ST. MARY'S UNIVERSTY

SCHOOL Of GRADUATE STUDIES

INSTITUTE OF AGRICULTURE AND DEVELOPMENT STUDIES

ANALYSIS OF TECHNICAL EFFICIENCY OF SUGARCANE PRODUCTION IN ETHIOPIA: THE CASE OF WONJI/SHOA SUGAR CANE ESTATE FARM

By

BEREKET EKUBAYGEBREGEORGIS

June , 2015
Addis Ababa

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ANALYSIS OF TECHNICAL EFFICIENCY OF SUGARCANE PRODUCTION IN ETHIOPIA: THE CASE OF WONJI/SHOA SUGAR CANE ESTATE FARM

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATESTUDIES, ST. MARY'S UNIVERSTY,INSTITUTE OF AGRICULTURE AND DEVELOPMENT STUDIES,FOR PARTIAL FULFILLMENT OFTHE REQUIREMENTS FOR THE MASTERS OF SCIENCE DEGREE INAGRICULTURAL ECONOMICS

BY

BEREKET EKUBAY GEBREGEORGIS

JUNE, 2015

ADDIS ABABA, ETHIOPIA

Declaration

I declare that this Msc. thesis is my original work, has never been presented for a degree in this or any other university and all source of materials used for the thesis have been duly acknowledged.

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Date of Submission: June 10, 2015

ENDORSEMENT

This thesis has been submitted to St. Mary's University, school of Graduate Studies for examination with my approval as a University advisor.

Adviser **:<u>Wondimagegne Chekol (PhD)</u>** _________________

APPROVAL OF BOARD EXAMINERS

As members of the Board of Examining of the final MSc thesis open defense, we certify that we
have read and evaluated the thesis prepared by Bereket Ekubay under the title "ANALYSIS OF TECHNICAL EFFICIENCY OF SUGARCANE PRODUCTION AT WONJI SUGAR CANE ESTATE PLOT" Were commend that the thesis be accepted as fulfilling the thesis requirement for the Degree OfMaster Of Science in Agricultural Economics

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ACKNOWLEDGMENTS

I would like to thank Dr. Wondimagegne Chekol, my advisor, for his comments and suggestions. His contributions to this thesis and his thoughtful contribution to my knowledge were very much helpful.

I am also extremely thankful to Wonji/Shoa Sugar cane Estate Farm staffs for providing me necessary material and cooperation. My especial thanks go also toDr. GomerawAdinew, Mr. Leyikun Birhanu Sugar, Mr. Aklilu Hile, Mr. Birkineh Wolde, Mr. Gutema Bati and Mr. Ermias Melaku for their especial cooperation and help. Above all I am very grateful to my parents, especially to my mother Ms. Rishan Teklu.

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ACRONYMS

ADLI	Agricultural development led industrialization
ADSWE	Amhara Design Supervision Work Enterprise
DEA	Data Envelopment Analysis
GTP	Growth Transformation Plan
GDP	Gross Domestic Product
Ha	Hectare
IPRSP	Interim Poverty Reduction Strategy Paper
MASL	Meters Above sea level
MLE	The maximum likelihood estimates
PASDEP	plan for Accelerated and Sustained Development to End Poverty
SDPRP	Sustainable Development and Poverty Reduction Program
SFP	Stochastic frontier parameter
TE	Technical Efficiency
WFP	World food program

ABSTRACT

Ethiopian sugar cane production is unsatisfactory to uphold the country's comparative advantage.Thus, this study was conducted to examine possible reasons for low productive performance of sugar cane production by using cross sectional data gathered from Wonji/Shoa Estate Farm and analyzing its technical efficiency.

Accordingly, both error component model and technical inefficiency effects model have been estimated in one step approach after data have been transformed to log. Maximum likelihood estimate of technical efficiency was obtained from half normal model which was supposed to describe the data adequately. Technical inefficiency effects are modeled as a function of area, cane age, cane variety, cane type (ratoon) and soil type.

The result revealed that various distributional assumptions of technical inefficiency have approximately similar impact of on technical efficiency estimates. On average, sugar cane production in each plot are 77% efficient, implying that there is ample opportunity for the estate plot to raise output level at present technology.

Key words: Technical Efficiency, half normal model and Sugarcane

1. INTRODUCTION

1.1. Background

Ethiopia is becoming one of the fastest economically growing countries in the world. In 2012/13 fiscal year; Ethiopia's economy grew by 9.7%, tenth in a row of robust growth. In 2012, Ethiopia was the twelfth fastest growing economy in the world with average annual real GDP growth rate for the last decade was 10.9% (Africa Economic Outlook 2014). Accordingly, agriculture, which accounts for 42.7% of GDP, grew by 7.1%, while industry, accounting for 12.3% of GDP, rose by 18.5% and services, with 45%of GDP, increased by 9.9% in 2012/13 albeit at a slower pace because of constraints on private-sector growth (Africa Economic Outlook 2014)

Although its share of GDP has been declining steadily over the past decade, agriculture continues to be the backbone of the Ethiopian economy, contributing 42.7% to GDP, about80% of employment and 70% of export earnings in 2012/13. Agricultural value added showed robust growth of 7.1% in 2012/13 as grain production hit a record level of 25.1 million tons. This came as a result of favorable weather conditions, increased access to extension services forsmallholder farmers, and expansion in cultivated land. Total crop cultivated land expanded by0.3 million hectares. Yield per hectare increased from 1.6 tons in 2010/11 to 1.8 tons in 2012/13 (Africa Economic Outlook 2014).

In order to reach in such situations, the country set out a series of economic reform programs since 1991 which comprises structural adjustment programme with the aim of economic growth and poverty reduction. Following this the country has adopted agricultural development led industrialization (ADLI) Strategy in 1993, Interim Poverty Reduction Strategy Paper (IPRSP) in 2000, Sustainable Development and Poverty Reduction Program (SDPRP) in 2002. All these strategies were intended to bring about economic growth through increase in agricultural productivity and were primary focused up on the poverty reduction.(Africa Economic Outlook 2014).

In 2005 a plan for Accelerated and Sustained Development to End Poverty (PASDEP) was introduced in the country. This strategy primary aimed in the promotion of small scale market oriented agriculture which goes beyond poverty reduction. The country adopted such strategies to bring about improvement in agricultural sector, which is the back bone of its economy. However, very little has been observed towards productivity improvement over past decades. As a result, to improve economic growth of the country, productivity growth of agriculture is inevitable. Despite substantial attempt on part of government to commence technological improvement in agriculture, the reason why the productivity of the agricultural sector remains very low and became a challenge in the road towards agriculture based economic growth in the country (Alemayehu, 2010).

Taking this in to account the Government of Ethiopia developed a five year (2010/11-2014/15) Strategic Plan named as Growth and Transformation Plan

(GTP).The GTP is designed forsustaining a rapid and broad-based growth path in the country.(MOFED 2010)

In order to achieve the GTP plan the government has chosen among others expansion of sugar cane plot and the sugar industry to be one of the tools to meet the pillars of as one means of economic growth, hence expansion and establishing sugar cane plots and construction of seven new sugar factories are under progress.

Currently, production of cane for commercial use is limited in three areas namely Wonji-Shoa, Methara and Fincha. The country has been covering its sugar requirement through local production using the three sugar industries. However, nearly more than 20% of sugar requirement is met through import due to the shortages created in the past few years. The increase in sugar consumption is mainly a result of four demand determining variables. These are population growth, improvement in income, consumption habit and the growth of the industrial & service sector, mainly hotels & restaurants as well as the food and beverage industries (ADSWE2013).

While the use of sugar and sugar cane is very diverse as well as important for one country's economy; Ethiopia's sugar cane production and productivity is very low for decades, the reason for this is various and numerous. As Wonji/Shoa Estate Farm is one of the producer of sugar cane in Ethiopia, it is also suffering from the low production and Productivity of sugar cane, thusin this paper a different attempts was made to examine the reason for low production and productivity of sugar cane in Wonji/Shoa Estate Farm by using the technical Efficiency.(Wonji/Shoa Sugar Factory Annual Report 2013)

1.2. Statement of the Problem

Ethiopia has very large potential for sugar cane production. Preliminary assessment reports indicated the availability of more than 20 million hectares of land that is biophysically suitable and over two million hectares of land potential for irrigation. The favorable physiographic setting of the country created different ecological zones that are complementary to each other. The highlands provide substantial water flow as surface and groundwater, nutrient and soil to lowland plain areas that has warm temperature suitable for cane production. The lowlands that surround the central highlands have easy access to ports and engulf the country in all directions (ADSWE, 2013)

Though there is a wide range of development of sugar cane plantations on the country, to meet the domestic and foreign demand still there is a problem of technical efficiency, because of the difference among sugarcane producing Ethiopian sugar factories such as; Metehara sugar factory harvest 5601 ha, Wonji/shoa harvest 2,777 ha per annum and Fincha's harvest7,372 per annum. There for, the importance of measuring and analyzing the level of technical efficiency of sugarcane is very important.

Despite the fact that technical efficiency of small holder farmers has been extensively studied in Ethiopia, there are limited studies on technical efficiency of the country's sugar industries. Some of the studies that were conducted regarding technical efficiencies are; Dejene Merga (2013) on sugar cane at Fincha sugar factory, God'swill, etal(2011) wrote a working paper on A Comparative Analysis of International Water Management Institute the Technical Efficiency of Rain-fed and Smallholder Irrigation, Alemayehu(2010) on coffee.

Nevertheless, these previous studies focused on the study of technical efficiency of cereal crops other than Sugar cane. Thus, little attention was given to the analysis of technical efficiency of sugar cane production in Ethiopia except Dejene Merga, who studies technical efficiency at Fincha sugar Factory. In this study an attempt was made to measure the technical Efficiency of sugar cane production at Wonji Sugarcane Estate Farm.

1.3. Research objective

1.3.1. General objective

The General objective of the study is to analyze the technical efficiency of Sugarcane production and to identify factors affecting level of technical efficiency among the Wonji Sugarcane Estate Plot.

1.3.2. Specific Objective

- To measure the technical efficiency of Sugarcane production at Wonji Sugar Cane Estate Plot
- To identify factors affecting the variation in the level of technical efficiency and sources of inefficiency among Wonji Sugarcane producing plot plots
- To identify factors that are significantly cause variations among plot per plots of Wonji sugar cane producers

- To show the decline or incline of the production of sugar, production of sugar cane productivity at Wonji/shoa Sugar Cane Estate farm and to identify the possible reasons.

1.4. Scope of the study

This research examines and covers the technical efficiency variation among Units of plotat Wonji Sugarcane Estate in each Plot

1.5. Significance of the study

The study result will show an entry point for further policy intervention to improve resource use efficiency of sugarcane production in Wonji/Shoa Sugar Factory Estate Farm. More Over; it helps investors engaged in the area, to come with some important idea of efficient utilization of available production input for those plot managers who are inefficient. They can play an important role informing inefficient Plot managers to derive lessons about better production practices from more efficiency farmers operating in the same environment and level technology.

The technical efficiency measurement is very important in any area of production because it is factory productivity growth. Generally it directs the then after areas of focus researchers to devote their attention towards investigation of sugarcane technical efficiency which is one of the core dimensions of sugarcane production improvement in Ethiopia to step forth to the maximum possible.

The study will have both a practical and theoretical importance. At the practical level, measuring the technical efficiency of sugarcane production, and identifying the factors that affect it, may provide useful information for the formulation of economic policies likely to improve producer technical efficiency. Moreover, from the microeconomic standpoint, identifying the factors that may improve Unit heads/sugar growers productivity is of major significance since, by using information derived from such studies, farms or Sugar plantations may become more efficientand hence more profitable.

2. LITERATURE REVIEW

2.1. Theoretical Literature

Technical Efficiency Concept

By efficiency of a production, unit it means a comparison between observed and optimal values of its outputs and inputs. The comparison can take the form of the ratio of observed to maximum potential output obtainable from the given input, or the ratio of minimum potential to observed input required to produce the given output, or some combination of the two. In these two comparisons the optimum is defined in terms of production possibilities. It is also possible to define the optimum in terms of behavioral goal of the production unit. In this event efficiency is economic and is measured by comparing observed and optimum cost, revenue, profit, or whatever the production unit is assumed to pursue, subject to the appropriate constraints on quantities and prices (Lovell,1993).

Walter Briec,Laurent Cavaignac and KristiaanKerstens(2010) analyze the definition of technical efficiency and rich with the conclusion to define efficiency measures complying with Koopmans' definition of technical efficiency in the framework of the traditional radial distance functions and of the rather recently introduced directional distance functions. After summarizing the original axiomatic literature on technical efficiency in terms of radial and non-radial efficiency measures, they redefine these same axioms in the context of the input directional efficiency measures. Thereafter, they analyze the properties satisfied by the input directional distance function and the Fare-Lovell directional efficiency measure. Neitherof these two measures turns out to simultaneously satisfy all of these newly defined properties.. Finally, they define a directional version of the asymmetric efficiency measure Fare (1975). Again, both of these newly defined input directional measures of technical efficiency do not satisfy all of the new axioms. More generally, they prove that no input directional efficiency measure can satisfy all of the newly required properties.

The measurement of economic efficiency has been intimately linked to the use functions. The modern literature in both plots begins with the same seminal paper, namely Farrell (1957). He characterized the different ways in which a productive unit can be inefficient either by obtaining less than the maximum output available from a determined group of inputs(technically inefficient) or by not purchasing the best package of inputs given their prices and marginal productivities (allocative inefficient).The analysis of efficiency carried out by him can be explained in terms of Figure 1.

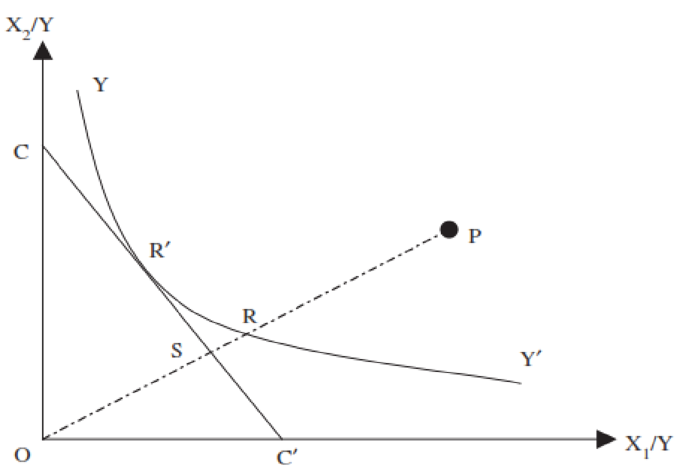

Fig1, Technical and Allocative Efficiency

Assuming constant returns to scale (CRS) as Farrell (1957) initially does in his paper, the technological set is fully described by the unit isoquant YY'that captures the minimum combination of inputs per unit of output neededto produce a unit of output. Thus, under this framework, every package of inputs along the unit isoquant is considered as technically efficient while any point above and to the right of it, such as point P, defines a technically inefficient producer since the input package that is being used is more than enough to produce a unit of output. Hence, the distance RP along the ray OP measures the technical inefficiency of producer located at point P. This distance represents the amount by which all inputs can be divided without decreasing the amount of output. Geometrically, the technical inefficiency level associated to package can be expressed by the ratio RP/OP, and therefore; the technical efficiency(TE) of the producer under analysis (1-RP/OP) would be given by the ratio OR/OP.

If information on market prices is known and a particular behavioral objective such as cost minimization is assumed in such a way that the input price ratio is reflected by the slope of the iso-cost line CC', **allocative inefficiency** can also be derived from the unit isoquant plotted in Figure 1.1. In this case, the relevant distance is given by the line segment SR, which in relative terms would be the ratio SR/OR. With respect to the least cost combination of inputs given by pointR', the above ratio indicates the cost reduction that a producer would be able toreach if it moved from a technically but not allocative efficient input package(R) to a both technically and allocative efficient one (R'). Therefore, the allocative efficiency (AE) that characterizes the producer at point P is given by the ratio OS/OR.(Sited in Murillo-Zamorano, 2004)

According to collie (2005) If information for prices is available, and a behavioral assumption, such as cost minimization or profit maximization, is appropriate, then performance measures can be devised which incorporate this information. In such cases it is possible to considerallocative efficiency, in addition to technical efficiency. Allocative efficiency ininput selection involves selecting that mix of inputs (e.g., labour and capital) that produces a given quantity of output at minimum cost (given the input prices which prevail). Allocative and technical efficiency combine to provide an overall economic efficiency measure.

The concept of efficiency can also be viewed with respect to productivity: Ever since the initial work of Farrell (1952), there have been numerous studies that estimated production efficiency (Forsund et al., 1980; Schmidt, 1985). In a pioneering study Farrell (1957) identified two components of production efficiency: Technicalefficiency which measures a firm's success in producing maximum output (or set of outputs)from a given set of inputs; Allocative efficiency, which Farrell calls "price" efficiency andmeasures the firm's success in choosing an optimal set of inputs. The underlying premise ofFarrell and the ensuing literature is that the removal of technical and allocativeinefficiencieswill yield efficient production. When cast in the dual cost minimization framework thecorresponding assumption is that deviations of actual production costs from the minimumcost is due to technical and allocative inefficiencies. (Kopp and Diewert (1982) show thecorrespondence between the primal production frontier and the dual cost frontier methods of efficiency analysis) Decomposing Production Efficiency into Technical, Allocativeand Structural ComponentsG.AnandalingamandKulatilakat(1987)

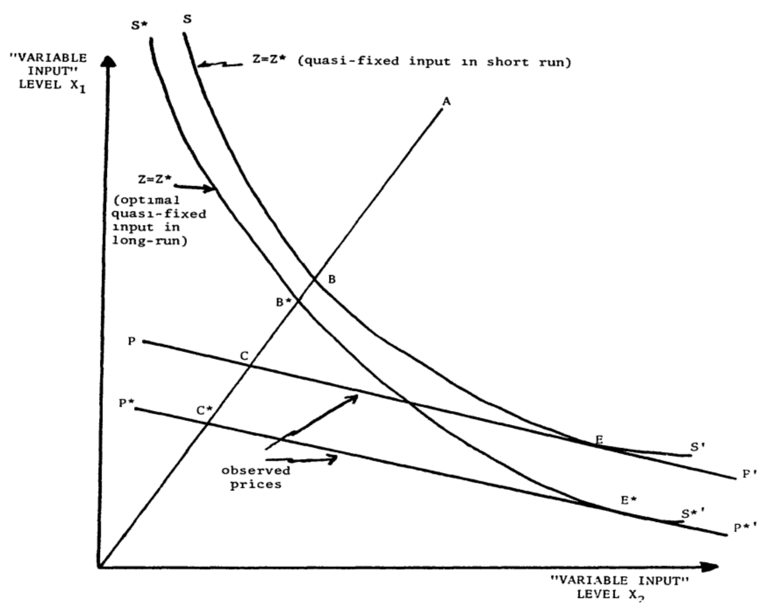

Fig2 Technical and allocative efficiency

Anandalingamand Kulatilaka (1987)examine the relationship between the technical efficiency *(T E)* and allocativeefficiency *(AE)* measures derived from full static equilibrium *(FSE)* models.

In *FSE* models the pairs of points *Band B**,* and C and C* (of Fig. 2) will coincide. That is, the model assumes structural efficiency *(SE* = 1)in estimating the frontier. Hence, *AE* and *TE*willbe well defined only, if in fact, the observed data is structurally efficient. Recent empiricalevidence has found significant departures from full static equilibrium invalidating themaintained hypothesis which forms the basis of previous frontier function models

Hence, such techniques are likely to mis-measure components of production efficiency.

Frontier Approaches have been used for the measurement of technical efficiency, it have been estimated using many different methods over the past 40years. The twoprincipal methods that have been used are data envelopment analysis (DEA) andstochastic frontier analysis, which involve mathematical programming andeconometric methods, respectively. Collie (2005)data envelopment analysis DEA involves the use of linear programming methods to construct a non-parametric piece-wise surface (or frontier) over the data. Efficiency measures are thencalculated relative to this surface. Comprehensive treatments of the methodologyare available in Fare, collie (2005)

The econometric approach is stochastic and attempts to distinguish between the effects of noiseand the effects of inefficiency, while the linear programming approach is deterministic and underthe voice inefficiency melt noise and real inefficiency; the econometric approach is parametricand as a result suffers from functional form misspecification, while the programming approach isnon-parametric and so it is immune to any form of functional misspecification (FrancescoPorcelli, 2009) (Sited in Merga 2013).

2.2. Empirical Literature

Fernandez and Nuthall (2009) attempts to identify the sources of input use inefficiency in sugar cane production in the Central Negros area, Philippines non-parametric Data Envelopment Analysis was used to determine the relative technical, scale and overall technical efficiencies of individual plots which use the same type of inputs and produce the same output (cane). Under a specification of variable returns to scale, the mean technical, scale and overall technical efficiency indices were estimated to be 0.7580, 0.9884 and 0.7298, respectively. The major source of overall inefficiencies appears to be technical inefficiency rather than scale effect.   Input use differences between the technically efficient and inefficient plots are highly significant in terms of area, seeds and labor inputs. There was no significant difference in the use of fertilizer and power inputs. For many plots, labor is the most binding constraint, followed by land and power inputs while seeds and NPK fertilizer are not binding.

Belen Iraizoz, Manuel Rapun and IdoiaZabaleta(2003) technical efficiency was estimated in the horticultural production sector in Navarra (Spain). Tomato and asparagus production are analyzed separately And The results indicated that both tomato and asparagus production are relatively in efficient, with potential in both cases for reducing input or increasing output. These results hold regardless of whether the frontier was parametric or non-parametric. The estimated measures of technical efficient were positively related with the partial productivity indices and negatively related with the cultivation costs per hectare. No conclusive results were obtained for the relation between sizes and efficient.

Thomas Masterson (2007) in Paraguayan Agriculture assesses the relationship between plot size and productivity using both parametric and non parametric methods to derive efficiency measures and smallerplots are found to have higher net plot income per hectare, and to be more technically efficient, than larger plots.

OyugiJohanaNyanjong' and Job Lagat (2012) in analyzing efficiency in sugarcane production in the case of men and women headed households in SONY sugar out-grower zone, Rongo and Trans-Mara districts, Kenya found that men headed households had a mean technical efficiency of 67.6%, a mean allocative efficiency of 82.48% and a mean economic efficiency of 58.0%. Women headed households had a mean technical efficiency of 72.0%, a mean allocative efficiency of 83.15% and a mean economic efficiency of 62.5%. Land under sugarcane cultivation was the single most important contributor to farmers' efficiency. Women managed plots were on average more technically, allocative and economically efficient than men managed plots.

ElibarikiMsuya and Gasper Ashimogo (2005) describe the technical efficiency of sugarcane production and the factors affecting this efficiency. The study was conducted in Turiani Division, Mvomero District, Morogoro Region, Tanzania. Specifically, the study determined and compared the level of technical efficiency of out grower and non-out grower farmers, and examined the relationship between levels of efficiency and various specific factors. The results of the estimation showed that there were significant positive relationships between age, education, and experience with technical efficiency.

S. A. Donkoh , M. Tachega and N. Amowine(2013) in Estimating Technical Efficiency of Tomato Production in Northern Ghana And they found that Mean technical efficiency was found to be 0.71, ranging from 0.36 and 0.99. The relatively high efficiency levels were as a result of agricultural intensification measures (such as the adoption of modern inputs) that the farmers followed as well as high levels of education and long years of experience in cultivating tomatoes. The most indentified effect of tomato influx into the country was that it drives farmers out of production. As a way out the farmers suggested that there should be a review of the country’s cross border relations with its neighbors. The farmers at ICOUR are technically efficientbut,their main problem howeverborders on the fierce competition they face from their foreign counterparts.

Ephraim W. Chirwa (2003) estimation of technical efficiency among smallholder maize farmers in Malawi and identify sources of inefficiency using plot-level data have been done and they find that smallholder maize farmers in Malawi are inefficient; with an average efficiency score of 53.11 percent and 58 percent of the plots have efficiency scores below 60 percent. The results of the study reveal that inefficiency falls with plot size, on plots that used hired labor, on plots that use hybrid seeds and membership to a ploter club or association.

The empirical results predict that technical inefficiency effects were significant in explaining the yield for Fincha Sugar Factory plot units. The mean technical efficiency was estimated at 84%. The inefficiency model indicated that all plot units were less efficient in their production and lost to the tune of 16% of their potential output. These losses differ from one plot units to another. Some Plot units had a slightly higher technical efficiency than plot units. The mean technical efficiency for the plot units was 0.84 compared with the minimum of 49% and 98% of the maximum technical efficiency for the plot units of Fincha sugar factory plotting units. This revealing that a most plot units have mean technical efficiency of 84%. The predominant variables that induce variation in level of technical efficiency in the study were Seed variety, experience, distance, land fertility, Irrigation settled type, number of plots, trainings, Number of sick leaves, age of the cane, soil type, education, location, irrigation setting time and planting system. (Dejene, 2013)

(Ethiopia, 2010) in analyzing the technical Efficiency of Ethiopian coffee it intends to examine possible reasons for low productive performance of coffee using cross sectional data gathered from Jimma zone. The result revealed that various distributional assumptions of technical inefficiency have approximately similar impact of on TE estimates. On average, coffee producers are 72% efficient, implying that there is ample opportunity for these farmers to raise output level atpresent technology. There is also advantage of scale economies linked to increasing returns toboost output. Except fertilizer, overutilization of other inputs leads to inefficiency.

Getachew, (2013) analysis of technical efficiency of small holder maize growing farmers of HoroGuduruWollega Zone, The MLE results reveal that plot size under maize cultivation, chemical fertilizer (DAP) and maize seed are the major factors that are associated with changes in the maize output. The effect of land area on output is positive and the coefficient is found to be significant, implying the economies of scale. The test result indicates that there is inefficiency in the production of maize in the study area. The relative deviation from the frontier due to inefficiency is 85 percent. The average estimated technical efficiency for smallholder maize producers ranges from 0.06 to 0.92 with a mean technical efficiency of 0.66 (66%). The analysis also reveals that the educational level of the ploter, age of household head, land fragmentation, extension services, engagement in off-plot/non-plot activities, and total land holding of the ploter are the major socioeconomic factors influencing farmers' technical efficiency and maizeoutput. The implication of the study is that technical efficiency in maize production in the study area could be increased by 34 percent through better use of available resources, given the current state of technology.

Selomon, (2014) evaluated the efficiency of crop production in Ethiopia, using econometric model, stochastic frontier model, to estimate the elasticity of production function, and the model output depicted that the mean level of technical efficiency for major crops was 63.56%. The inefficiency effect analysis shown that, education, participation in soil and water conservation, poverty status, livestock ownership and adoption of improved seed were found to have negative and significant effect on technical inefficiency of major crops.

3. RESEARCH METHODOLOGY

3.1. Description of the Study Area

Wonji- Shoa Sugar Factory is found in Oromiya Regional State at 108 kilo meter South of Addis Ababa near Adama city in Woniji town which was established by a Dutch holding HVA company, 1954.

At the beginning, the Company was granted a concession of 5,000 ha of land at Wonji Awash River flood plain for the establishment of a Sugar Estate and Sugar Factory. Because of the increasing demand for sugar in Ethiopia the Wonji Sugar Cane Estate Plotexpanded itself and included an additional 1,600 ha of land fromShoa 1962, which is within a 7 km distance from Wonji, and known then after as Wonji/ShoaSugar Factory.

Wonji plain has average elevation of about 1530 m.a.s.l , which is in the range of 1500 – 2300 m.a.s.l. The Plain is surrounded by steep topography where it is bounded by River Awash in the north and east and by border drains in the south and west. It is characterized by very flat land having a small general slope (<5%) predominantly varying from NW to SE (north to south), where the maximum drop in topography is about 6 m within a horizontal distance of 12 km.

The mean annual rainfall of the area is about 704 mm. The mean average minimum and maximum temperatures of the region are 15.2 ^{o}C and 27.6 ^{o}C, respectively with average value of 21.4 °C. The average pan evaporation of the area is 6.8 mm/day. Thearea is between the transition of the two zones: Semi-arid to dry sub-humid.

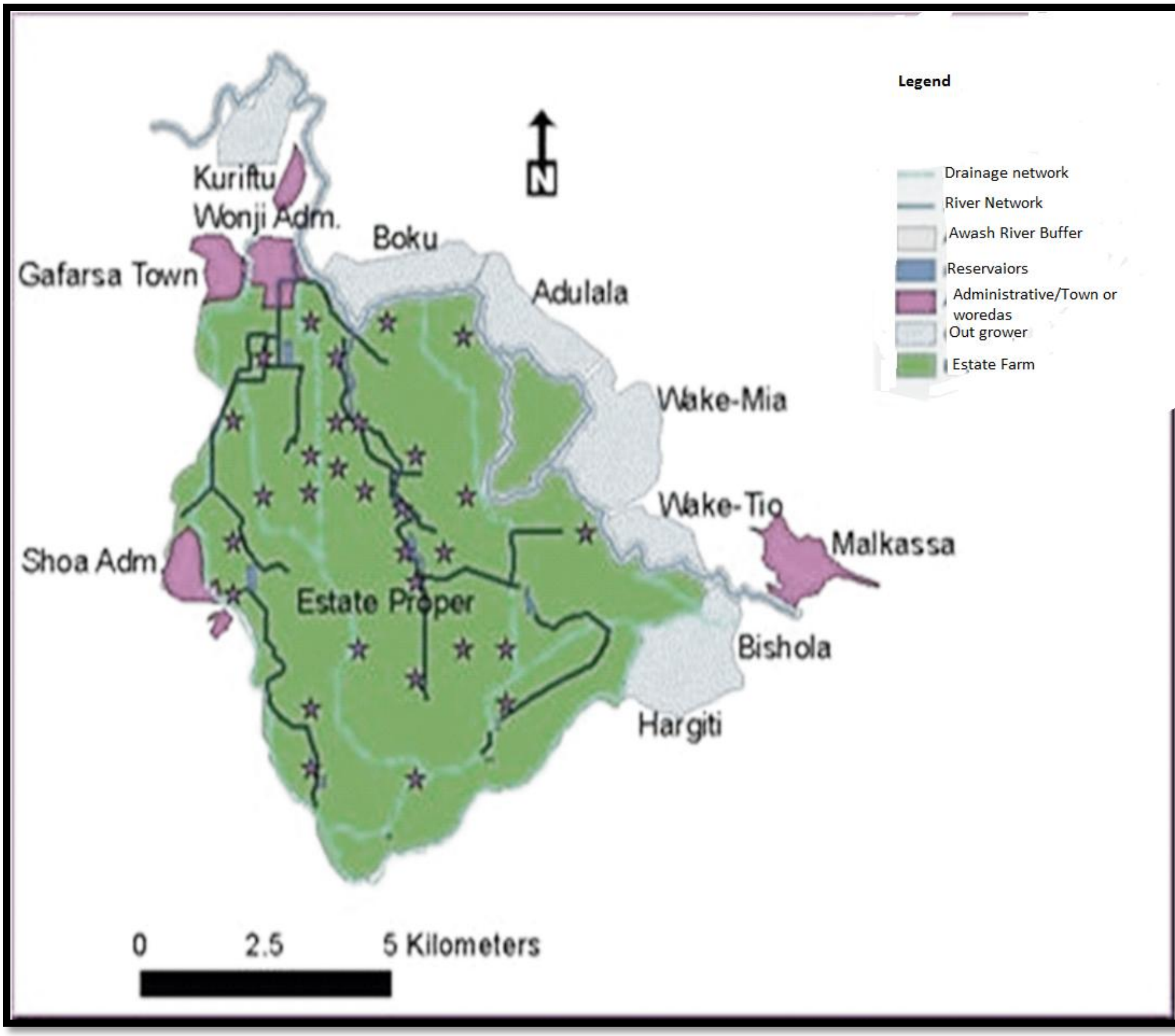

Fig. 3Map of Wonji-Shoa Sugar cane Plantation.

3.2. Data Sources and Data Collection Method

In the study Secondary data was obtained from irrigation water supply sector, plantation office, and planning and project office.

3.3. Data Analysis Method

The analysis basically wasemployed both descriptive and econometric methods. Descriptive statistics (mean, percentage, range, etc.) was used to summarize the variables used in the model and describe the study area. Econometric model, stochastic frontier model, was employed to estimate the elasticity of production function, identify the determinants of inefficiency and estimate the level of efficiency.

The variables both inputs and outputs in the production function and determinants of inefficiency were transformed to their corresponding log values in estimating the Cobb Douglas Production Function.

3.4. Model Specification

3.4.1. The Stochastic Frontier Model with Technical Efficiency Effect

The stochastic frontier production function has two error terms one to account for random effects (e.g., measurement errors in the output variable, weather conditions, diseases, etc. and the combined effects of unobserved/uncontrollable inputs on production) and another to account for technical inefficiency in production.

The stochastic frontier production function can be written as

$Yi = f(Xi;\beta) \exp(Vi-Ui)$

Where Yi is the production of the ithplot Xi is a vector of inputs used by the ithplot; β is a vector of unknown parameters Vi is a random variable which is assumed to be independently and identically distributed (iid) N $(0,V^2)$ and independent of Ui and Ui is a random variable that is assumed to account for technical inefficiency in production Following Battese and Coelli (1995), Ui is assumed to be independently distributed as truncation (at zero) of the normal distribution with mean, μ variance σU^2 $(|N(\mu i, \sigma U^2)|)$ where $\mu i = Zi\, \delta$

Where, Zi is a 1xc vector of plot-specific variables that may cause inefficiency and δ is a c x 1vector of parameters to be estimated. The plot-specific stochastic production frontier representingthe maximum possible output (Y*) can be expressed as:

From cobb Douglas production function $Y=f(K,L) = k^{\alpha} L^{1-\alpha}$

$Yi^* = f(Xi^*;\beta) \exp(Vi)$ thus

$Yi = Yi^* \exp(-U)$ Thus, technical efficiency of the i^{th}plot, denoted by

$TEi = Yi/ Yi^* = \exp(-U)$

This means the difference between Y and Y * is embedded in the Ui. If Ui = 0, then Y is equal to Y* This means production lies on the stochastic frontier and hence technically efficient and the plot obtains its maximum possible output given the level of inputs. (Dey et-al., 2000) .

Since stochastic frontier production models were proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), there has been a vast range of their applications in literature. Battese and Coelli (1995) proposed a stochastic frontier production function, which has firm effects assumed to be distributed as a truncated normal random variable, in which the inefficiency effects are directly influenced by a number of variables. Given our research objectives, the generalized stochastic frontier model can be expressed for the plotas:

$$Ln\ Y_i = \beta_0 + \beta_1 lnL_i + \beta_2 lnLb_i + \beta_3 lnHl_i + \beta_4 ln\ R_{io} + \beta_5 lnC_i + \epsilon_I$$

Ln = denotes logarithms to base e

Y = the maximum attainable output for a given level of all inputs, measured in quintals.

L = Land area cultivated, measured in hectares.

Lb = labor utilized, measured in cost in birr.

R = Total variable inputs (seeds, fertilizer, pesticides, harvesting bags) used and measured inbirr.

C = the value of total capital equipment (Tractor, hand hoe, bicycle, axe, forked hoe, and sickle) measured in birr.

β i ‘s = are unknown parameters to be estimated.

According to Aigner, Chu and Lovell (1977), the error term is really a composite of two terms:

where $\epsilon i = Vi - Ui$; $i = 1 \ldots N$

where Vi = represents independently and identically distributed random errors N $(0,\sigma v^2)$ This are factors outside the control of the firm.

Ui = represents non-negative random variables which are independently and identically

distributed as N $(0, \sigma u^2)$ i.e. the distribution of Ui is half normal. |Ui|>0 reflects the technical efficiency relative to the frontier production function. |Ui|=0 for a firm whose production lies on the frontier and |Ui|>0 for a firm whose production lies below the frontier

Knowing that firms are technically inefficient might not be useful unless the sources of the inefficiency are identified. Thus, the second stage of thisanalysis investigates the sources of the plot-level technical inefficiency. The model specification will be.

$Ui = \delta 0 + \delta 1\ Z1 + \delta 2\ Z2 + \delta 3\ Z3 + \delta 4\ Z4 + \delta 5\ Z5 + Wi$

Z1 =land size in hectares

Z2= cane age in month

Z3= cane variety

Z4=Soil type

Z5= cane type

Wi =an error term that follows a half normal distribution

δ I's= inefficiency parameters to be estimated

3.5. Variable Description

These sections provide the description of variables used for the analysis which include the output quantity , input cost, input quantity and the input qualities variable.

Variable of the Study in the Area

Type of Variable	Variables	Description
Dependent		
	Production	Production of sugar cane in quintal during the year 2012/13
Independent		
	Land	The amount of land in hectare planted with sugar cane by Wonji/Shoa Estate Farm
	Equipment	The total cost of tractor and other machineries that are used for land preparation measured in birr
	Labor	The total cost of labor that are engaged in the plot measured in birr
	Material cost	The total cost for fertilizer and pesticides measured in birr
	Can age	The age of sugarcane at the time of harvest in month

Cane variety	The type of sugar cane variety which is a dummy variable labeled from 1up to 5
Soil type	The type of soil in the area which is a dummy variable labeled from 1up to 5
Cane type (ratoon)	The type of rationing which is a dummy variable labeled from 1up to 7

4. RESULTS AND DISCUSSION

4.1. Descriptive results

4.1.1. SummaryStatistics of The Variable

Production of Sugar Cane

The total production of sugarcane production varies from one plot to other plot . The variation which emanates from the plot the mean average output was 14,937 quintals but the minimum production 855quintals and the maximum production under plot was 48,061 quintals.

Land

Are is the major determinant of the sugar cane yield, the mean hectare of land from the total plot is 12 and the maximum area under the observed plot is 25 hectare , the minimum area is 1 hectare which is expected to constitute a low yield of sugar cane.

Equipment

The Equipment constitute the total cost of tractors and other for land preparation like uprooting, plowing, harrowing, sub soiling, and planning, the estate uses renting and purchasing of this tractors. The maximum cost that incurred during the study year was 218,630 birr with a mean of 31,489 birr.

Labour

Labour cost is a cost that is paid for the labor that is engaged in cane planting, cane husbandry, cane cutting and other activities there are 1230 laborers in the Wonji/Shoa Estate Farm and among this 607 are semi-permanent and 623 are seasonal.

Material

The Material includes both the cost of fertilizer and pesticides the mean material cost 33495 and the maximum material cost is 247,645 birr.

Cane variety

The total area of each plot at wonji Sugar cane estate plot during the study year planted on 4,792hectares of land incorporate of 5 types of seed cane variety which is 5percent of N-14 type of seed cane, 32 percent of NCO334 type of cane variety, 35 percent of B52298 type of seed cane variety, 13 percent of Mex 54 seed cane type of seed cane variety and 13 percent of Co-680types of seed cane were captured by 4, 792 hectares of land during the study year.

Cane Age

The maximum cane age from the 153 observation of plot of sugar cane is 30 months and the minimum age is 12 months with mean 23 months as the study Wonji estate (2001) confirms that the optimum age to get the best yield from sugar cane is at the age 23 of month

Soil Type

According to FAO/UNESCO (1972) soil classification system , the levee soils that occur along the river course are categorized under Fluvisol/Entisol while the adjacent basin formations (the basin proper and back swamps are categorized under vertisol. The soils in the cane plantation of the estate are divided into the following five basic categories.

Description of the Soil Type AtWonji/Shoa Estate Farm

S.n	Physiography	Description	SMG
1	Alluvial back swamp	Clayey black soils	A1
2	Alluvial Basin	Clayey black soils	A2
3	Alluvial levee	Loamey brown soils	BA2
4	Piedmont Colluvial	Sandy brown soils	B1.4
5	Alluvial levee	Sandy brown soils	C1

From the above classification in the table the pre dominant soil type in the estate plot is C1 type which is followed by A2 type of soil which consists of 23 present of the total harvested area the final soil type BA2 type of soil which holds 8 present of the area

Cane Type (Ratooning)

Cane type or Ratooning (from Spanish retoño, "sprout") is a method of harvesting a crop which leaves the roots and the lower parts of the plant uncut to give the ratoon or the stubble crop. The main benefit of ratooning is that the crop matures earlier in the season. Thus at WWSE from the observed 153 data 29 % of the cane type or ratoon is 7^{th} and the 28 % is 1^{st} ratoon. The descriptive results of the variables are presented in the table below

Results for the variable description

Variable	Unit Of Measurement	Minimum	Mean	Maximum
Production of Sugar Cane	Qt	855	14,937	48,061
Land	Ha	1	12	25
Equipment	Br	12586	31,489	218,630
Labor cost	Br	291	24059	181329
Material	Br	9500	33495	247,645
Cane Age	in month	12	23	30
Cane Type (Ratooning)	no.	1^{st}	5th	7^{th}

4.1.2. Current Sugar Cane Production at Wonji/Shoa

The sugarcane plantation land of the two factories is 7,000 hectares out of which 1,000 had been planted by out growers.Both cane cultivation plot and factory plant expansion project has come into its completion in July, 2013. Accordingly, the newly built and highly automated Wonji/Shoa Sugar Factory wasinitiallyhasa capacity of crushing 6,250 tons of cane a day and producing 174,946 tons of sugar per annum with further expansion will reach up to 12,500 TCD maximizing its production to 220,000 tons of sugar a yearby2020 (Source). At the same time the new plant is assumed to have a capacity of producing 10,000 meter cube ethanol per annum with further expansion expected to reach 12,800 meter cube(Ethiopian Sugar Corporation annual sweet newsletter 2013),

The newly built Wonji Shoa Sugar Factory Expansion Projects of Existing Sugar Factories Its agricultural expansion project is currently being carried out around the areas known as WakieTiyo, Welenchiti and North Dodota areas. (Ethiopian Sugar Corporation annual sweet newsletter 2013).

The Wonji Irrigation Scheme is the first commercial large-scale irrigation project in Ethiopia (Wonji- Shoe Sugar Estate Plot (WSSF) 2006 Annual Report). Wonji- Shoe Sugar Estate Plot is crossed by Awash River, the only perennial river in the Awash basin. The river divides the sugar plantation into two: west-bank and east-bank.

Plot water application is through furrow irrigation system where the water in the feeder ditch (malang) is diverted to furrows by raising the water level in the malang using canvas dam. Opening and closing of furrows is possible by the aid of a shovel. Irrigation is practiced with block ended furrow system with a furrow length of 32, 48 and 64 m. The excess water is drained from the plot through the network of surface drains: plot drains which collects water from the plot and conveys it into the collector drains and the collector drains convey to the main drains which then conveys the drainage water directly to the Awash River.

The irrigation water is diverted to the estate from Awash River using eight centrifugal pumps (with combined capacity of 5.5 m^3s^{-1}) and then to masonry lined main canal of 480 m. In addition, there are small size pumps, which irrigate the out grower farmers area. The water is then distributed to two branch canals, then to a number of different size canal network. There are different night storage reservoirs (seven main, and twelve tertiary) distributed across the estate to store water during the continuous pump operation in the night time from Awash River.

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Plate .1 Cane Production on Furrow in Wonji/Shoa Estate Farm.

Water loss from Irrigation

At Wonji/Shoa Estate Farm the irrigation water is diverted from Awash River using eight centrifugal pumps (with combined capacity of 5.5 m^3s^{-1}) and then to masonry lined main canal of 480 m. In addition, there are small size pumps, which irrigate the out grower farmers' area. The water is then distributed to two branch canals, then to a number of different size canal networks. There are different night storage reservoirs (seven main, and twelve tertiary) distributed across the estate to store water during the continuous pump operation in the night time from Awash River.

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Hydraulic performances study of the irrigation canals of Wonji estate scheme, conducted by Habib (2005), suggested that non uniform top and bed dimensions; absence of measuring structures; siltation of reservoirs and canals; and seepage losses from canals were the main problems for proper water management operations and were causes for shallow groundwater table of the irrigation scheme. A study conducted on identifying causes of ground water rise by Yusuf et al. (2010) identified that applications of excess irrigation water and seepage from canals were major causes and both are related to poor irrigation water management practices of the estate.

Based on conditions of canals and visual observations, various reports have estimated that seepage losses from supply canals may reach up to 20% to 40%.

Problem of water table

In irrigated areas, the spatial and temporal variability of groundwater table can be of great economic and environmental importance (Olumana, 2010). Shallow GW levels are the results of any or the combination of the soil property, topography of the area, drainage facilities and most importantly un-controlled irrigation water management. Shallow GW levels can cause crops to perish and agricultural plots to become inaccessible for machinery and harvesting operations. A large proportion of irrigated land in WSSE(Wonji/ Shoa Estate Plot) is affected by water logging due to the continuous furrow irrigation, partial inundation requiring large amount of water, in the absence of optimum irrigation scheduling and appropriate drainage system. The shallow water table (drainage problem) in the cane plantation is clearly observed and as the result the area is susceptible to perched water table. Cane loss due to this problem is economically significant and even touchy (Dilsebo, 2015).

4.1.3. Sugar Cane and Sugar Production

The production of sugar cane and sugar production for 14 consecutive years of Wonji/ Shoa Sugar Factory is showed in Table 1. From the table I it can be seen that the maximum production of sugar cane was during the year2011/12 which is 5282 hectare of land the high production of sugar cane is because of the Estate plot has manage to expand to plant sugar cane, and the minimum production was at the year 2012/13 which was 2777 ha the reduction of sugar cane is as a result of the factory's in expansion process.

Table 1. Wonji/Shoa Sugar Factory Sugar Cane and SugarProduction

S.no	Milling Season	Total area harvested (hectare)	Average age (month)	Total Cane production in Qts	Productivity Cane/hectare /Month	Production of sugar in ton
1	2000/'01	4,106	17.6	6,166,420.	87	71,244.5
2	2001/'02	3,905	18.6	5,935,665.	82	73,163.3
3	2002'03	4,379	18	6,294,312.	80	74,045.1
4	2003/'04	4,110	17.3	6,282,340.	88	72,515.8
5	2004/'05	4,173	17.9	6,370,668.	85	74,191.6
6	2005/'06	4,094	18.3	6,153,118.	82	73,721.7
7	2006/'07	4477	17.3	6,045,737.	78	70,414.0
8	2007/08	4181	15.8	4,880,358.	74	57,375.0
9	2008/09	4783	16.4	5,951,260.	76	70,409.0
10	2009/10	4579	16.4	5,341,443.	71	60,394.0
11	2010/11	4904	16.9	640,791.0	77	75,220.0
12	2011/12	5,281	16.3	6,285,820.	71	70,113.0
13	2012/13	2,777	19	362,951.3	69	42,091.0
14	2013/14	4,718		6,417,040		77,051

Source: Ethiopian Sugar corporation's data

As it can be observed from the graph the productivity of sugar cane is declining as the time passes and the total area that is harvested is declining so productivity is the major factor for the production of sugar cane.

4.2. Econometric Results

This chapter discusses the results of the estimation of the Stochastic Frontier Approach (SFA) . Both the error component model and technical inefficiency effects model were developed using the one step approach. The estimate of technical efficiency and the value of technical inefficiency component were also predicted, without violating different distributional assumptions attached to ui, using the maximum Likelihood method in Stata13.0. In this chapter Cob-Douglas production functionwasused. The distributional assumptionsis half-normal distribution of error term, ui. The effect of these distributional assumptions on technical efficiency levels of each plot was investigated. Nonetheless, analysis was made using this half normal distribution of stochastic frontier model.

The stochastic and inefficiency models estimated before the data are transformed show that most variables in error component model and technical inefficiency effects model are statistically insignificant (see Appendix 1). However, lamda ʎ (the variance parameter showing the ratio between the normal error term and half normal positive error term) is statistically significant. This verifies the fact that there are measurable inefficiencies in cane production probablycaused by differences in age and type of cane as well as the soil type of the area. The value of gamma, furthermore, signifies us that around 80% of variation in the model are caused by technical inefficiency. The result from this model also illuminate that the mean technical efficiency of sugar canefor each plot at Wonji/Shoa Estate Farm is around 77%.

4.2.1. Hypothesis Testing of Efficiency and In Efficiency

After the important test have been made it was followed that the γ value of 0.80 was found and interpreted as, 80% of the variation in output among plots is explained by technical inefficiency.The second test, following the existence of inefficiency, is to check if there exist one or more variables that could explain the variation in technical inefficiency. Since the calculated LL ratio value (38.39) is greater than the critical value of LL ratio (20.69) the null hypotheses that determinant variables in the inefficiency effect model are simultaneously equal to zero is rejected.

4.2.2. Production Frontier and the Technical Efficiency Estimates

The results of maximum likelihood (MLE) and ordinary least square (OLS) of the cob Daglas SFPF are presented in the Table 3theinput coefficients in the two models are positive as expected and significant at 1 percent level except for the coefficient of material cost which is not significant. The sum of the coefficients is 1.04 indicating increasing return to scale. The largest contributor to sugar cane production in wonji sugar factory is area which has an elasticity of 0.88 this means a 1 percent increase in land will increase the sugar cane production by 0.88 percent.

The labor cost have positive sign and significant to the production of sugar cane that is increasing one percent in Labour input cost in birr increase output by 0.06 percent. The coefficient is less because most activities like plowing and other land preparation in the plot are done by tractors and other machineries.

Contrary to many studies, output has lower responsiveness to material cost, showing material cost is less productive factor of production in the maintenance of sugar cane farming at wonji sugar factory.

As expected Equipment cost has positive sign and significantly determine the output and is the second largest coefficient with 0.15 this implies that increasing one present cost of Equipment cost will lead to 0.15 present increases in sugar cane. The results are shown in table 2.

Table 2.MLE of the Stochastic Frontier and OLS Production Function for Sugar Cane Estate Farm

Variable	MLE		OLS	
	Coef.	**P>|z|**	**Coef.**	P>|t|
Ln(area)	0.882***	0.000	0.873***	0.000
Ln(Equipment)Cost	0.15***	0.000	0.06***	0.000
Ln(LabourCost)	0.062***	0.001	0.097***	0.000
Ln (MaterialCost)	0.0090	0.679	0.0255	0.172
Constant	6.11***	0.000	5.591***	0.000
Variance				
$sigma^2$	0.1460	0.120		
Gamma	0.80***	0.037		
Lambda	1.98***	0.0082		
Log likelihood	-12.687			
$chibar^2(01)$	6.51			
Wald $chi^2(4)$	1185.53			
Adj R-squared			0.871	
F-statistics			257.62	

*** is significant at 1 %

Source own survey

4.2.3. Variance Parameters

Maximum likelihood estimates was used to estimate the gamma value with the estimation of mean technical efficiency and the value of parameter estimates for the inefficiency effects model.

The theory says that the true value of gamma should be greater than zero but less than one and its value can be calculated through the estimated values of variance parameters lambda λ through σ_u/σ_v The maximum likelihood estimates (MLE) of the stochastic frontier production function estimates a positive coefficient of variance parameter ($\sigma\ u^2$) which is significant at10% level and shows goodness of the distributional assumption of the composite error term.

The value of gamma (γ) was calculated by the formula $\sigma^2 u/\sigma^2$, which is 0.80 and significant at 1% level indicating 80 % variation in sugar cane yield due to inefficiency factors. However, 20 percent of the variation in output was due to random noise beyond the control of Estate plot. Examples of such random shocks include weatherfloods, bushfires and diseases. These values are in the ranges of the findings of many of the research works reviewed (Hasan and Islam 2010, Teshome, 2005, Khairo and Battese, 2004, Oji *et al*., 2007).

4.2.4. Estimation of Plot Level Technical Efficiency

From table 3 frequency distribution of mean technical efficiency of sugarcane producing of plot units of Wonji/Shoa Estate Farm there is a big gap between plot units ranging from mean technical efficiency 96 % to 10 %. Accordingly this variation as caused by seed variety, age of sugarcane on time of harvest, cane type, soil type and area are the predominant variable that affect the technical efficiency of plot units of Wonji Estate Farm. As it is observed from the value of gamma which is 80 % implying the total variation in technical efficiency is caused by inefficiency variables

The highest frequency of Mean technical efficiency range is between 81 and 90, where the number of plot units in this range is thirty four (70) plot units of Wonji/Shoa Estate Farm46 percent of total plot units of Wonji/Shoa Estate Farm, where as the second maximum efficiency range lies between 71 and 80 which is 36 plot units and 24 percentage of the total plot units of the study area.

The number plot units under the range of 90 to 100 mean technical efficiency is 12 plot units involving 8 percentages of total plot units of Wonji/Shoa Estate Farm where as the range between 61 to 70 mean technical efficiency holds 18 plot units as per the result estimated using stochastic frontier model.

Generally among the total plot units of Wonji/Shoa Estate Farm as maximum mean technical efficiency range exist, also minimum mean technical efficiency range also persist incorporating 2 plot units and 0.7 percentages of the total plot units of the study area respectively. The other mean technical efficiency range is represented by the table for further understanding refer totable 3.

Table3.Frequency Distributions of Technical Efficiency of Wonji/Shoa Sugar cane Estate Farm

Efficiency range	Frequency	%age
10-20	2	1%
21-30	1	1%
31-40	0	0%
41-50	1	1%
51-60	13	8%
61-70	18	12%
71-80	36	24%
81-90	70	46%
90-100	12	8%
Average Technical Efficiency		77

Source own survey

4.2.5. The factors of Technical Inefficiency

In the analysis of technical inefficiency effects model, the sign of coefficients of the model is
taken in to account based on the analysis of (Coelli, 1996). If the coefficient of the parameter in the model is positive, it means that the variable is increasing the level of technical inefficiency of the farmer and whereas, if the sign of the coefficient of the parameter is negative, it shows that the variable under consideration is

decreasing the level of technical inefficiency or increasing the level of technical efficiency of the production of sugar cane.

The inefficiency factors were estimated by using the estimated (σ) coefficients of the inefficiency effects. The inefficiency effects were specified as those related to **cane age**, **Cane variety**, **Area** and **Soil type** under sugar cane.

Area: -The relative size measured by the total area of land operated on each plot was supposed to determine in efficiency difference among the plots. It was hypothesized that production of cane operated in large area of land are more efficient than smaller ones. The result in Table shows the coefficient of area is negative, which shows a negative relationship with technical inefficiency.

Cane age: -as the study made by the Wonji estate (2001) the coefficient of cane age is negative as well as insignificant and relationship between cane age and technical inefficiency is negative which means as the age of increases the better the yield of the sugar cane. The maximum age for sugar cane is at 23 month.

Cane variety: -The coefficient of cane variety is positive (0.004) as well as insignificant showing that the relationship between cane variety and technical inefficiency is negative. The inefficiency effect of the sugar cane varieties is positive and it indicates that**Nco-334 variety** is the best seed variety for production of sugar cane and the next best variety is N-14 but at Dejene (2013) study it was found that N-14 Variety was first, the lowest contributor to the technical efficiency is B52-298 variety.

Soil type: -The other important variable affecting technical inefficiency of sugar cane production is soil type. The measure of soil type is constructed by forming soil management group based on previously studied results made by Wonji sugar factory by physiographic character of the soil. The soil in the cane plantation of the estate are divided in to five categories this are:- Alluvial back swamp, Alluvial basin, Alluvial levee , piedmont collvial and Alluvial levee . Even though the type of soil insignificantly influences technical inefficiency of the production of the sugar cane it has positive effect. Operating on Alluvial levee soil type seems to be more technically inefficient than operating on Alluvial back swamp.

Cane type (ratoon): The coefficient of cane type is negative (-0.002) as well as insignificant showing that the relationship between cane type and technical inefficiency is negative. The Inefficency results are shown on table 2

Table 4 InefficiencyStochastic frontier normal/half-normal model

Variable	Coef.	Std. Err.	z	P>|z|
Lnareainha	-0.01	0.018	0.580	0.565
LnCaneage	-			
	0.020	0.068	0.290	0.774
Cane variety	0.004	0.006	0.550	0.583
Soiltype	0.001	0.005	0.270	0.789
Canetype	-			
	0.002	0.005	0.390	0.696
cons	0.303	0.222	1.360	0.172

5. CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

The empirical results predict that technical inefficiency effects were significant in explaining the yield for Wonji Sugar Cane Estate plot units. The mean technical efficiency was estimated at 77%. The inefficiency model indicated that all plot units were less efficient in their production and lost to the tune of 23% of their potential output. These losses differ from one plot units to another. Some Plotunits had a slightly higher technical efficiency than other plot units.

The mean technical efficiency for the plot units was 0.77 compared with the minimum of 10% and 96% of the maximum technical efficiency for the plot units of wonji sugar can estate plot. This revealing that almost plot units have mean technical efficiency of 77%. The predominant variables that induce variation in level of technical efficiency in the study were Seed variety, cane age, area, cane type and soil type.

Regarding the level of ground water and its effect as the information from different researches and interviewed staff ofWonji/Shoa Estate Farm shows that, the plot is facing a serious problem in land (seed bed) preparation and late harvesting operations. The first problem (late commercial cane planting), since sugarcane has optimum planting period, affects the normal growth of sugarcane (germination, stock population, tillering, stock height), which are indicators for final sugar yield (quality and quantity). Delayed time for harvesting operation (beyond the normal growing period) has economic implications because of its effects on the yield as well as land preparation (in case uprooted), the later effect will result in the problem of delayed seed plantation. Delayed harvesting will reduce crop yield per hectare per month as well as the deterioration of sugar quality. Sugarcane requires adequate moisture supply throughout the growing period (i.e. establishment, early vegetative, stem elongation and early yield formation) in order to obtain the maximum potential yield. Sugar content seems to decrease with increased cane tonnage yield. Therefore, cane harvesting should be done at the most suitable moment when an economic optimum of recoverable sugar per area is reached. However, water surplus during the late growing periods (stem elongation and maturity) has an adverse effect on the yield than the water surplus during the first periods (establishment and early vegetative (tillering). Excess (frequent) during the yield formation period has an accelerating effect on flowering, which is not desirable as far as sugar production is concerned since its significant reduction of sugar yield (both quality and quantity) .Therefore, efforts on the management of water resources, especially ground water in such areas is extremely important for the sustainability of agriculture.

Canal performances were highly affected by deformed canal shapes and trees grown along an embankment which is manifested by very slow water velocity. Leakages because of damaged canals, canal breaches and broken structures were also causing large quantities of water to be wasted. Such conditions lead not only to inadequacy, but also to inequity, in water supply. Hence, water losses should be minimized.

The need for rehabilitating the irrigation system demonstrate that the system has previously not been properly maintained and control structures are frequently reported as being either in a very poor condition or very inoperable. Moreover, addressing of the entire canal network is necessary due to the fact that seepage and leakage are not limited to specific canal category and to some parts of canal network. Most of the canals and canal structures have problems with comparable magnitude.

5.2. Recommendations

The mean technical efficiency of Wonji sugarcane Estate Plot found in this study is77% where as the maximum and minimum technical efficiency is 96 % and 10 % respectively. Thus, there is a need to increase the technical efficiency by 23% by adopting the following points

- The pump irrigation type of sugarcane watering system is highly prone to suffer from hydroelectric power fluctuation and as well it is time taking to access all over plot units if once interrupted because of hydroelectric power break which have a significant impact on reducing the technical efficiency of sugar cane yield. There for enough generators should be available in such situations, in regard to the water loss from the canals

- Rehabilitating of the canal system is necessary before lining with lining materials. After that lining of selected canals with any lining material is preferable. The work must be started from upper reach of the scheme and should go down to smaller canals following topography and discharge capacities. Besides, repairing of water controlling structures at each junction along the way should be carried out simultaneously.

- The other recommendation is for each plot unit plots it is better to use the maximum age at 22 month , more of 22 month or less will cause the yield of sugar cane to decrease .

- It is better to expand N-co -334 type of seed cane variety which directly related to technical efficiency of plot units. This is to mean, a plot unit with appropriate seed cane variety N-co -334 is less technically inefficient than a plot unit with other types of seed selection (B52298,OV, CO421 and N-14). This result shows that N-co -334 seed cane Variety is the best and most producing and maximum output among all the seed cane variety.

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7. Annex

Annex table 1 Correlation matrix of coefficients of regress model

e(V)	Lnarea~aLnMech~tLnMann~tlnMate~tlnCane~hCaneVa~ysoiltypecanetypecons								
Lnareainha	1.0000								
LnMechanic~t	-0.3556	1.0000							
LnMannualC~t	-0.4243	-0.0584	1.0000						
lnMaterial~t	-0.2963	-0.0198	0.1589	1.0000	.				
lnCaneagei~h	0.0802	-0.4198	-0.2122	-0.1743	1.0000				
CaneVariety	0.1398	0.0230	-0.0912	-0.1192	-0.0013	1.0000			
Soiltype	0.0560	0.0649	-0.0219	0.1549	0.0896	0.0101	1.0000		
Canetype	0.2970	-0.7495	-0.1092	0.0117	0.2378	0.0085	-0.035	1.00	
Cons	0.1398	0.2138	-0.2297	-0.2510	-0.7768	-0.0330	-0.2966	-0.0501	1.00

In the above table none of the value is greater than 0.80 which suggests that the basic assumption of multico linearity has not been violated so multico linearity problem does not exist in the model.

Annex table 2 The VIF of a variable

Variable	VIF	1/VIF
LnMechanic~t	3.87	0.258657
Canetype	2.57	0.388378
Lnareainha	1.92	0.520496
LnMannualC~t	1.66	0.603875
lnCaneagei~h	1.65	0.606506
lnMaterial~t	1.28	0.77836
Soiltype	1.11	0.900836
CaneVariety	1.03	0.968126
Mean VIF	1.89	

As shown in the table none of the variable are more than 10

Annex table 3 descriptive results

tabulatesoiltype

soiltype	Freq.	Percent	Cum.
1	21	13.73	13.73
2	11	7.19	20.92
3	27	17.65	38.56
4	11	7.19	45.75
5	19	12.42	58.17
6	15	9.80	67.97
7	49	32.03	100.00
Total	153	100.00	

. tabulatecanetype

canetype	Freq.	Percent	Cum.
1	44	28.76	28.76
2	32	20.92	49.67
3	20	13.07	62.75
4	7	4.58	67.32
5	4	2.61	69.93
6	1	0.65	70.59
7	45	29.41	100.00
Total	153	100.00	

. tabulateCaneVariety

CaneVariety	Freq.	Percent	Cum.
1	49	32.03	32.03
2	9	5.88	37.91
3	21	13.73	51.63
4	20	13.07	64.71
5	54	35.29	100.00
Total	153	100.00	

. . summarizeCaneVarietysoiltypecanetypeinefficency Efficiency Production Area EquipmentCostMannualCostMaterialCostCaneage

Variable	Obs	Mean	Std. Dev.	Min	Max

CaneVariety	153	3.137255	1.697749	1	5
soiltype	153	4.54902	2.19731	1	7
canetype	153	3.509804	2.460524	1	7
inefficency	153	.22733	.1343653	.04227	.900
Efficiency	153	.7730	.1344398	.1	.96
Production	153	14937.38	10078.64	855	48
Area	153	12.5719	6.679236	1.04	25.2
Equipment~t	153	31489.07	50725.27	164.74	218630.1
MannualCost	153	24059.01	29505.67	290.62	181329.1
MaterialCost	153	43121.17	33495.54	0	247645.9
Caneage	153	23.52941	3.937102	12	30

. tabulateCaneage

Caneage	Freq.	Percent	Cum.
12	1	0.65	0.65
17	8	5.23	5.88
18	7	4.58	10.46
19	12	7.84	18.30
20	14	9.15	27.45
21	14	9.15	36.60
22	12	7.84	44.44
23	8	5.23	49.67
24	7	4.58	54.25
25	9	5.88	60.13
26	17	11.11	71.24
27	11	7.19	78.43
28	19	12.42	90.85
29	8	5.23	96.08
30	6	3.92	100.00
Total	153	100.00	

. summarize, separator(10)

Variable	Obs	Mean	Std. Dev.	Min	Max
Lnproducti~t	153	9.362876	.7602689	6.75	10.78
Lnareainha	153	2.354379	.6565969	.04	3.23
LnMechanic~t	153	8.851634	1.865681	5.1	12.3
LnMannualC~t	153	9.540654	1.077888	5.67	12.11
lnMaterial~t	153	10.2666	1.297019	0	12.42

lnCaneagei~h	153	3.14366	.1753596	2.48	3.4
CaneVariety	153	3.137255	1.697749	1	5
Soiltype	153	4.54902	2.19731	1	7
Canetype	153	3.509804	2.460524	1	7
Inefficiency	153	.2273338	.1343653	.0422743	.9002381

Annex 4 econometrics results

frontierLnproductioninqtLnareainhaLnEquipmentCostLnMannualCostlnMaterialCost

Stoc.frontier normal/half-normal model Number of obs = 153
Wald chi2(4) = 1185.53
Log likelihood = -12.686958 Prob> chi2 = 0.0000

Lnproductioninqt	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Lnareainha	.8817466	.0429768	20.52	0.000	.7975137	.9659795
LnEquipmentCost	.0615024	.0130353	4.72	0.000	.0359538	.0870511
LnMannualCost	.0857824	.0255547	3.36	0.001	.0356962	.1358686
lnMaterialCost	.0088265	.0213557	0.41	0.679	-.0330299	.0506829
_cons	6.103858	.315047	19.37	0.000	5.486377	6.721339
/lnsig2v	-3.525337	.3667179	-9.61	0.000	-4.244091	-2.806583
/lnsig2u	-2.151754	.3249315	-6.62	0.000	-2.788608	-1.5149
sigma_v	.1715864	.0314619			.1197864	.2457867
sigma_u	.3409985	.0554006			.2480055	.4688604
sigma2	.1457219	.0302687			.0863962	.2050475
Lambda	1.987328	.08211			1.826395	2.148261

Likelihood-ratio test of sigma_u=0: chibar2(01) = 6.51 Prob>=chibar2 = 0.005

Anextable 5 OLS estimates result

regressLnproductioninqtLnareainhaLnEquipmentCostLnMannualCostlnMaterialCost

```
     Source |       SS       dfMSNumber of obs =     153
-------------+------------------------------          F(  4,   148) =  257.62
Model |  76.8238713     4  19.2059678         Prob> F      =  0.0000
 Residual |  11.0334574   148  .074550388         R-squared     =  0.8744
-------------+------------------------------          Adj R-squared =  0.8710
      Total |  87.8573287   152  .578008742   Root MSE      =  .27304
```

Lnproductioninqt	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Lnareainha	.8734841	.0440733	19.82	0.000	.7863898	.9605783
LnEquipmentCost	.0596983	.0142269	4.20	0.000	.0315842	.0878125
LnMannualCost	.0969121	.0256751	3.77	0.000	.046175	

	.1476492					
lnMaterialCost	.0254967	.0185761	1.37	0.172	-.011212	.0622054
_cons	5.591566	.2653999	21.07	0.000	5.067103	6.116029

Data of input and out put

s. N.	Production of sugar cane in quintal	Area	Equipment Cost	Labour Cost	Material Cost	Cane age	cane per ha	Efficiency
1	33134	23.12	10434.9	31214.4	105768	28	1031.96	0.87
2	20254	18.86	4655.58	8583.06	73055.8	23	797.458	0.85
3	14238	12.57	1856.73	24973.8	57757.6	23	1324.06	0.83
4	6816	4.21	3519.35	14926.6	28392	26	1245.78	0.89
5	14609	17.2	10517.5	11148.1	67906.5	22	932.632	0.77
6	23219	22.5	265.96	11506.7	99453.8	24	779.931	0.87
7	5646	7.08	2624.84	11673.2	31339.7	24	790.556	0.63
8	12326	10.25	2292.95	10236.9	50553.5	28	1033.26	0.79
9	4797	9.6	2303.07	4002.41	14429.1	28	1208.64	0.2
10	14002	9.2	7173.41	5223.92	42958.4	26	807.822	0.91
11	17993	23.07	5465.05	29776.1	80871.7	26	865.722	0.6
12	19922	25.2	5631.51	24961.4	89857.4	25	527.66	0.65
13	23889	23.12	4464.62	29974.4	107199	28	936.128	0.76
14	13706	11.34	7266.59	7519.06	58851.3	23	1164.35	0.89
15	5267	6.52	2425.83	5166.36	23362.9	27	979.159	0.59
16	6112	7.06	1269.07	3065.15	30399.2	19	643.909	0.85
17	9672	18.33	2796.33	27841.4	26344.3	26	1032.22	0.3
18	24604	22.45	12980.8	26308.4	27337.3	27	1089.77	0.74
19	7929	8.47	4945.15	8795.59	38202.1	27	1309.64	0.67
20	10712	9.2	4060.47	68993.3	43404.9	22	1807.63	0.83
21	19265	12.7	4168.08	87499.7	56209.9	28	1454.15	0.83
22	7847	9.48	6619.47	3854.97	5263.25	20	779.177	0.74
23	14761	10.21	2691.79	19357.9	10424.8	27	1676.71	0.87
24	15476	12.7	4411.47	35597.3	57145.3	21	1304.99	0.89
25	2844	2	361.43	14321.5	13525.9	18	1218.58	0.92
26	25954	22.42	5219.8	21218.3	87462.1	24	1422	0.86
27	17388	13.81	5114.8	40276.5	63025.7	26	1157.63	0.83
28	8998	11.24	1564.05	6337.12	40435.8	21	1259.09	0.75
29	9471	10.82	2322.37	4366.25	39088	21	800.534	0.81

s. N.	Production of sugar cane in quintal	Area	Equipment Cost	Labour Cost	Material Cost	Cane age	cane per ha	Efficiency
30	18885	10.72	4000.69	73809.9	1304.74	27	875.323	0.89
31	13962	13.02	2503.89	21838.3	247646	28	861.085	0.72
32	12894	13.98	164.74	10848.6	10181	20	730.573	0.81
33	10453	6.07	45534.9	55906.7	30928.4	28	1007.38	0.85
34	19355	15.36	3930.68	126855	1304.74	26	822.115	0.8
35	38139	22.41	3191.64	23759.5	56594.3	28	1372.2	0.9
36	37157	22.93	11040.2	21263.4	20799.8	26	1452.8	0.9
37	10114	7.14	2490.04	15967.7	31323	25	1676.64	0.84
38	2061	1.75	774.12	2168.25	2015.32	18	862.767	0.87
39	5160	4.4	282.71	2967.88	21891.7	20	1731.31	0.88
40	23307	14.39	1687.62	9488.27	68254	25	1072.35	0.92
41	37063	22.47	8541.88	27204.5	110782	28	1083.02	0.9
42	10112	7.25	1445.22	10209.8	14893.5	29	1304.98	0.82
43	9052	9.05	853.12	78866.7	35899.9	25	1973.76	0.65
44	10533	10.53	1703.12	17500.2	45758.9	25	1453.25	0.72
45	28121	23.44	20085.2	27120.3	100295	28	1260.09	0.77
46	5064	6.46	1376.22	4477.28	23362.9	22	622.429	0.63
47	4999	4.79	710.93	3384.29	4226.2	20	1345.52	0.84
48	7918	9.48	7817.08	6968.15	37699	21	300	0.7
49	13623	22.77	4214.67	3215.57	24976.3	18	870.845	0.69
50	3552	3.02	316.43	1386.04	12037.7	20	1132.2	0.9
51	15598	15.93	6239.88	18028.3	66013	26	1069.44	0.73
52	1486	1.92	863.07	3265.29	19241.5	21	1000.22	0.56
53	12001	9.3	6438.67	33554.1	45167.8	21	1000.28	0.87
54	14483	9.9	6438.67	9542.09	45189.9	26	1788.64	0.88
55	15369	13.36	10727.1	17191.8	61260.2	26	849.36	0.77
56	6825	9.73	7630.77	3691.18	41186.1	23	1513.79	0.54
57	10323	14.13	651.89	9976.99	61104.3	22	952.027	0.65
58	15879	15.45	2373.22	30733.1	42364.5	19	853.652	0.83
59	8341	9.03	537.16	7235.07	55612.7	20	951.997	0.78
60	9314	8.6	9519.01	2704.63	44335.6	22	896.426	0.86
61	2872	4.72	500.13	8220.95	17971.5	17	1011.25	0.53
62	9261	12.72	1943	27167.8	0	17	1508.18	0.68
63	7778	11.24	5403.33	13399.3	13368.5	22	1722.08	0.47
64	23303.4	24.05	7726.11	9767.46	22984.6	22	1649.44	0.78

s. N.	Production of sugar cane in quintal	Area	Equipment Cost	Labour Cost	Material Cost	Cane age	cane per ha	Efficiency
65	11742	11.25	6826.66	8850.12	13368.5	23	1572.77	0.75
66	22232	24.75	8036.28	49711.9	23214.9	20	1325.95	0.74
67	13420	11.95	4956.94	11216.3	52952.5	22	670.154	0.83
68	7569	7.67	2674.06	6502.37	34103.4	29	1549.79	0.6
69	11800	11.67	2026.54	4633.28	2533.28	20	1062.83	0.85
70	3350	2.13	1284.73	3076.09	66432	24	1612.91	0.89
71	2453	1.85	527.38	2782.34	8549.37	30	1063.26	0.74
72	4357	7	1548.24	3401	2635.28	19	1056.58	0.59
73	16052	11.93	52562.8	15255.8	41473.8	25	1066.79	0.85
74	2994	9.98	7752.25	4085.72	19119.5	17	1062.2	0.1
75	6183	7.1	221.63	3991.79	33774.9	19	679.213	0.82
76	7244	4.05	1118.18	4922.67	2356.21	17	1215.44	0.96
77	25269	20.79	7559.3	9855.8	105409	20	1521.96	0.92
78	30427	22.98	10754.9	27015.4	115761	24	598.287	0.9
79	9863	10.36	2361.24	3120.07	49634.3	19	1176.16	0.87
80	7611	11.82	673.67	40426.3	55979.5	18	1663.33	0.62
81	7752	7.51	3806.82	5893.21	27487.7	21	1445.74	0.85
82	5768	5.84	1022.66	5213.03	29328.9	19	1290.43	0.82
83	4038	4.74	1009.45	5095.04	23199.1	17	1462.93	0.77
84	19284	22.59	1469.25	8984.55	108212	19	1150.37	0.83
85	11323	11.24	8340.42	7547.4	50320.2	21	701.439	0.83
86	855	1.04	474.64	15163.2	5301.59	17	1619.67	0.65
87	12633	13.27	247.11	30102.8	64573.7	19	898.263	0.82
88	12039	13.43	1529.41	5070.51	42483.6	19	1123.01	0.84
89	4854	4.8	2116.96	6846.79	33951.2	22	986.832	0.76
90	18564	15.75	3974.28	8588.76	87943.2	21	1011.14	0.87
91	3700	4.91	2494.39	792.46	22015.1	17	652.459	0.75
92	1592	2.44	805.72	290.62	10782.9	20	717.459	0.58
93	9657	13.46	9723.48	7339.98	75156.6	19	1317.72	0.65
94	13899	20.74	2496.61	14529.9	18012.1	21	1111.27	0.58
95	5864	5.55	2043.91	9638.85	30288.6	19	1394.76	0.84
96	2859	2.68	1235.8	2195.58	13304.5	20	788.145	0.82
97	8272	6.64	1426.09	30528.6	36015.7	23	1302.72	0.86
98	13128	11.47	1042.7	7868.62	51668	20	1207.42	0.88
99	5399	6.27	896.6	6207.46	35361.7	20	999.308	0.76

s. N.	Production of sugar cane in quintal	Area	Equipment Cost	Labour Cost	Material Cost	Cane age	cane per ha	Efficiency
100	29248	22.69	9957.09	34917.6	106873	21	982.11	0.87
101	18329	18.99	500.01	13079	95704.8	17	1328.73	0.87
102	16630	11.1	4170.69	8922.43	55148.7	21	773.958	0.91
103	7531	7.09	6530.05	4805.01	31528.9	18	1172.73	0.87
104	3116	3.36	2640.21	10903.7	14030.6	19	927.381	0.72
105	7247	6.65	1107.5	8108.77	30360.1	25	851.899	0.79
106	6732	5.68	11548.2	39198.5	10884.3	18	827.743	0.82
107	10895	7.03	582.15	18063.5	400.74	18	968.956	0.94
108	14979	13.23	9741.41	17067.6	49671.3	21	1043.73	0.84
109	35461	17.24	85851.4	20524.6	15513.8	30	1498.2	0.92
110	27218	17.76	135785	25608	40386.3	28	1433.13	0.85
111	17519	11.94	65864.1	5555.78	35601.5	28	1073.91	0.86
112	38817	23.78	218630	133615	75564.4	30	1132.7	0.82
113	33238	23.65	131228	37083.2	68314.6	29	1619	0.8
114	24486	21.03	106905	23671.9	70279.5	29	2056.9	0.7
115	22042	16.92	101764	53849.4	52572	25	1532.55	0.8
116	23593	19.54	154415	14277.2	164523	26	1467.25	0.8
117	10103	10.11	43914.6	21666.8	29966.9	26	1632.34	0.62
118	4313	6.35	27582.4	17606.8	29039.3	12	1405.41	0.79
119	11089	11.89	82820.2	13018.2	41831.9	24	1164.34	0.68
120	15592	10.3	65755	33810.2	33810.1	26	1202.54	0.86
121	38166	23.31	169620	27387.4	55973.6	29	499.688	0.86
122	34586	24.56	120988	26605.5	81560.6	27	1095.95	0.83
123	18468	12.71	111600	15823.1	34864.9	26	1199.7	0.84
124	23276	23.7	126954	56013.6	67943.2	26	783.901	0.6
125	25671	19.32	169892	52404.8	48709.9	25	1043.63	0.8
126	33200	19.96	82137.5	140468	18488.5	27	835.232	0.86
127	8421	6.43	26585.1	4351.12	24098.9	27	1637.32	0.82
128	11135	6.16	95287.4	14525.3	18776.5	22	1408.22	0.93
129	14207	9.77	83681.1	15344.6	29793.9	28	1453.03	0.84
130	12498	16.04	2795.12	68944	1745.2	20	1516.93	0.64
131	17639	10.52	95783.4	22460.4	29347.1	28	1144.55	0.88
132	17539	13.44	96174.7	54111.2	41591.4	28	987.671	0.75
133	37724	18.63	86085	22140.7	44200.1	28	2024.91	0.92
134	32878	23.96	162860	22366.4	56258.2	30	1761.66	0.8
135	9850	6.78	23393.8	45656.8	19664.6	26	922.318	0.81

s. N.	Production of sugar cane in quintal	Area	Equipment Cost	Labour Cost	Material Cost	Cane age	cane per ha	Efficiency
136	7176	4.28	13985.1	5235.34	9722.87	28	1027.77	0.88
137	10103	11.71	173323	21984.6	10961.9	23	923.699	0.58
138	31908	18.43	166284	4148.87	44539.2	30	1023.91	0.91
139	9635	9.41	39237.6	11985.6	20623.9	23	608.475	0.67
140	34281	22.73	196612	26407	69451.5	27	1701.87	0.86
141	11797	9.04	120187	54111.2	25589.6	28	1620.45	0.7
142	48061	24.35	154739	146794	81753.6	29	1416.53	0.9
143	11408	7.85	21197.3	9023.65	23133.2	27	1177.71	0.84
144	37338	23.93	98553.9	76991.6	54101.2	28	728.066	0.8
145	38605	23.46	124250	181329	80277.8	30	691.993	0.77
146	2957	2.51	2647.18	17789.8	13608.7	27	1178.67	0.56
147	5651	7.17	34304.6	6695.48	19571.9	22	753.564	0.51
148	19331	14.67	52981.7	19144.3	48130.3	29	1289.03	0.73
149	17347	15.61	87371.5	18284.9	38036.5	24	965.192	0.73
150	21044	19.8	88587.4	89343.1	52973.3	22	1185.21	0.71
151	15113	9.37	78841.2	22235.7	29412.7	26	1560.3	0.86
152	10824	10.18	107752	29281.7	19119.5	21	1645.57	0.74
153	10149	9.49	59723.3	81138.5	30807.1	29	1178.09	0.51

Annextable: Technical Efficiency at Plot Unit Level (in %)

Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency
1	87	22	74	44	72%	66	74%	88	84%	110	85%	132	75
2	85	23	87%	45	77%	67	83%	89	76%	111	86%	133	92
3	83	24	89%	46	63%	68	60%	90	87%	112	82%	134	80
4	89	25	92%	47	84%	69	85%	91	75%	113	80%	135	81
5	77	26	86%	48	70%	70	89%	92	58%	114	70%	136	88
6	87	27	83%	49	69%	71	74%	93	65%	115	80%	137	58
7	63	28	75%	50	90%	72	59%	94	58%	116	80%	138	91
8	79	29	81%	51	73%	73	85%	95	84%	117	62%	139	67
9	20	30	89%	52	56%	74	10%	96	82%	118	79%	140	86
10	91	32	81%	54	88%	76	96%	98	88%	120	86%	142	90

Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency	Plot number	Efficiency
11	60	33	85%	55	77%	77	92%	99	76%	121	86%	143	84
12	65	34	80%	56	54%	78	90%	100	87%	122	83%	144	80
13	76	35	90%	57	65%	79	87%	101	87%	123	84%	145	77
14	89	36	90%	58	83%	80	62%	102	91%	124	60%	147	51
15	59	37	84%	59	78%	81	85%	103	87%	125	80%	148	73
16	85	38	87%	60	86%	82	82%	104	72%	126	86%	149	73
17	30	39	88%	61	53%	83	77%	105	79%	127	82%	150	71
18	74%	40	92%	62	68%	84	83%	106	82%	128	93%	151	86
19	67%	41	90%	63	47%	85	83%	107	94%	129	84%	152	74
20	83%	42	82%	64	78%	86	65%	108	84%	130	64%	153	51
21	83%	43	65%	65	75%	87	82%	109	92%	131	88%		
Mean technical efficiency													**77%**