THE DEVELOPMENT OF OBJECTIVE PROCEDURES TO ESTIMATE YIELD FOR PECAN TREES

By

Ronald A. Wood

Research and Development Branch
Research Division
Statistical Reporting Service

December 1972

TABLE OF CONTENTS

SUMMARY

The 1971 Pecan Research study near Raymond, Mississippi was designed to evaluate variables for forecasting weight of nuts per tree, developing a model for weight of nuts per tree and refining data collection procedures.

Four variables for forecasting nuts per tree were studied. Two of these, counts of nuts through binoculars expanded to tree totals and collection of nuts that dropped prior to harvest, failed to be significantly correlated with pounds of good nuts harvested in the same tree for more than one observation period ($\alpha = .05$). Counts of nuts from photographic slides expanded to tree totals and counts of nuts on selected sample limbs expanded to tree totals, were both significantly correlated ($\alpha = .01$) to pounds of pecans harvested on the same trees for all observation periods.

Two models for weight of nuts per tree were developed. A weighted linear regression model for a September 1 forecast based on 1971 parameters would be:

$\hat{y}_1 = 22.86125 + 0.01227\ x_1$ where x_1 = photo count of nuts

$\hat{y}_2 = -5.35299 + 0.02962\ x_2$ where x_2 = limb counts of nuts

$\hat{y} = .577\ \hat{y}_1 + .423\ \hat{y}_2$

and the y's represent pounds of nuts per tree.

A multiple regression model for September 1 forecast with 1971 parameters would be:

$\hat{y} = 4.29 + .009\ x_1 + 0.11\ x_2$

No significant differences existed between counts of nuts from opposite sides of trees for any of the months studied. Thus, the amount of photography required for a forecasting model using photography can be reduced.

INTRODUCTION

The pecan industry has shown a continuing interest in improving early season forecasts of pecan yields. The cooperative research with the Mississippi SSO for the last two years has shown that some relationships exist upon which procedures could be developed to make an early season objective yield forecast of pecan production.

Based on encouraging results found in a 1970 research project, a similar project was set up for 1971. Variables under study in 1971 were counts of nuts from sample limbs less than 28 feet high, counts of nuts from ground level at a distance of 50 feet, counts of nuts seen through 7.5 power binoculars, and counts of nuts which dropped prior to harvest. While some difficulties continue to exist in sampling the tree, it is believed that methods can be devised for measuring any biases in the procedures on a subsample of trees.

DATA COLLECTION

General

The 1971 pecan project was located southwest of Jackson, Mississippi near Raymond. Five orchards (blocks) were subjectively selected; three of these were used in the previous year's research.1/ All five blocks were of the Stuart improved variety with an age range of fourteen years to thirty-five years.

Sample Selection

It was necessary to select trees in the two new blocks; the previously used trees in the three old blocks would suffice for this study. The tree selection procedure for each new block was:

1. Determine the number of rows in the block.
2. Systematically select two rows.
3. Use random number table to select two trees in each selected row with equal probabilities (no significant difference in cross-sectional area of trunk was evident in 1970 research to warrant probability proportional to size sampling).

In the new blocks stereo photographs were taken of the sample trees at a distance of fifty feet prior to foilage appearing on the trees. All sections of the tree were identified on black and white

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1/ For detailed procedural explanation of the 1970 project, refer to "A Study of the Characteristics of the Pecan Tree for Use in Objective Yield Forecasts," Ronald A. Wood, Research and Development Branch, Standards and Research Division, Statistical Reporting Service.

photo enlargements (24x) made from the stereo photography. A section was defined as either a path section or terminal limb. The intention was that a terminal limb would be a limb whose CSA (cross sectional area) was between 1.8 and 5.5 square inches at point of origin (point at which limb branched from larger section). This corresponded to a thickness of 1/16 to 3/16 of an inch on the photo enlargements. A path section was a portion of a limb whose CSA at point of origin was greater than 5.5 square inches. The first path section was the trunk. Each branching thereafter defined two or more path sections or path section(s) and terminal limb(s). (Small branches with CSA of less than 1.8 square inches were not considered a branching point but part of a path section). Each path section was assigned to the first terminal branching from the path section. When two terminals branched from the same fork, the path section was assigned to the terminal limb with the smallest CSA. A "sample unit" was defined as a terminal limb and any associated path sections.

The sample units were placed into one of two strata:

1. Stratum A (accessible) - sample units zero to twenty-eight feet above the ground. These units were reached with a mechanical hoist.
2. Stratum U (unaccessible) - sample units higher than twenty-eight feet. These units could not be reached with the mechanical hoist.

Sample units were selected for nut counts within stratum A. The number of sample units selected was a function (twelve percent) of the total number of terminals in the stratum. Sample units were selected by simple random sampling assigning equal probability to each sample unit.

Count of Nuts on Sample Limbs

All nuts on the selected sample units were to be counted at the end of July, August, and September. These counts were to be made from a mechanical hoist. The hoist was not available in late September so only those units which could be reached with ladders were counted. Counts of nuts on path sections assigned to the sample unit were recorded separately from the counts on terminal limbs.

Photography Procedures

The procedures in this years work are completely different than that of the 1970 research. The reason for the changes was that poor quality of photography often occurred in 1970 when shooting into the sun. In order to eliminate this problem the following procedures were followed during the 1971 research.

All sample trees were photographed at the end of July, August, and September. Photographs were taken from two sides of sample trees (180° angle). Only one position of the tree was photographed at a time. The position of shooting was determined as follows:

1. The a.m. position for each sample tree was determined by placing the sun directly at the photographers back.
2. The a.m. position was marked with a florist stake, a compass reading of the position was recorded, and the times of first and last shots recorded. No new tree was started after 11:30 a.m.
3. The p.m. shots were the second positions of the trees photographed in the morning. The p.m. shots were photographed in reverse order. That is, the last tree photographed in the morning was the first photographed in the afternoon. The second position was selected by moving 180° around the tree from the a.m. position. This position was marked by a florist stake, a compass reading was recorded and the times of the first and last shots were recorded.
4. The camera was set fifty feet from the trunk of the sample tree at each selected position.
5. The distance from the trunk to edge of canopy and edge of canopy to camera position was recorded.
6. The width of photo unit at edge of canopy by viewing through view finder was recorded.

Light meter readings were taken near the edge of canopy and trunk of tree. The F-stop for a given speed split the difference of the two readings.

Pictures were taken of a vertical strip running up the center of the tree. A Miranda Sensorex camera with a 135mm lens was used for all photography work. An aluminum frame divided into eight segments was placed two feet in front of the camera. A segment equaled the viewing area of one exposure. In most instances, the full vertical strip of the tree was completely contained within the eight segments.

Counts of Nuts From Photography

Each slide was projected on a screen divided into blocks (cells). A photo interpreter counted the number of nuts in each cell and recorded the count on a form which was a reduced image on the large screen. For one-third of the slides, a second counter recounted the nuts for use in computation of adjustment factors.

Counts of Nuts That Drop Prior to Harvest

On the 28th of June, the area under the canopy of all twenty sample trees was cleaned of old nuts. On July 26th and every two weeks after until October 7th, all nuts that dropped from the sample trees were collected and the number of bad nuts recorded for each tree.

Counts of Nuts With Binoculars

Counts of nuts through a 7.5 power pair of binoculars were taken at three different times: July 30, August 30, and September 30.

Using the photography positions, nuts on two of the sample trees were counted in each block.

The counts were taken of a strip comprising the middle of the tree. Each position (starting with the second) going up the tree trunk was chosen by noting a visual characteristic in the upper boundary of the previous position and relocating it as the lower boundary of the present position. The total viewing area using the binoculars was approximately 1/2 that of the photographs.

RESULTS

General

This is the second year that the Research and Development Branch of the Statistical Reporting Service has investigated various characteristics of the pecan tree. These characteristics will now be partitioned such that one set in the future will be used in a model for evaluation and a second set will be further experimented upon. The sections below will show the methods of arriving at final individual variable values and their correlations with pounds of good pecans harvested.

Counts of Nuts From Sample Limbs

The height of the pecan tree makes it practically impossible to draw a sample from the entire tree. Therefore, the tree was divided into an accessible (0-28 feet) and inaccessible (height >

28 feet) region. The objective of this portion of the study was to determine whether a significant relationship existed between counts of nuts in the accessible region expanded to a tree total and pounds of good pecans harvested from the same tree.

An estimated number of pecans per tree was obtained by the expansion of nut counts from accessible sample limbs **(Table 2).** The expansion procedure followed was:

Let: x_{ij} = count of nuts on jth sample limb in the ith tree.

E_i = expansion factor for the ith tree. This was the reciprocal of the fraction the jth sample limb was of the total number of limbs in the ith tree. The fraction for the jth limb equals $1/N_i$ where N_i = the number of accessible and inaccessible sample limbs for the ith tree.

$\hat{X}_{ij}$ = the estimated number of nuts on the ith tree using the jth sample limb. $\hat{X}_{ij} = E_i\, x_{ij}$

n_i = number of selected sample limbs in the ith tree.

$\hat{X}_{i.}$ = the mean of the expansion of nuts to tree total from individual limbs for the ith tree.

$$\hat{X}_{i.} = \sum_{j=1}^{n_i} \frac{\hat{X}_{ij}}{n_i}$$

Table 1.--Harvest data for sample trees, Mississippi peans, 1971

Block	Tree	Pounds of good nuts	Pounds of bad nuts in husk	Good nuts per pound	Estimated number of good nuts 1/
A	1	55.8	8.6	42	2343.6
A	2	3.9	.6	41	159.9
A	3	17.2	1.4	41	705.2
A	4	17.8	3.0	42	747.6
B	1	120.5	9.8	42	5061.0
B	2	10.7	15.8	51	545.7
B	3	134.5	10.7	49	6590.5
B	4	39.7	9.1	49	1945.3
C	1	24.2	21.5	82	1984.3
C	2	24.0	.9	51	1224.0
C	3	3.4	14.7	66	224.3
C	4	17.1	13.2	79	1350.9
D	1	153.7	17.8	45	7122.9
D	2	47.5	6.3	43	2100.9
D	3	121.5	19.4	51	6191.1
D 2/	4	69.8	8.8	42	2991.6

1/ Estimated from pounds of good nuts at harvest.
2/ The fifth block was not harvested by the operator and was therefore lost.

Table 2.--Total nuts counted on accessible sample limbs (CNASL) and estimated number of nuts per tree: July, August, September 1971

Block	Tree	Number of sample units	July: Total CNASL	July: Estimated number nuts	August: Total CNASL	August: Estimated number nuts	September: Total CNASL	September: Estimated number nuts
A	1	4(3)1/	263	2104.0	244	1952.0	197	2102.0
A	2	2(2)	62	155.0	48	120.0	29	72.5
A	3	4(3)	110	907.5	86	709.5	48	528.0
A	4	3(3)	112	971.0	76	658.6	89	771.6
B	1	5(3)	247	3309.1	216	2894.5	95	2121.4
B	2	4(3)	167	2379.8	150	2137.5	74	1406.0
B	3	3(3)	491	7036.0	590	8454.7	454	6505.8
B	4	5(3)	331	3839.6	254	2946.4	130	2512.9
D	1	3(2)	317	4016.4	297	3763.0	223	4237.0
D	2	4(3)	321	3531.0	338	3718.0	167	2449.9
D	3	4(3)	364	4186.0	345	3967.5	149	2284.7
D 2/	4	2(2)	136	2176.0	137	2192.0	141	1504.5
Total.............			2921.0	34,611.4	2781.0	33,513.7	1796.0	26,496.3
Mean ($\bar{X}$)...........			243.417	2,884.283	231.750	2,792.808	149.667	2,208.025
Variance σ^2........			16,427	3,464,234	22,957	4,800,588.	12,572	3,031,649
Rel-Variance $\frac{\sigma^2}{\bar{X}^2}$ ...			.277	.416	.427	.615	.561	.622

1/ In September, a mechanical hoist was not available. Number in parenthesis is number of units reached in September.
2/ Only three orchards were used for limb counts.

The correlation coefficients between the estimated number of nuts each month and pounds of good nuts harvested were computed from the data in Tables 1 and 2. The correlations are shown in Table 3.

Table 3.--Correlation values of pounds of good nuts harvested with nut counts expanded to tree totals: Mississippi pecans, 1971

Item	July	August	September
r..................	.764	.739	.770
r^2................	.584	.546	.594
n..................	12	12	12
$r_{.01}$...............	.708	.708	.708
$r_{.05}$...............	.576	.576	.576

The correlation coefficients are all significantly greater than zero at $\alpha = .01$. The August r value can be compared with the 1970 research results. In 1970, on approximately the same dates of data collection, an r value of .86 was observed. The August value of 1971 being low relative to August 1970. One possible interpretation of this drop in correlation may be poor operational efficiency. That is, data collection was not as good at this stage in 1971 as 1970. The project was plaqued with bad weather and mechanical difficulties with the hoist during every survey period.

Counts of Nuts From Photographs

Counts of nuts on photographs in 1971 were made by three photo interpreters. Each slide was projected onto a screen divided into a grid such that each pecan could be identified within a cell of the grid. The sum of these cells was the unadjusted count of nuts for the slide.

An adjustment factor was derived for each interpreter by using a balanced incomplete block model for assignments.2/ The adjustment factors are shown in Table 4.

Table 4.--Photo adjustment factors for interpreter differences for the months July, August, and September, Mississippi pecans, 1971

Month	Counter 1/		
	1	2	3
July	0.77	0.92	1.48
August	.72	1.11	1.46
September	1.01	.70	2.04

1/ A correction factor of less than one indicates that this counter consistently counts higher than the average of all counters, and vice versa for a correction factor less than one.

To correlate the photo counts with pounds of good nuts at harvest at this point would introduce a bias into figures. This is because the sample unit was not the same in each tree; anywhere from one to 40 percent of the tree was photographed. It was necessary to place these figures on a comparative basis. Therefore, the adjusted nut counts were expanded to tree totals.

2/ 1970 Mississippi Pecan Report.

The method of expanding count of nuts on photographs to tree totals was based on similar triangles and the formula for the surface area of a sphere.3/ Measurements were taken from edge of canopy to camera 4/ and trunk to camera (50'). The figures were used along with the given height at the base of the trunk to compute the area of the middle frame of the tree. This area was further expanded to total area (TA) exposed by multiplying the middle frame area by the number of slides (corrected for area on slides not containing tree). The surface area of the sphere (SAS) was computed as $4\pi r^2$, where r (radius) is the average of the two distances (edge of canopy to trunk). This new method compared to 1970 may help alleviate problems arising from extreme protrusions or gaps in the tree's branching pattern. The expansion factor was then defined as SAS/TA. The expanded counts of nuts from photographs (ECNP) were

$$ECNP = SAS/TA \sum_{i=1} Y'_{jkmi}$$

where: Y'_{jkmi} represents the adjusted photo count of the ith slide in the mth side of the kth tree for the jth block.

The correlation coefficients for the three months are shown in Table 5.

3/ 1970 Mississippi Pecan Report, previously cited.
4/ For the 1971 project, the values were expanded using two measurements from edge of canopy to camera: the distance at each camera position and the average of the distances at the two positions.

Table 5.--Correlations of pounds of nuts harvested per tree and counts of nuts from photographs using three different photo count expansion methods, Mississippi pecans, 1971

Item	August			September			October		
	Old 1/	New 2/	Total tree 3/	Old 1/	New 2/	Total tree 3/	Old 1/	New 2/	Total tree 3/
r......	.801	.751	.771	.826	.915	.880	.742	.769	.809
r^2.....	.641	.564	.594	.682	.830	.774	.551	.592	.655
n......	22	22	13	17	17	12	26	26	15
$r_{.01}$...	.537	.537	.684	.606	.606	.708	.496	.496	.641
$r_{.05}$...	.423	.423	.553	.482	.482	.576	.388	.388	.514

1/ This photo count variable was computed the same as 1970. The value used for edge of canopy to tree was the actual measured distance.
2/ This photo count variable was computed using the average distance for the two camera positions from edge of canopy to tree.
3/ This photo count variable was computed by computing a new expansion factor (EF) and totaling adjusted nut counts from both sides of tree (and then expanding to tree total with new EF).

$EF = SAS/[TA_1 + TA_2]$ where TA_1, TA_2 represent area of side one and two respectively. Estimate of total number of nuts on tree from photo counts = $EF\left(\sum_{m=1}^{2}\sum_{i=1}^{s_i} Y'_{jkmi}\right)$

All correlation coefficients were significant at the one percent level ($\alpha = .01$). From the standpoint of these correlation results and the fact that conventional limb count techniques can not be applied, the use of photography for pecan estimation would seem highly desirable.

In order to utilize photo counts some problems would have to be overcome. More consistency in photo results must be achieved. Too often exposures of a tree have such poor resolution that they have to be eliminated from the set of observations. A fast, inexpensive method of getting field photography work completed must be developed. Finally, since this would be the first time in operational use, the biggest problem may be to gain acceptance of photography counting as a method of obtaining estimated total count of nuts on a tree.

Counts of Nuts That Drop Prior to Harvest

Nuts fall from the tree prior to maturity for a variety of reasons: weather, disease, lack of proper pollination, set too heavy, and insect damage. The correlation between nut drop and pounds of pecans at harvest was significant only for the October 7th collection (Table 6).

Table 6.--Correlation of nut droppage prior to harvest with pounds of good pecan; and average nut droppage per tree prior to harvest, Mississippi pecans, 1971

Item	Date				
	8/8	8/23	9/9	9/23	10/7
r	.289	.443	.232	.443	.629
n	16	16	16	16	16
$\bar{x}$	103.0	142.1	146.4	127.3	30.0
$r_{.01}$	.623	.623	.623	.623	.623
$r_{.05}$	.497	.497	.497	.497	.497

Two explanations of the low correlations found in Table 6 are pollination variations and unworkable conditions under the tree. Early in the season pollination plays a key role. For example, two trees may appear to have an entirely different set (and hence different yield prospects); yet as the season progresses one tree holds its set while the other (not as well pollinated) loses its set bringing their yield closer together. This gives two entirely different drops to the same yield. Hence, the relationship of nuts that drop early to final yield per tree is either a random variable or a variable proportional to total set.

The second problem deals with leaves and high grass found under some trees. Bad nuts are overlooked in varying quantities depending on how bad the area under a particular tree is. That is, how tall is the grass or how many leaves remain from last year? A scatter effect of bad nuts that drop to final yield per tree points indicates that some dropped nuts were not counted.

At this point in the pecan forecast research nut droppage prior to harvest should be of secondary nature to any future pecan research. Any new research in this area should deal primarily with reducing the size of the sampling area in which bad nuts are collected so a complete gleaning can take place.

Counts of Nuts Through Binoculars

The counts of nuts seen through a 7.5 power pair of binoculars expanded to tree totals were not significantly related to pounds of good nuts harvested for two of the three dates for which counts were made. The only significant relationship was the September counts which was significant at $\alpha = .05$ (Table 7).

Table 7.--Correlation between pounds of good nuts harvested and counts of nuts through binoculars expanded to tree totals, Mississippi pecans, 1971

Item	July	August	September
r.........	.179	.379	.574
r^2........	.032	.144	.330
n 1/......	16	16	16
$r_{.01}$......	.623	.623	.623
$r_{.05}$......	.497	.497	.497

1/ Expanded counts of each side of trees were used in the correlations.

The photography work done for the computation of the expansion factor and total surface area were used for the binocular expansion. The total area counted by binoculars (on one side) was a constant proportion (.424) of the total area counted (on one side) by photography. The binocular area was divided into the total surface area of the tree to obtain an expansion factor by which the binocular counts of nuts were multiplied.

The low correlations between counts of nuts seen through binoculars expanded to a tree total and pounds of good nuts harvested per tree may be due to either the counter or the viewing area. With respect to the counter there is no way of quality checking his work. What is seen one time may change on a second count due to wind or droppage; likewise, what a counter sees each time may change. It is impossible to freeze the picture as with photography. The second source of a low correlation may be that the viewing area is too small; the viewing area is only about one-half that used for photography work and hence may not give as representative a sample of the tree. A limited study of these counts should be continued but not in the extensive manner undertaken for this year's research project.

PECAN FORECAST MODEL

General

Two possible models for estimating (and forecasting) pecan production are available. Assuming that methods are available to obtain tree population estimates, the next step is to ascertain whether to use weighted simple regression estimates versus multiple regression estimates. What follows is a discussion of each model, and possible projected pounds at harvest models.

Simple Regression

This model involves a system of simple regression equations, each with the same dependent variable (y) but different independent variables (x). When a forecast is to be made each equation produces a $\hat{y}_i$, the forecast (or estimate) of the dependent variable given the independent variable. From the set of $\hat{y}_i$'s a final estimate, $\hat{y}$, is obtained by weighting the $\hat{y}_i$'s by their equation's coefficient of determination:

$$\hat{y} = [r_1^2\, \hat{y}_1 + r_2^2\, \hat{y}_2 + \ldots + r_n^2\, \hat{y}_n] \;/\; [r_1^2 + r_2^2 + \ldots + r_n^2]$$

For this year's data the model takes on the form:

August for September 1 Forecast Model

$\hat{y}_1 = 22.86125 + 0.01227\, x_1$ where x_1 is expanded count of nuts from photography

$\hat{y}_2 = -5.35299 + 0.02962\, x_2$ x_2 is expanded count of nuts from sample limbs

$\hat{y} = .577\, \hat{y}_1 + .423\, \hat{y}_2$ $.577 = \dfrac{r_1^2}{r_1^2 + r_2^2}$ 1/

and the standard error of the estimate is 21.896.

September for October 1 Forecast Model

$$\hat{y}_1 = 21.29193 + 0.00961\, x_1$$

$$\hat{y}_2 = 14.00935 + 0.02357\, x_2$$

$$\hat{y} = .530\, \hat{y}_1 + .470\, \hat{y}_2$$

and the standard error of the estimate is 27.536.

At lease two more years of "expanded" work is necessary to verify a stable relationship. "Expanded" means a larger scale research sample involving a random selection of blocks.

Multiple Regression

This model takes a set of independent variables against a dependent variable and sets forth a forecast in one step for individual trees. For the data available in 1971, the following model was generated for a September 1 and October 1 forecast.

1/ This is true only if the expanded counts of nuts from photography and from sample limbs are uncorrelated.

August for September 1

$\hat{Y} = 4.29 + .009\ x_1 + 0.011\ x_2$ where x_1 = photo expansion

x_2 = limb expansion

and the standard error of the estimate is 22.735.

September for October 1

$\hat{Y} = 6.48 + .0065\ x_1 + .0132$ where x_1 = photo expansion

x_2 = limb expansion

and the standard error of the estimate is 28.503.

The advantage to this model is that it will dampen fluctuations that occur with a weighted simple regression model.

DATA COLLECTION REFINEMENT

Photography

A large cost component of this project is found in the photography. For the two years this project has been in operation photographs have been taken from both sides of each sample tree selected. Other fruit and nut studies have indicated that photography on only one side is necessary. Through the analysis of variance technique, this possibility was explored for pecans (Tables 8 to 10).

Table 8.--Nested analysis of variance, expanded counts of nuts from July photographs, Mississippi pecans, 1971

Source of variation	Degrees of freedom	Mean square	F ratio	$F_{.01}$	$F_{.05}$
Between blocks	4	2115.7	2.18	6.42	3.63
Between trees	9	971.4	22.13	7.98	4.10
Between sides	6	43.9	0.38	2.85	2.20
Slides	89	116.9			
Total	108	258.1			

Table 9.--Nested analysis of variance, expanded counts of nuts from August photographs, Mississippi pecans, 1971

Source of variation	Degrees of freedom	Mean square	F ratio	$F_{.01}$	$F_{.05}$
Between blocks	4	4721.4	4.65	5.21	3.18
Between trees	13	1016.2	3.48	7.72	4.00
Between sides	6	292.0	1.00	2.96	2.18
Slides	116	293.0			
Total	139	488.0			

Table 10.--Nested analysis of variance, expanded counts of nuts from September photographs, Mississippi pecans, 1971

Source of variation	Degrees of freedom	Mean square	F ratio	$F_{.01}$	$F_{.05}$
Between blocks............	4	3707.7	2.53	5.21	3.18
Between trees.............	13	1463.4	4.69	4.16	2.69
Between sides.............	12	312.0	1.52	2.18	1.75
Slides....................	153	205.3			
Total.....................	182	379.2			

For the three months in which photography was taken no significant difference was observed between sides. This information coupled with similar information from 1970 research means it is unnecessary to continue photographing both sides of the tree.

This reduction will decrease man hours per tree and hence the cost per tree. This new procedure (using only one side of tree) will allow the field crews to complete all work on one tree at the same time.

Sample Limb Counts

This research work has pointed out one major obstacle to future use of counts of nuts on sample limbs. The mechanical hoist used to lift a counter into the tree has proved not to be operationally feasible. The reasons behind this are that mechanical failures are too numerous causing lengthy time delays. Secondly, rain and the period immediately after the rain stops are not workable periods due to bogging down. Thirdly, the cost is high relative to other cost components of the survey.

Without the hoist the number of accessible sample limbs is greatly reduced. In some trees, no accessible sample limbs will be found. The only solution which has not been justified to date is to select sample limbs from those available in the first twelve feet of the tree. This will mean in some cases no limbs will be used.

Counts of Nuts That Drop Prior to Harvest

One of the problems with droppage is the state of the ground under the tree. Grass and leaves are the greatest obstacle to accurate drop counts. In future research two new methods will be tried to eliminate this problem. First, two 2'x2' plots will be laid out under the tree and expanded to estimate of total droppage under the tree. Secondly, twenty nut clusters per tree will be identified and they will be observed during each survey period to determine the number of nuts that have fallen since the last survey period. The number of nuts that dropped will then be expanded to a tree estimate by the method used for counts of nuts on sample limbs that stay on the tree.

FUTURE STUDY

In the 1971 research, two variables have proven to be related to pounds of good pecans harvested per tree. This relationship has only been shown to hold over one variety of pecans in one small geographical area. The first consideration of any future research is to consider widening the geographical distribution of blocks and diversifying into several improved varieties.

A second consideration in future studies is the estimation of cost components. This will require that time records be kept for each segment of the project.

Finally, consideration of possible new variables must be kept in mind. Other characteristics may prove to be highly related to the pounds of good pecans per tree.