530342	-0.334820	-0.314510	1.000000

Source: Authors computation

Note: Suc implies sucrose percentage in cane; LOGTS implies Tons of cane to 1 Ton of sugar; LOGTC implies Tons of cane crushed; YP implies Tons of sugar made; Tons implies yields per hectare of harvested cane

Table 2 replicates the result of the correlation matrix in the variables adopted in our time series model. From the information supplied in the Table 2 and taking sucrose as dependent variable, the variables exhibit different forms of relationship with one another within the model. The study particularly, gives special attention to the noticeable relationship between sucrose and the other independent variables as indicated in the table, of course this is the main focus of this study. Suc maintains positive but weak relationship with LOGTS, whereas from the Table 2, it is clear that Suc reflects inverse relationship with all other variables respectively. In terms of weak association, all other variables have weak correlation with Suc except Tons which exhibit a high correlation. This is an interesting result as it indicates that the variables under investigation have no multicollinearity problem.

Table 3: The result of Summary Statistics on the series Suc. (dependent variable), LOGTS; LOGTC and YP Tons

	SUC	LOGTS	LOGT_C	Y_P	TONS
Mean	13.55353	14.62045	16.77559	64.92529	8.633529
Median	13.68000	14.63489	16.79734	65.14000	8.530000
Maximum	14.24000	14.83179	16.98839	73.95000	9.170000
Minimum	12.92000	14.30249	16.51428	54.36000	8.330000
Std. Dev.	0.378318	0.139621	0.125383	4.577430	0.279149
Skewness	-0.129136	-0.578284	-0.367312	-0.274145	0.770162
Kurtosis	2.410539	2.917479	2.600903	3.472520	2.250200
Jarque-Bera	0.293369	0.952325	0.495089	0.371094	2.078816
Probability	0.863566	0.621162	0.780715	0.830650	0.353664
Sum	230.4100	248.5477	285.1851	1103.730	146.7700
Sum Sq. Dev.	2.289988	0.311902	0.251534	335.2458	1.246788
Observations	17	17	17	17	17

Source: Authors computation

Note: Suc implies sucrose percentage in cane; LOGTS implies Tons of cane to 1 Ton of sugar; LOGTC implies Tons of cane crushed; YP implies Tons of sugar made; Tons implies yields per hectare of harvested cane

Table 3 reports the summary statistics results for all variables engaged in this study. The mean result of every variable used in this study is given in the second row, mean is one of the Essential statistical tool for measuring central tendencies. In the third and fourth rows, the value of maximum and the minimum are recorded for all the variables. While the result of standard deviation is reported in row five. As for the case of sucrose percentage in cane which is the study's dependent variable, the study compared the maximum value with its minimum in the value of 14.24000 as against 12.92000. Again, with the mean value of 13.55353, was compared with them egre value 0.378318 of the standard deviation, then the study can conclude that the amount of sucrose percentage in relationship to other explanatory variable is low and this typically signifies a decline in the value of sucrose when compared with others. A further comparative look of Tons of cane to 1 Ton of sugar shows that the maximum value 14.83179 is closer to the mean than the minimum value 14.30249 and we also noted that the standard deviation which is a good measure of dispersal has a low value of 0.139621. This claim is further supported and strongly confirmed by the value of the standard deviation which is closer to the mean. Indicating that there is considerable gap between the expected sucrose percentage and that of Tons of cane to 1 Ton of sugar. This result is supported substantially by the existing prior expectations in the South Africa sugar producing company which concurred that the value of sucrose is declining. The same trend of event is obtainable for tons of cane crushed (LOGTC); tons of sugar made (YP); yields per hectare of harvested cane (Tons), the maximum values are all closer to the mean than the minimum. Hence, there is clear indication that the value of sucrose percentage is significantly low in comparison with other values under investigation. However, the study takes a further step by examining principal company analysis.

Table 4: The result of the principal component analysis on the series: Suc (Dependent variable), LOGTS; LOGTC and YP Tons

Principal Components Analysis					
Date: 11/03/17 Time: 21:47					
Sample: 2000 2016					
Included observations: 17					
Computed using: Ordinary correlations					
Extracting 5 of 5 possible components					
Eigenvalues: (Sum = 5, Average = 1)					
Number	Value	Difference	Proportion	Cumulative Value	Cumulative Proportion
1	3.029429	1.292057	0.6059	3.029429	0.6059
2	1.737372	1.529287	0.3475	4.766801	0.9534
3	0.208085	0.182983	0.0416	4.974886	0.9950
4	0.025102	0.025090	0.0050	4.999988	1.0000
5	1.17E-05	---	0.0000	5.000000	1.0000
Eigenvectors (loadings):					
Variable	PC 1	PC 2	PC 3	PC 4	PC 5
SUC	0.092412	-0.741012	0.222217	0.626867	0.004312
LOGTS	0.563876	0.082381	-0.343466	0.130955	0.734942
LOGT_C	0.536581	0.241349	-0.338337	0.330641	-0.655772
Y_P	0.510731	0.196959	0.825873	-0.135203	-0.003877
TONS	-0.353184	0.589128	0.190034	0.679916	0.172600

Source: Authors computation

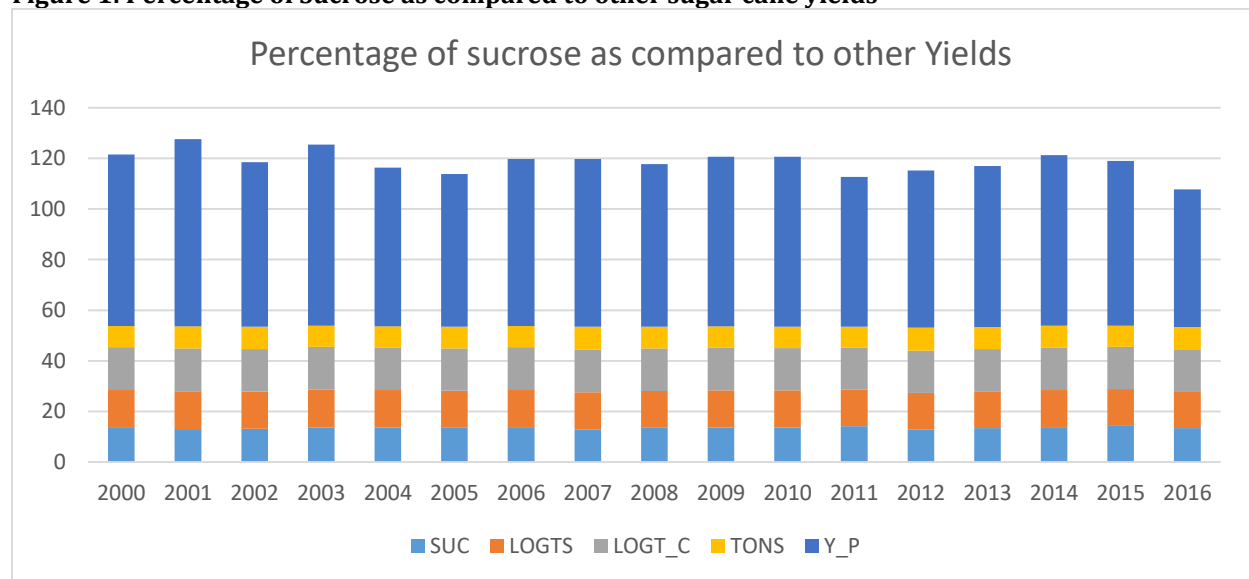
Note: Suc implies sucrose percentage in cane; LOGTS implies Tons of cane to 1 Ton of sugar; LOGTC implies Tons of cane crushed; YP implies Tons of sugar made; Tons implies yields per hectare of harvested cane

Principal Component Analysis: The principal component analysis (PCA) is one powerful statistical method widely applied to classify phenotypic traits in crop germplasm into groups based on similarities (Rukundo, et al., 2015). The purpose of principal component analysis is to find the best low-dimensional representation of the variation in a multivariate data set. We can carry out a principal component analysis to investigate whether we can capture most of the variation between samples using a smaller number of new variables (principal components), where each of these new variables is a linear combination of all or some of the traits. PCA reduces the original variables into a new set of uncorrelated variables known as principal components

(PCs). These PCs clarify the connections between traits and divide the total variance of the original traits into a small number of uncorrelated new variables (Wiley, and Lieberman, 2011). The PCA allows visual differentiation among entries and identify possible associations (Mohammadi, and Prasanna, 2003) by providing a two dimensional scatter plot consisting of individual entries. This section addresses the result on the principal component analysis on the series Suc. (dependent Variable), LOGTS; LOGTC and YP Tons

Table 4 showcase the result of the principal component analysis. The basic phenomenon in the Principal component analysis (PCA) rest in its ability to adopt a statistical procedure to operate through orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. This study uses this underlying principle to examine and to compare the declining level of sucrose percentage in cane in the model. The value 0.092412 for Sucrose percentage in cane when compared with other value has shown a consistent decline under the Eigenvectors (loading). However, the proportional composition of 0.6059 of sucrose is the highest particularly as we compare this value with others in the model, indicating it is principally an essential component in the chain of sugar production. The result of statistical analysis has clearly shown the importance of sucrose in the production of sugar cane but at a declining state. The implication of this declining and yet essential product generates the possible questions as to why the decline. In answering this question, Harris (2016) argue that the decline in the sucrose yield in the average from 11%-38% across the South African geographic and climatic zones is more than what can be attributed to reduction in climatic potential (Anon, 2014). Harris (2016) substantiated that the major factors responsible to this bulk of reduction includes the followings: the sugarcane production area originated from the segment of small scale grower that witness a reduction for the period from 2001 to 2014 in area in the order of 47 000 Ha. Again, rising costs of input, a lack of economies of scale and cohesion from the grower's group appear to be one of the important contributing factors to the decline in sucrose in South Africa (Anon, 2014; Stainbank, 2011). In addition, the ever available and the ongoing South African real threat of land claims has triggered the general opinions, particularly among large scale commercial farmers, of minimum replanting and soil health, reinvestment into farm infrastructure, as these factors have considerably contributed to the prolonged passage of sucrose yield decline in the industry (Anon, 2014).

Figure 1: Percentage of Sucrose as compared to other sugar cane yields



Source: Authors' Computation, 2017.

Again, this study has taken further step to represent the decline in sucrose in a graphical form as noted in figure 1. From the figure, the portion of the sky blue which has the lowest yield is the sucrose. This is immediately followed by Tons of cane to 1 Ton of sugar; Tons of cane crushed; Tons of sugar made and yields per hectare of harvested cane respectively.

5. Conclusion, Summary and Recommendations

The study is out to investigate with empirical evidence whether there is an existence of decline of sucrose in the cane sugar among the South African sugar industry. In achieving this objective, the study compared principal component analysis result with that summary statistics and correlation matrix. The result clearly indicates that a low sucrose level exists when compared with other content of sugar cane. The implication of this ratio is that sucrose does not grow in proportion with other component of sugar cane. Implication of this findings is that South African sugar cane growers suffer for the decline as farmers are only paid based on the quantity of sucrose in the sugar cane. The findings negated the result of Ahmed et al. (2010) but it however corroborates the findings of Barnes, Meyer and Schmidt (2000) in their study in Sezela mill area in South Africa. Hence the result has shown that the objective of the study has been achieved. The improvement of sucrose cultivation could be achieved by identifying genes associated with important agronomic traits in sucrose content. These genes can then be used to generate transgenic plants or can serve as molecular markers for map-assisted breeding which will eventually improve the sucrose content sugar over time

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