A sugar milling district consisting of a milling facility and an area producing cane in Central Punjab, Pakistan was selected to develop descriptive statistics of yield models and mill performance models as inputs to a larger management optimization model for the scheduling of milling operations and harvesting of the crop. The study indicated that the area planted and harvested was responsive to the mill performance in terms of transportation, weighing and pricing at the purchase centers. The harvests following a flood in the monsoon season had exceptionally good cane yields, whereas drought in the monsoon season results in markedly lower cane yields in the following harvest season. Linear and logarithmic regressions were used for yield modelling using number of plowings, number of irrigations, amount of fertilizer, number of manual hoeings, number of animal hoeings, ground water table depth, age of crop at harvest and month of harvest as inputs. The linear and logarithmic models used explained 33% to 68% variability in the yield and the results include only those inputs which were significant at 99% level of probability. The yield of sugarcane crop gives comparatively better fit as compared with logarithmic regression. The mill performance models for cane crushed and defined sugar bagged were developed by linear regression while the sugar recovery model was developed by quadratic regression.

INTRODUCTION

Sugarcane systems in Pakistan

A particular cane supply management system was chosen for study in Punjab.
jab. This sugarcane district is considered representative of many sugar cane systems in the country. The primary responsibility of the cane management department is to assume steady supply of sugarcane over time for the mill. The department achieves the goal by:

1) Survey system. It may also be referred as the area inventory. There are two periods in which the surveys are conducted. The first period is from June-July and the second period is from February to the first week of March.

The object of the first survey is to determine the total acreage of sugarcane in the mill zone area (MZA) for both sown and ratoon crop.

Hired labor is used for this purpose. Each surveyor is allocated three villages and he has to conduct the survey at the rate of 120 hectares/day. The first survey will thereby yield the total tonnage of sugarcane obtainable from MZA (using an assumption of 37 tons/hectare). This will enable the mill schedule to accept cane from free area outside the MZA.

The purpose of the second survey is to determine the rest of acreage of sugar cane from MZA, which has been previously estimated by the first survey. Hence this survey will help to allocate more indents to those farmers whose production is higher than 37 tons/hectare.

2) Indent Allocation System. This indent allocation system was resorted to because 1) the crushing capacity of the mill is limited (daily), 2) the mill has limited capacity of yard/storage, and 3) sugar content decreases after 72 hours of harvest. Therefore the mill has to schedule the acceptance of sugarcane from the growers in order to have feasibility for the mill and for the growers by indent allocation system. The indent allocation system is as follows:

a) Crushing capacity for the mill is determined (for Sample Sugar Mill, it is 2000 MT/day).

b) Total acreage of sugarcane in mill zone area is determined (16,000 hectares for sugar mill).

Depending on the individual holding size, the permit interval is determined in the following way. If a farmer has 0.8 hectare of sugarcane, then the proportion of his area to the total area in the mill zone is:

$$\text{Proportion (PA)} = \frac{0.8}{16,000} = 5 \times 10^{-5}$$

The rate at which he can supply cane to the mill ($R_{cs}$) = Crushing capacity of mill.

Proportionate area of the farmer (PA):

$$= 2000 \times 5 \times 10^{-5} = 10,000 \times 10^{-5} = 0.1 \text{ MT/day}$$
The means of transportation that the individual possesses determines the Rate of Indent allocation (IR).

\[
IR = \frac{\text{Capacity of the mean of transportation}}{\text{the rate of supply (Rcs)}}
\]

If the farmer has a transportation mean with a capacity of 1 MT, then the Indent Interval Rate (IIR) is:

\[
IIR = \frac{1.0}{0.1} = 10 \text{ days}
\]

Possibilities for Improvement in the System

The major defect in the present indent allocation system is that the ratoon crop is treated in the same fashion as the sown crop. The ratoon crop matures earlier when compared with sown crop. The advantage of early maturity of ratoon is therefore not availed by the mill. Hence there should be a management policy to treat the ratoon independently from sown crop in order to obtain the comparative economic advantages to the grower and to the mill. It is therefore recommended that ratoon should be accepted earlier based on field information. It is proposed that more detailed and frequent surveys be made to make such distinction.

The maturity of the crop is also affected by the depth of water table. Hence accordingly the indents should be allocated to those areas where the sugar cane matures earlier due to the lack of effect of high water table. As such a groundwater contour map should be developed and used as a basis for allocation of indents.

The frost and rainfall are microclimatic elements, information on which if collected at one center location (city) does not apply to all the countryside. Therefore it is recommended to install non-recording raingauge and thermometer at each purchasing station that can be an aid and a good tool for the cane supply department to allocate the indents based on severity of frost and rainfall encountered.

MATERIALS AND METHODS

Production Modelling

Stepwise multiple regression was used for production modelling. The method of stepwise multiple regression is by successively adding variables into regression equation. The variable to be added at any stage is the one which makes the greatest improvement in the goodness of fit or the one which causes greatest variance reduction. At each stage after the variables have been added into the regression, a test for significance of variables already in the regression is also made. If the var-
The important property of stepwise multiple regression is based on the fact that a variable may be indicated to be significant in an early stage and thus enter the equation. After several other variables are added to the regression equation, the initial variable may be indicated to be insignificant. The insignificant variable will be removed from the regression equation before adding an additional variable. Therefore only significant variables are included in final regression equation (Early and Dillon).

**Data Description for Production Models**

The area selected for this study has a large acreage under sugarcane cultivation and the farmers in this area had been growing this crop for many years. Since sugarcane requires a long growth period of time in the field, the study of the current crop was not possible, hence the crop of the preceding season was selected for the study. The collection of the data included the entire period from planting until disposal of the crop. A questionnaire schedule was prepared in consultation with the cane manager of the mill. Since the time available was very short, one farmer was selected randomly from each village. The questionnaire was protested in the area before it was finally accepted. Each farmer was visited separately along with the research officer of the sugar mill to get the desired information. The farmers answered the questions from their memory and results were meticulously recorded in the questionnaire. The survey involved about 30 man-days interview efforts (Ayub).

The information sought related to all farming operations of the sugarcane crop, its cost, its production, returns, hazards and inputs. Besides those types of data, information was also collected which indicated the attitude of the farmer about certain policies and reveal unscrupulous practices surrounding the sugarcane enterprise.

An extensive survey was also conducted throughout the whole mill zone area for the determination of ground water table because this information was not available from the farmer’s interview. The depth of water of persian wells or open wells for at least two sources (either open or persian well) located either in the field or near the fields were selected from each village. The height of the edge of the wall above field was subtracted from the measured depth in order to obtain the ground water table for field conditions. In few villages where there was no source available, the blacksmith who installs the hand pump was interviewed to determine the ground water table depth. The survey involved about 22 man-days (Ayub).

The data was recorded in the following format: the number of plowing, plantings and hoeings, kilograms/hectare of fertilizers, number of bullock cart, volumes of manure, and the age of crop at harvest in days. Since the fertilizers and the manure were nutritive elements, these nutritive contents were accumula-
ted in order to find out the total input values. Standard conversions were used, with a bullock cart of manure weighing 0.75 ton assumed to have 3.5 kg of nitrogen, 2.5 kg of phosphorus and 5.0 kg of potassium.

**Mill Performance Model**

The mill performance models were developed by using linear and polynomial regression. The performance evaluation data like cane crushed and sugar bagged, and recovery was obtained from sugar mill located in the district. A six-year record from October 1969 to April 1975 was used in the development of mill performance model. The description of the data follows:

1) Cane crushed as observed from 07:00 am to 07:00 am the following day and recorded in tons of cane crushed/day.

2) Sugar bagged, as the amount of white sugar refined in tons/day.

3) The ratio of the sucrose content to the total juice, referred to as recovery.

**RESULTS AND DISCUSSION**

**Description of the Study Area**

The area chosen in this study is in district Faisalabad, Punjab, Pakistan. The district lies between east latitudes 73° and 74° and north latitudes 30° and 31.15°.

The climate of the district is on the whole hot and dry. The temperature varies considerably from season to season. The mean maximum temperature in summer is 36°C and minimum 24°C while the winter mean temperatures are 24°C and 8°C. The highest temperature in the hot weather may touch the 49°C mark and the minimum 21°C. In winter the temperature falls considerably and in January it sometimes goes below the freezing point.

**Mill Zone Area and Free Zone Area**

The sugar mill in the district of Faisalabad, Punjab, Pakistan was established in 1960 with the aim to overcome the sugar shortage in the country. In order to have the assurance of supply of fresh raw material for the mill, the authorities of the mill requested the government to provide the legislative support for the regular supply of raw material. Consequently in 1962, the government approved a statute by which 124 villages in the vicinity of the mill were declared as mill zone areas. It was further stated that the farmers in the mill zone area are bound to supply the sugarcane to the mill, Khandsari and gur making is prohibited, 20% of the crop grown by the farmers is for domestic purposes, and the mill is responsible for all the crop grown in the area.
The total acreage under sugarcane crop in 124 villages in 1969-70 season was approximately 14,000 hectares with an average supply of 1000 to 1500 tons per day. In 1975-76 season it was only 10,500 hectares. In order to compensate for the possible shortcoming of raw material, the mill was also permitted to accept the sugarcane from the other areas not included in the mill zone. The areas which supply sugarcane to the mill from outside the declared mill zone are termed as free zones. Fig 1 shows the villages of the zone area and the villages in the surrounding area of Faisalabad.

Sugarcane is a 10-18 month crop. It competes with other cash and food crops and the acreage of cultivation of the sugarcane crop to a greater extent depends on the relative market price of other competing crops.

There was a gradual decrease of 9% and 12%, respectively, from the season 1969-1970 to 1971-1972, due to farmers' dissatisfaction of excessive cane crop in 1969-1970, and the mill's inability to crush the entire supply of that year. The farmers reported unharvested standing cane after July and burned canes in the field which were complete losses. After 1972-1973 season the cropped area again increased by 12% and remained stable through 1974-1975 season. The 1975-1976 season saw another decline of 16%. The reasons for the latter fluctuations are not known.
Purchase Centers

Communication, transport and marketing facilities are the main agricultural support infrastructure and play an important role in the agricultural development of a particular region. In this context, the mill zone area does not have adequate facilities in terms of paved roads by which the farmers could market their products at a lesser cost. Only some earthen roads link different villages with each other with the mill gate, and the condition of these roads is very bad. Thus, the movement of farm supplies and produce is somewhat difficult and a time-consuming process.

Considering the difficulties which the farmers face and to meet the requirements of sugarcane quality, the mill planned to establish the purchasing (transshipment) centers in its mill zone area. During the season 1972-1973, six purchasing centers were established, as shown in Fig. 1.

Each purchase center is operated under the supervision of a field man who is an employee of the mill. Each purchasing center is inspected by the field officer daily. On the bases of the inventory of each purchase center, transportation is allocated. The price offered at the purchase centers is the price at the factory gate less transportation and service charges.

The growers selling their product to the purchase centers are not satisfied with the system of evaluation of the product especially with the weighing of the cane. Another source of farmers' dissatisfaction is the level of charges assessed by the mill for transportation and services. The purchase centers operate during the period of October through April.

Farmers and their Distribution by Purchase Center

About 10,000 farmers in the mill zone area grow the sugarcane crop, the yields of which are generally low by world standards. During the year 1973-1974, more than 1600 farmers were in the yield category of less than 13.6 tons/ha (category No. 1) and only 100 farmers have their production in the yield category No. 8, which is greater than 54.4 tons/ha (Fig. 2). This was the crop year following the flood of August, 1972 and indicated generally high yield. In the year 1974-1975, the number of farmers in the yield category No. 1 was increased by 256% No. 8 was decreased by 13%. The season 1975-1976 was quite impressive for crop production. The crop production data shows a decrease of 59% in the yield category No. 1 and an increase of 37% in the yield category No. 2 and 3 (13.6-22.7 tons/ha) and (22.7-27.2 tons/ha) respectively, again attributed to the year following a flood. An increase of 30% was also observed in the yield category No. 8.

The aggregate analysis of the production data for a period of three years...
indicates that about 39% of the farmers have their yield in category No. 1; 34% in category 2; and 12% in yield category 8. For these three-year data, the maximum number of farmers growing sugarcane occurred in year 1974-1975 and equalled 8994. The average number of the growers in mill zone area is about 8,000.

The distribution of the farmers by purchase center show a positive trend of the farmers towards the use of purchase center facilities. The aggregate percentage distribution of the farmers who avail of the purchase facility increased from 32% in 1973-74 to 34% in 1974-75 and to 37% in 1975-76.

At present there are six purchase centers working in the zone area. Out of total 124 villages in the mill zone area only 34 have the facility of selling their sugarcane produce to the purchase centers, whereas the farmers in the remaining villages supply sugarcane at the mill gate.

Ground water Table

The ground water table plays an important role on the maturity, tonnage and rendement yield of the sugarcane. The information about the ground water table were obtained by conducting a survey in April 1977. It was observed that during the survey 18% of the mill zone area has a ground water table depth less than 1 m., 32% of the total area has 1-1.5 m, and rest of the area has greater than

![Figure 3. Ground water table map of cane supply area](image-url)
1.5 m. (Fig. 3). The effect of the ground water table can be visualized in the succeeding section on the production modelling.

**Yield Production Model**

There are two different types of models used in this study. In Model 1 it is stipulated that the yield of sugar cane varies with the number of plowings, irrigations, amount of fertilizer, manure, number of weeding, groundwater table, age of the crop at the time of harvest, and the month of harvest. The effects of Model 1 are additive in nature. Model 2 is constructed in such a way that the effects are of multiplicative nature.

*Model 1 Additive Function*

The general linear function of this model is:

\[ Y = b_0 + b_1X_1 + b_2X_2 + \ldots + b_kX_k \]  

This type of model expresses the relation of crop production as the summation of the effects of various production factors. The models 1A for sown crop, 1B for intersown crop, 1C for ratoon crop based on additive functions are presented in Table 1.

*Model 2 Multiplicative Functions*

A disadvantage of Model 1 was that the predicted values of yield may be negative. To overcome this, a model of multilog functions was constructed as:

\[ Y = b_0X_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}X_5^{b_5}X_6^{b_6}X_7^{b_7}X_8^{b_8}X_9^{b_9}X_{10}^{b_{10}} \]  

This model guaranteed that all the predicted values would certainly be positive, provided that constant \( b_0 \) is positive. The results are presented in Table 2.

*Plant Cane Crop — additive model*

All the ten independent variables entered are significant. However, the value of \( R^2 \) is not very impressive. The equation explains about 33% of the variation in the value of output per acre. It is noted that coefficients of all the variables have the expected sign with the exception of both animal and manual hoeing, and potassium. It would appear that hoeing have negative contribution towards the yield. But this need not be taken seriously since the standard error is much higher than the coefficient signifying that the probability is very low, that it is significantly different from zero. The variable Potassium, \( X_6 \) have negative sign, as the Punjab district soils are normally rich in potassium, and addition of potassium may have adverse effect.
Intersown Crop — additive model

All the ten independent variables are in the final regression equation. The value of $R^2$ is quite impressive: it explained 68% of the variation in the sugarcane yield. The variables $X_1$, $X_6$, $X_7$, $X_9$, have negative sign. It is further noted that the variables have very high standard error as compared with their regression coefficient indicating that the probability is very low and that they are significantly different from zero. The variable $X_3$, which is nitrogen, also has negative coefficient, indicating that application of nitrogen is toxic to the crop. This is true, since the intersown crop is normally sown together with leguminous crop in the same field which fixed the nitrogen into the soil. The variable $X_2$, irrigation has also shown an inverse relationship with the yield of the crop. As explained earlier, intersown crop is sown with some leguminous crop. Since there is very less plowing of the soil, the soil is normally compact and had lower capabilities to retain moisture. Because of the nature of intercropping, the farmers tend to overirrigate as often as weekly. Hence sign indicates possible yield depression. Moreover, the intersown crop has deep root zone due to competition with other crop thereby making use of ground water ($X_8$). The variable age ($X_9$) had negative sign, suggesting that the earlier the harvest of crop the better is the yield. The most contributing factor to yield production for intersown crop is phosphorus.

Ratoon Crop — additive model

The value $R^2 = .66$ is significant and explains the 66% of the total variation sugarcane production. The eight independent variables are in the final regression equation. Variable age ($X_9$) was not significant so it is not entered in regression equation. The regression coefficient of all independent variables have a positive sign except the variables $X_2$ and $X_4$, which are irrigation and phosphorus, respectively. The standard error of $X_2$ is much higher as compared with its regression coefficient signifying that the probability is very low, that it is significantly different from zero. The phosphorus negative sign can be justified by the fact that the primary function of phosphorus is the development of the root system. However, since the root system of the ratoon crop have already been developed, the addition of phosphorus may be toxic to the crop. The major contributing factors to the ratoon crop's production are hoeing, ground water table, nitrogen and potassium as shown in Table 1.

Production Model Evaluation

The comparison of logarithmic and linear production models indicate that the value of $R^2$ for all the three cases i.e., plant crop, intersown crop and ratoon crops are better in linear regression equations. It is therefore concluded that independent variables in the regression equation gives better fit with linear relation than the logarithmic variables.
TABLE 1. Summarized results of step-wise linear regression analysis of sugarcane production

| Sugarcane crop and yield equation | Intercept | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | Multiple $R$ | Multiple $R^2$ | $F$ | $Se$ |
|----------------------------------|----------|------|------|------|------|------|------|------|------|------|------|----------|----------------|----------------|-----|-----|
| Plant crop                       | 128.40   | 3.61 | 0.70 | 0.81 | 0.62 | -0.34 | -51.58 | 88.68 | 0.24 | 0.66 | 7.51 | 0.58     | 0.33           | 1.93 | 184.76 |
|                                  |          | (0.64) | (1.96)** | (1.79)** | (0.81) | (-0.42) | (-1.53)* | (-2.47)** | (0.49) | (0.86) | (0.91) |          |                     |     |       |
| Inter sown crop                  | 1933.85  | 188.81 | -0.09 | -0.99 | 2.75 | 2.84 | -60.29 | -131.05 | 0.66 | -2.33 | -26.65 | 0.83     | 0.68           | 2.34 | 138.99 |
|                                  |          | (-2.10)* | (-1.39)* | (-1.41)* | 1.73* | (0.87) | (-1.30)* | (-2.70) | (0.96) | (-2.03)* | (-2.43)** |          |                     |     |       |
| Ratoon crop                      | 431.96   | -30.75 | 1.89 | 0.67 | 2.04 | 13.29 | 71.73 | 2.78 | 9.89 | 0.81 | 0.66 | 1.67     | 122.01        |          |     | |
|                                  |          | (-3.23)** | (1.59)* | (-0.96) | (2.24)** | (0.76) | (1.10) | (2.51)** | (0.72) |          |          |          |                     |     |       |

**NOTE:** $F$ is variance ratio
$Se$ is standard error of estimate of the multiple linear regression equation
The coefficients within parenthesis are t values
*** Significant at 0.01 level
** Significant at 0.05 level
* Significant at 0.10 level

$X_1$ = Plowing
$X_2$ = Irrigation
$X_3$ = Nitrogen
$X_4$ = Phosphorous
$X_5$ = Potassium
$X_6$ = Hoeing by animal labor
$X_7$ = Hoeing by manual
$X_8$ = Ground water depth
$X_9$ = Area at harvest
$X_{10}$ = Month of harvest
### TABLE 2. Summarized results of logarithmic regression of sugar cane production.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Sugarcane yield</th>
<th>Intercept</th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
<th>$X_5$</th>
<th>$X_6$</th>
<th>$X_7$</th>
<th>$X_8$</th>
<th>$X_9$</th>
<th>$X_{10}$</th>
<th>R</th>
<th>$R^2$</th>
<th>F</th>
<th>$F_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3.2.5</td>
<td>Plant crop</td>
<td>1.20</td>
<td>-0.035</td>
<td>0.25</td>
<td>0.36</td>
<td>0.021</td>
<td>-0.029</td>
<td>-0.31</td>
<td>-0.51</td>
<td>-</td>
<td>0.24</td>
<td>0.019</td>
<td>0.63</td>
<td>0.39</td>
<td>2.91</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-0.26)</td>
<td>(1.68)**</td>
<td>(3.38)**</td>
<td>(0.42)</td>
<td>(-0.90)</td>
<td>(-2.08)**</td>
<td>(3.12)**</td>
<td>(0.53)</td>
<td>(0.28)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3.2.6</td>
<td>Inter sown</td>
<td>4.02</td>
<td>-0.52</td>
<td>-0.25</td>
<td>0.11</td>
<td>0.13</td>
<td>0.09</td>
<td>-0.08</td>
<td>-0.17</td>
<td>0.22</td>
<td>-0.49</td>
<td>-0.18</td>
<td>0.69</td>
<td>0.48</td>
<td>2.022</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>crop</td>
<td></td>
<td>(-1.24)</td>
<td>(-0.50)</td>
<td>(-0.55)</td>
<td>(1.56)</td>
<td>(0.73)</td>
<td>(-0.36)</td>
<td>(-0.57)</td>
<td>(1.14)</td>
<td>(-0.45)</td>
<td>(-1.55)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.3.2.7</td>
<td>Ratoon crop</td>
<td>1.68</td>
<td>-0.93</td>
<td>0.20</td>
<td>-0.03</td>
<td>0.13</td>
<td>0.10</td>
<td>-</td>
<td></td>
<td>0.26</td>
<td>0.57</td>
<td>-0.17</td>
<td>0.80</td>
<td>0.635</td>
<td>1.523</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-3.06)**</td>
<td>(1.05)</td>
<td>(-0.69)*</td>
<td>(1.68)*</td>
<td>(0.68)</td>
<td></td>
<td></td>
<td>(1.59)*</td>
<td>(0.94)</td>
<td>(-0.47)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** $F$ is variance ratio  
$S_e$ is standard error of estimate of the multiple linear regression  
*** Significant at 0.01 level  
** Significant at 0.05 level  
* Significant at 0.10 level

$X_1$ = Plowing  
$X_2$ = Irrigation  
$X_3$ = Nitrogen  
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$X_5$ = Potassium  
$X_6$ = Hoeing by animal labor  
$X_7$ = Hoeing by manual  
$X_8$ = Ground water depth  
$X_9$ = Area at harvest  
$X_{10}$ = Month of harvest
In the linear regression model, the final regression equation of the plant crop has a value of $R^2 = 0.33$ which explains only 33% of variation in the yield. As a greater percent of variation is not accounted by the model it is recommended that this model should not be used for prediction purposes. However, in the absence of any other model, this model can give some idea about the type of relationship of production functions and yield. The model should be calibrated before use.

The linear regression model of intersown crop explains 68% of total variation in the crop production. The values of $R^2$ and $F$ are quite impressive, indicating that regression line has a good fit with actual observed data. This model can be used safely for the yield prediction in order to test alternative management policies. Since 32% of the total variation is not explained by this model, it is suggested to calibrate the model for any particular situation.

The ratoon crop model is also satisfactory since the 63% of total variation in the crop yield is explained by the independent variables present in the regression equation. It can be used for yield forecasting. However, it is suggested that the model should be calibrated before it is applied to a specific situation as the model fails to explain the remaining 37% variation of crop production.

In order to have an insight of the mill performance, the following three models were constructed.

(i) Sugar cane crushed versus time,
(ii) Sugar bagged versus time, and;
(iii) Recovery versus time.

The summarized results of the first three models are shown in Table 3. In these models, 'Y' is the dependent variable which is the accumulated value of sugar cane crushed and sugar bagged in successive 7-day intervals in models 1 and 2 and is the percentage recovery in model 3. The first two models (Figs. 4 and 5) show a linear relation with time, while model 3 has a parabolic relationship. The recovery is parabolic because when the mill starts processing the cane, the crop is still not fully mature due to rains of monsoon, thereby continuing its growth and having high water and low sucrose content. As the sugar cane reaches maturity, the water content decreases and sucrose content increases, indicated by a gradual increase in the recovery (Fig. 6). The recovery attains its peak value during the period Jan-Feb. That period is followed by a high temperature, thus forcing the sucrose content to decrease causing the behaviour of recovery to be parabolic.

In model 4, it is stipulated that sugar bagged was measured as tons of sugar produced in 7-day intervals. 'Y' varies with the product of cane crushed and recovery. The model was subjected to simple regression analysis and the resultant
The overall regression equation of cane crushed has the same $R^2 = 0.98$ which explains 98% variation in the tonnage of cane crushed. This model can be used with confidence for the prediction purposes.
The values of $R^2$ for the model of sugar bagged and recovery are quite reasonable. As it is clear that some of the variations in the output of the cane crushed is not explained by that variable, therefore, it is suggested to calibrate them before they are used in any particular situation.

The model of sugar bagged versus product of cane crushed and recovery explains 79% variation in the sugar production. The model cannot be used satisfactorily as 21% of the variation is not explained by independent variables considered in the model for forecasting purpose. To be on the safe side, calibration of the model is required before use.

**Limitations of Data**

1. **Production Models**

   (a) Models are solely dependent upon the farmers memory.

   (b) Soil fertility, which is the most important factor of production has not been considered here.

   (c) Timeliness factor have not been taken into account.

   (d) The sample of farmers interviewed was only 0.8% of the total
<table>
<thead>
<tr>
<th>Year</th>
<th>Sugar bagged</th>
<th>Sugar cane crushed</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y = 0.2171 + 0.06784 t</td>
<td>Y = 4.7749 + 2.07797 t</td>
<td>Y = 7.6040 + 0.0245 t - 0.000078 t²</td>
</tr>
<tr>
<td></td>
<td>R² = 0.9886, F = 3202.0</td>
<td>R² = 0.9979, F = 7601.5</td>
<td>R² = 0.9854</td>
</tr>
<tr>
<td>1970-71</td>
<td>Y = -0.4051 + 0.0673 t</td>
<td>Y = -5.3669 + 2.0677 t</td>
<td>Y = 7.6568 + 0.0149 t - 0.000046 t²</td>
</tr>
<tr>
<td></td>
<td>R² = 0.9921, F = 2877.4</td>
<td>R² = 0.9939, F = 3565.8</td>
<td>R² = 0.9998</td>
</tr>
<tr>
<td>1971-72</td>
<td>Y = -0.2901 + 0.0629 t</td>
<td>Y = 2.4086 + 1.7668 t</td>
<td>Y = 7.9849 + 0.0190 t - 0.000067 t²</td>
</tr>
<tr>
<td></td>
<td>R² = 0.9976, F = 7733.5</td>
<td>R² = 0.9932, F = 2767.6</td>
<td>R² = 0.963</td>
</tr>
<tr>
<td>1972-73</td>
<td>Y = -0.5029 + 0.1173 t</td>
<td>Y = 0.1903 + 1.7321 t</td>
<td>Y = 7.5823 + 0.0236 t - 0.000089 t²</td>
</tr>
<tr>
<td></td>
<td>R² = 0.9972, F = 7105.6</td>
<td>R² = 0.9965, F = 5735.7</td>
<td>R² = 0.9753</td>
</tr>
<tr>
<td>1974-75</td>
<td>Y = -0.8201 + 0.1153 t</td>
<td>Y = -5.3657 + 1.7435 t</td>
<td>Y = 7.3152 + 0.0271 t - 0.000012 t²</td>
</tr>
<tr>
<td></td>
<td>R² = 0.9957, F = 3465.8</td>
<td>R² = 0.9946, F = 2755.3</td>
<td>R² = 0.9</td>
</tr>
<tr>
<td>Overall</td>
<td>Y = 0.5938 + 0.0699 t</td>
<td>Y = -13.6949 + 2.0983 t</td>
<td>Y = 7.6812 + 0.0191 t - 0.000067 t²</td>
</tr>
<tr>
<td></td>
<td>n² = 0.8466, F = 673.3</td>
<td>R² = 0.9837, F = 7366.9</td>
<td>R² = 0.7837</td>
</tr>
</tbody>
</table>
population.

2. **Mill Production Data**
   
   (a) Data was not available in stratified form.
   
   (b) No separate record of cane supply from mill zone area and free zone area was available.
   
   (c) Contribution of various varieties to the total cane supplied was not recorded.
   
   (d) Supply and quality of sugarcane from each purchase center was not recorded separately.

**CONCLUSION**

**Yield Model**

(a) Linear regression gives a better fit when compared with the logarithmic regression, but the advantage is slight.

(b) Irrigation and nitrogen are the major contributing factors towards the yield of the plant crop. Potassium need not be applied if better result is desired. Higher tonnage can be obtained by the late harvesting.

(c) Intersown crop is very sensitive to the moisture regime of the soil. Ground water is normally used by the crop, therefore, surface irrigation need not be so frequently applied. Due to competition with the intersown crop, earlier harvest results in better yield. Phosphorus is the main contributing factor towards the production of the crop.

(d) Hoeing and the ground water are the major contributing factors for the ratoon crop production. Nitrogen and potassium are the essential requirements for better yield.

**The Mill Performance Model**

(a) Refined sugar and cane crushed show linear relationship with time.

(b) The recovery has parabolic relationship with time.

(c) The quantity of sugar bagged has shown linear dependency upon the product of cane crushed and recovery.

**Description of the District**

(a) Area planted and harvested is responsive to the performance of the mill.

(b) Farmers have grievances about mill performance in terms of transportation
difficulties, weighing of the produce, and the pricing system at purchase centers.

(c) A flood in the monsoon season of one year is generally followed by good crop yield in the following milling season.

(d) The monsoon seasons with drought or significantly less than the ordinary amount of rainfall are followed by exceptionally poor crop yield in the subsequent milling season.

REFERENCES


OPORTUNIDADES DE SISTEMAS DE SINCRONIZACION DE CAÑA DE AZUCAR Y MODELOS DE PRODUCCION FACTIBLE EN PUNJAB EN PAKISTAN

A. C. Early and M. K. Ayub

RESUMEN

Para este estudio se seleccionó un distrito de molienda de caña en Central Punjab, Pakistan, que consiste de un ingenio y un área productora de caña. Los objetivos del estudio fueron establecer estadísticas descriptivas del sistema en uso actual, modelos de rendimiento y modelos de funcionamiento del molino como posibilidades de producción hacia un modelo de mejoramiento administrativo para la programación de las operaciones de molienda y recolección de la cosecha. El estudio mostró que el área sembrada y cosechada fue adecuada para la capacidad del molino, en términos de transporte, peso y evaluación en los centros de compra. La cosecha, después de una inundación durante la
temporada de monzón, tiene rendimientos de caña excepcionales; mientras que una sequía durante la temporada de monzón, resulta en una reducción notable en el rendimiento de caña durante la siguiente cosecha. Para modelos de rendimiento, se empleó regresión lineal y logarítmica, utilizando el número de cultivos, número de riegos, cantidad de fertilizante, número de azada manual, número de cultivos con animales, nivel freático, edad de la caña al tiempo de la cosecha y mes de la cosecha. Los modelos lineales y logarítmicos explican la variación de 33% a 68% en el rendimiento y los resultados incluyen únicamente las posibilidades significativas a un nivel de 99% de probabilidad con esos factores de producción. El rendimiento de cosecha de caña de azúcar da una mejor adaptación, comparado con regresión logarítmica.