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1973 Mississippi Pecan Research

by

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INTRODUCTION

From 1964 to 1968, official forecasts of United States pecan production averaged between 10 and 15 percent difference from the final production. Generally, this error percentage is a reflection of larger errors at the State level. Because of this variability in pecan forecasts, industry requested that research be pursued by the Statistical Reporting Service to investigate methods to improve pecan production forecasts.

Initial research endeavors commenced in the Mississippi SSO during 1970 and 1971 to examine various methods of forecasting yield in terms of weight of nuts per tree. These methods included preharvest nut counts from sample limbs, from ground level photography, from a 15 power spotting scope, and from droppage. Results from nonprobabilistic samples of blocks (orchards) near Jackson, Mississippi in 1970 and 1971 indicated that nut counts from ground level photography and from sample limbs were each significantly correlated with pounds of pecans harvested. (Wood, (2), p. 2) (Wood, (3), p. ii)

Additional research was conducted during 1972 utilizing a nonprobabilistic sample of blocks in central and southwest Mississippi. Results demonstrated that the count of nuts from ground photography was the "best" variable for forecasting yield. (Gleason, (1), p. 26)

The 1973 pecan research was designed to further test the applicability of nut counts from ground photography as a forecasting technique. Earlier research had been limited to one or two varieties. Therefore, a probabilistic sample of blocks was selected from all varieties and ages to determine if forecasting models need be distinct for different variety and age classifications. The necessity of monthly models to forecast yield was also to be determined. Finally, various methods of expanding nut counts from ground photography to the tree level were to be analyzed.

The analysis of the 1973 pecan data was dependent upon the preharvest nut counts from ground photography and the associated harvest data for each tree. A flood at harvest prevented the acquisition of harvest data from most sample trees. Therefore, with an incomplete set of data, analysis was not possible.

Since analysis of the incomplete data would not provide answers to any of the research questions, this paper will not present any analysis results. Instead, this paper will describe the sample design, data collection and "proposed" data analysis for a probabilistic sample of trees with accurate harvest data.

SAMPLE DESIGN

The scope of the Mississippi pecan research was enlarged in 1973 to include all blocks from Bolivar and Coahoma counties in the sampling frame. The sampling frame, which consisted of a list of pecan growers, was acquired from the ASCS county agents. The purpose of constructing this frame was to provide a probability selection of trees from which statistical inferences could be drawn.

Each pecan grower in the sampling frame provided varietal and age information for each block. This information was obtained by telephone interview by the Mississippi SSO. Appendix A shows the interview form used to obtain this information. The sampling frame was then divided into six strata. However, since one stratum contained no blocks, the six strata were collapsed to five strata. Each stratum, assumed to be internally homogenous, was comprised of similar yielding varieties in a distinct age bracket. This stratification was performed in order to determine if distinct forecasting models are required for different varietal types and tree ages.

Within each stratum, three blocks were randomly selected with probability proportional to the number of trees in each block. Within each block, a simple random sample of two trees was selected. Therefore, the sample was comprised of 30 randomly selected trees. The stratification design is displayed in Appendix B.

DATA COLLECTION

Data collection consisted of two phases: (1) preharvest collection of ground photography required to expand nut counts to the tree level and (2) procurement of harvest data.

Ground photography was obtained for each sample tree in August and October. Photography was taken in October to determine if monthly forecasting models were necessary. Photography was obtained of one side of each tree starting at the bottom of the canopy and incrementing a clinometer angle 9° until the top of the canopy had been photographed. At each level of photography, an approximate tree width was obtained from protractor readings. In addition, the height of the tree based upon clinometer readings, the slope of the terrain, the radius of the canopy and the distance from the camera to the tree trunk were obtained. All these data are pertinent to expanding nut counts made by photography interpreters to the tree level.

Harvest data were to be obtained for each sample tree. Since photography interpreters cannot distinguish between good and bad nuts, nuts were to be classified into pounds of good and bad nuts in order to adjust biological yield to marketable yield by means of a ratio or regression estimator. Average nuts per pound were to be determined in order to derive pounds of nuts per tree from the nut counts made by photography interpreters. Also, the average nuts per pound for each tree were to be used to decide if a significant difference in nuts per pound was present among strata and blocks within a stratum.

Appendix C displays the data collection forms used to obtain the preharvest photography and harvest data.

PROPOSED DATA ANALYSIS

Much of the proposed data analysis has already been presented in describing the purpose for stratification of blocks, collection of August and October photography, and collection of harvest data. Had accurate harvest data been available, statistical inferences could have been stated concerning the need for stratification by variety and age and monthly forecasting models. Yet to be discussed is the methodology to be utilized to expand preharvest nut counts from photography to the tree level.

Two methods of expanding photography to the tree level had previously been developed. The first method assumes that the shape of the tree is spherical. (Wood, (2), p. 20) The second method assumes that the shape of the tree is parabolic. (Gleason, (1), p. 5) To supplement these methods, two additional methods were to be investigated using the preharvest and harvest data. The additional methods both assume that the surface area of a tree can be approximated by the sum of the surface areas of different sized cylinders at different levels within the tree. The methods differ in that the first approach assumes that the distance from the camera to the canopy is constant for all levels of photography while the second approach does not assume that this distance is the same for all levels photographed on the tree.

These four methods of photography expansion were to be tested to determine which method or methods displayed the "best" relationship with the harvest data from the different strata. However, again, the lack of harvest data prohibited this analysis.

Appendix D develops in detail the mathematical theory of these additional methods and provides examples of their use.

CONCLUSION

From the experience gained in the frame construction and data collection, several improvements can be made.

More accurate estimates of the number of trees in each block by variety and age should be obtained to ensure a sound sampling frame from which a probability sample could be drawn.

Additional information concerning varietal and age characteristics should be sought to provide better varietal and age groupings in each stratum. This would be necessary to accurately test for differences among strata in future research. The groupings into strata for this study were by no means optimal.

Field enumerators should possess a good knowledge of varietal traits in order to avoid misclassifications of sample trees. Since the number of harvest shakings varies by variety, age and operator, field enumerators should be hired from local areas to guarantee that harvest data will be properly collected.

Aerial photography should be used to aid in sample tree selections in selected blocks.

Future research should be designed to provide answers to the questions set forth for this study that could not be answered due to lack of harvest data. In addition, methods to estimate harvest loss should be investigated. Future research should be designed to determine the optimum number of blocks per stratum and trees per block. Finally, the influence of different management techniques on yield should be examined. If management techniques affect yield, another level of stratification would be needed to divide the list of pecan growers into commercial (managed) or noncommercial (nonmanaged) blocks.

APPENDIX A

Pecan Objective Yield Research Project

Mississippi Pecan Information,
Variety and Age Classifications.

Variety and age information is needed on pecans in Bolivar and Coahoma Counties. This information will be used to select individual trees. The trees will be studied to investigate methods of forecasting pecan production.

Pecan producer (on list)	Operator (makes the day to day decisions for the operation)
Name:	Name:
Address:	Address:
Phone:	Phone:

Pecan Information by Variety and Age Classes.

Ask what varieties he (she) has. Then for each variety ask for the year(s) planted. For each variety and each year planted (age) classification, obtain information on tree spacing, no. trees, no. acres, and the production last year (if available).

Variety	Year planted	Spacing between trees	No. trees	No. acres	Production last year

Once you have obtained variety and age information ask if this is all of his pecan operation in Bolivar and Coahoma Counties. Specifically ask if he has any (other) commercial seedling trees.

Date: ______________ *Information obtained by:* ______________________
(Please enter comments on back)

APPENDIX B

STRATIFICATION DESIGN

Age \ Variety	Mahan Owens Desirable	Stuart Success Moneymaker Schley	Native (Seedling)
6 - 25 years	*Stratum* 1	*Stratum* 2	*Stratum* 5
26 - 30 years	*Stratum* 3	*Stratum* 4	

APPENDIX C

PECAN OBJECTIVE YIELD RESEARCH 1973

Tree Photography and Associated Information

Operation Information

Name:

Address:

Phone:

Block Identification

Variety: ____________________

Age: ____________________

Tree I.D. No. ____________________

	Block Dimensions	Random Location of Tree
Width (Rows or ft.)	________	________
Length (Rows or ft.)	________	________

Date: ____________________

Time Started: ____________________

1. Radius of Canopy:

a. Radius 1 ______.______ ft.

b. Radius 2 ______.______ ft.

c. Distance to camera ______.______ ft.

d. Radius 3 ______.______ ft.

Time Completed: ____________________

2. Height of tree and canopy:

a. Top of canopy ______.______ %

b. Bottom of canopy ______.______ %

c. Base of trunk ______.______ %

d. Slope of terrain ______.______ %
(if necessary)

Time Completed: ____________________

3. Photography of tree column

Taken in (A.M. or P.M.) ____________________

Camera direction (Degrees from due North) ____________________

Roll No.

Level of tree	Clinometer reading 1/ (deg.)	Exposure No.	Camera settings 2/ Shutter speed	F-stop	Weather conditions	Protractor reading at canopy boundaries Left (deg.)	Right (deg.)
I.D.	XXXXXXXXX					XXXXXXXXX	XXXXXXXXX
	o					. o	. o
	o					. o	. o
	o					. o	. o
	o					. o	. o
	o					. o	. o
	o					. o	. o
	o					. o	. o
	o					. o	. o
	o					. o	. o
	o					. o	. o
	o					. o	. o

1/ Increment Clinometer readings by 9°.
2/ Photography must be taken at zero degrees on the protractor.

Enumerator initials ____________________ Time Completed: ____________________

4. Field notes, comments, and block sketch (pertains to this block only).

a. Approximate harvest date____;

b. Availability of shaker (owns, rents, hires (by whom))________________;

c. Harvest method (hand, mechanical, both)________________________________;

d. Disking (yes, no)____________; No. times__________Begin______________;

e. Spraying (yes, no)____________; No. times____________________________;

Interval between sprays (days)____________; Begin (month)____________;

f. Pruning (yes, no)_______________________; Month done_________________;

g. Fertilize (yes, no)_______________________; Month done________________;

PECAN OBJECTIVE YIELD RESEARCH
HARVEST DATA

Tree Number:______ Date of Harvest:______

Age:______ Trunk Girth:______

Variety:______

Total weight of nuts harvested by field grades:

"good"______lbs. "bad"______lbs.

NUT SAMPLES

From those field graded "good":

Sample 1

Number of nuts:______

Weight of entire sample:______gms.

Weight of sound nuts only:______gms.

Sample 2

Number of nuts:______

Weight of entire sample:______gms.

Weight of sound nuts only:______gms.

Sample 3

Number of nuts:______

Weight of entire sample:______gms.

Weight of sound nuts only:______gms.

From those field graded "bad":

Sample 4

Number of nuts:______

Weight of entire sample:______gms.

Weight of faulty nuts only:______gms.

Sample 5

Number of nuts:______

Weight of entire sample:______gms.

Weight of faulty nuts only:______gms.

Sample 6

Number of nuts:______

Weight of entire sample:______gms.

Weight of faulty nuts only:______gms.

Notes:

APPENDIX D

PHOTOGRAPHY EXPANSION

SECTIONED CYLINDRICAL METHOD (Approach I)

This method of photography expansion is based upon the assumption that the surface area of a tree can be estimated by the sum of the surface areas of different sized cylinders at different levels within the tree. Also, assuming that the nuts are on or near the periphery of the tree, the nut count on a subset of the tree can be expanded by the ratio of the surface area of the tree to the area photographed on the tree.

In order to expand the nut count at a particular level of photography, the width of the image taken by the camera must be determined.

STATEMENT 1: Let β be the horizontal angle of the camera. Then the width of the image on the tree surface at level i, b_i, is $2*dcc*\tan(\beta/2)/\cos(\gamma_i)$.

PROOF: Let dct = the distance from the camera to the center of the trunk, dcc = the distance from the camera to the edge of the canopy, and $\{\gamma_i, i=1,2,....,p\}$ represent the angles of declination or inclination at which the photographs were taken. Figure 1 gives a visual representation of these notations.

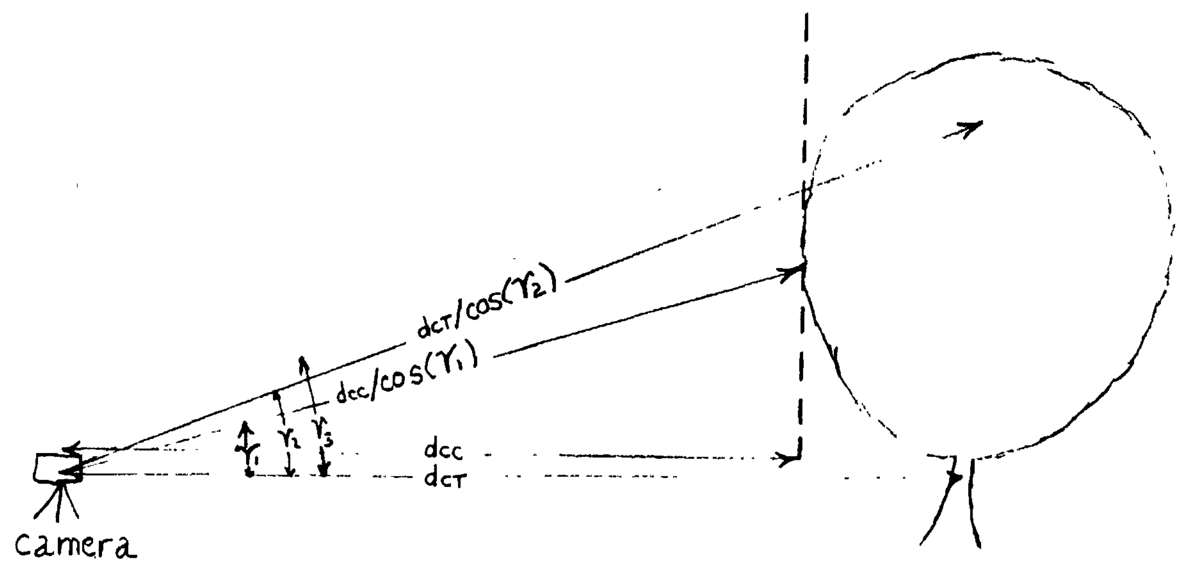

Figure 1

Let Figure 2 represent the top view of the camera with β = the horizontal camera angle and b_i = the width of the image on the tree surface at level i.

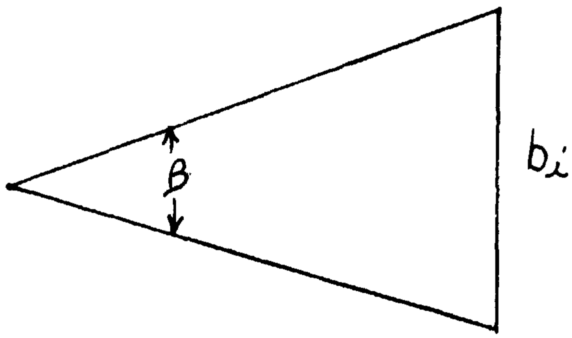

Figure 2

An approximation of the width of the frame can be made by assuming that the distance from the camera to the canopy is $dcc/\cos(\gamma_i)$ for each level at which photography was taken. The dotted line prependicular to dcc in Figure 1 shows this assumption. Note that for the sections of the tree at which the distance from the camera to the edge of the canopy is greater than $dcc/\cos(\gamma_i)$, the width of the image will be understated. Thus, in reality, the image width at certain levels will not reflect the actual image width.

Using the trigonometric function, the tangeant of an angle, Figure 3 shows that:

$$\tan(\beta/2) = \frac{b_i/2}{dcc/\cos(\gamma_i)} \quad . \text{ Therefore,}$$

$$b_i = 2*dcc*\tan(\beta/2)/\cos(\gamma_i).$$

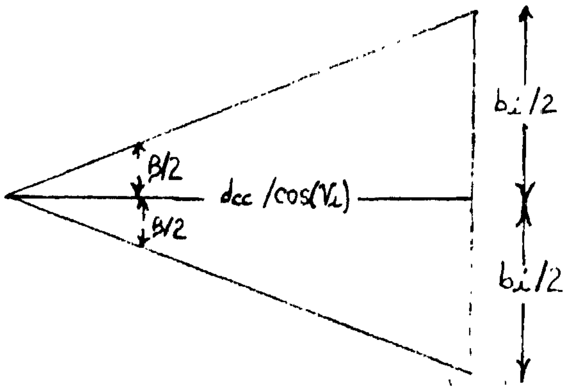

Figure 3

Next, it is necessary to determine the radius of the tree at level i. For the top view of the tree in Figure 4, let α_i be the angle traversed from the edge of the canopy on one side of the tree to the edge of the canopy on the opposite side of the tree at level i;i=1,2...,p. Let a_i = the diameter of the tree at the ith level. It will be assumed that for the edge of the canopy at points c and d the segment $\overline{cd}$ is perpendicular to the line from the camera to the center of the trunk and passes through the center of the tree.

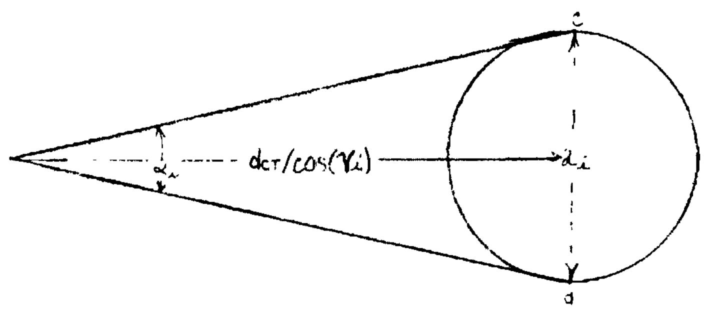

Figure 4

STATEMENT 2: The radius of the circle at the ith level, $a_i/2$, is equal to $dct*\tan(\alpha_i/2)/\cos(\gamma_i)$.

PROOF: Since the segment $\overline{cd}$ has been assumed to be perpendicular to the line $dct/\cos(\gamma_i)$ and to pass through the center of the tree, $a_i/2$ can be determined by the tangeant function since the distance from the camera to the center of the trunk is $dct/\cos(\gamma_i)$. Therefore, by inspection of Figure 5:

$$\tan(\alpha_i/2) = \frac{a_i/2}{dct/\cos(\gamma_i)} \quad . \text{ Therefore,}$$

$$\frac{a_i}{2} = dct*\tan(\alpha_i/2)/\cos(\gamma_i)$$

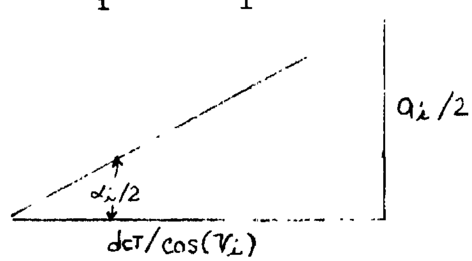

Figure 5

To expand the count of nuts for an image on the tree's surface at level i to the count on the tree, the area of the circle in Figure 6 at the ith level must be determined.

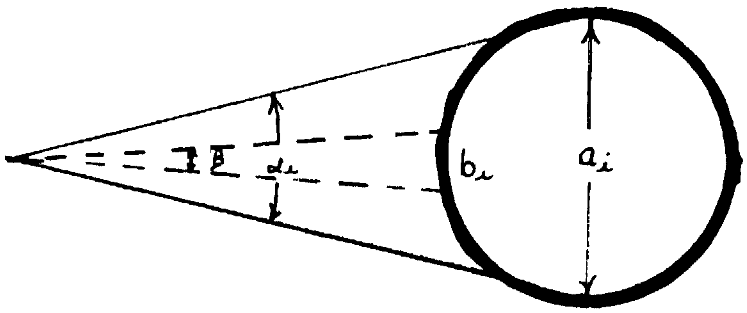

Figure 6

Since the circumference of a circle equals π* the diameter, the circumference at the ith level equals $2*\pi*dct*\tan(\alpha_i/2)/\cos(\gamma_i)$. The area of the the cylinder at level i is therefore $2*\pi*h*dct*\tan(\alpha_i/2)/\cos(\gamma_i)$, where h is the height of the frame. The area imaged on the surface of the tree at level i is $2*h*dcc*\tan(\beta/2)/\cos(\gamma_i)$.

The photography expansion factor for the ith level, $(PEF)_i$, is the ratio of the surface area of the cylinder at level i to the area imaged on the tree's surface at level i. In formula notation:

$$(PEF)_i = \frac{2*\pi*h*dct*\tan(\alpha_i/2)/\cos(\gamma_i)}{2*h*dcc*\tan(\beta/2)/\cos(\gamma_i)}$$

$$(PEF)_i = \frac{\pi*dct*\tan(\alpha_i/2)}{dcc*\tan(\beta/2)}$$

In conclusion, the photography expansion of the number of fruit or nuts on the jth tree, $(PE)_j$, is:

$$(PE)_j = \sum_{i=1}^{p} \frac{\pi*dct*\tan(\alpha_i/2)*N_{ij}}{dcc*\tan(\beta/2)}$$

where N_{ij} is the nut count for the ith level of the jth tree.

As previously mentioned, for certain sections of the tree the width of the image on the surface of the tree will be understated. Therefore, the photography expansion will be overstated for understated image widths since the width of the image is in the denominator of the photography expansion.

EXAMPLE 1: For the fourth nut tree let $\alpha_1 = 30^o$, $\alpha_2 = 60^o$, $\alpha_3 = 90^o$, dcc = 20, dct = 30, $N_{14} = 10$, $N_{24} = 5$, $N_{34} = 50$ and $\beta = 13^o$.

The photography expansion of the number of fruit or nuts on the fourth tree is:

$$(PE)_4 = \sum_{i=1}^{3} \frac{\pi * 30 * \tan(\alpha_i/2) * N_{i4}}{20 * .1148}$$

$$= 41.04864 \sum_{i=1}^{3} N_{i4} \tan(\alpha_i/2)$$

$$= 41.04684 \; (10(.2679) + 5(.5774) + 50(1.0))$$

$$= 41.04684 \; (2.679 + 2.887 + 50)$$

$$\doteq 2,281$$

In conclusion, to determine the photography expansion of a tree by the sectional cylindrical method, the distance from the camera to the edge of the canopy, the distance from the camera to the center of the trunk, the nut count of the area imaged on the tree surface at each level, the horizontal angle of the camera and the angle traversed from one edge of the canopy to the other edge of the canopy at each level must be determined.

SECTIONED CYLINDRICAL METHOD (Approach II)

This approach to photography expansion will obtain a more accurate approximation of the image width, b_i, by assuming that the distance from the camera to the canopy is not necessarily the same for each level at which a photograph was taken, as was assumed in the first approach. Therefore, the width of the image will not be understated. The distance from the camera to the canopy for the ith level will depend upon the radius of the tree, $\frac{a_i}{2}$, for the ith level. Thus,

$$\frac{dcc}{\cos(\gamma_i)} = \frac{dct}{\cos(\gamma_i)} - \frac{a_i}{2\cos(\gamma_i)} \qquad (1)$$

will approximate the distance from the camera to the canopy for level i (cf. Figure 7).

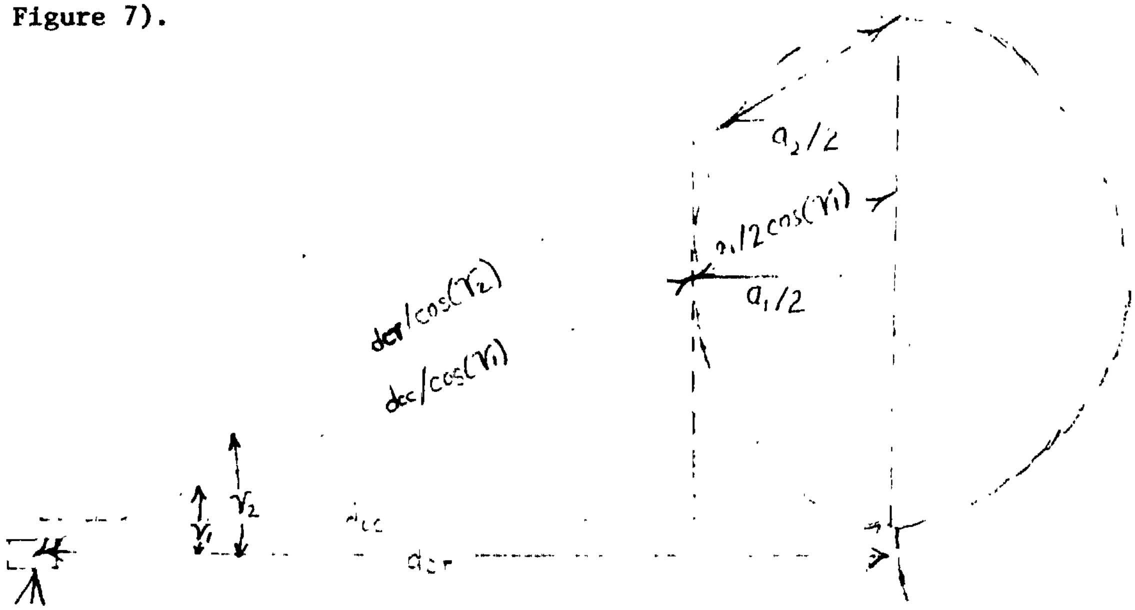

Figure 7

The radius of the tree and the width of the frame for the ith level by the sectioned cylindrical method are respectively:

$$\frac{a_i}{2} = dct*\tan(\alpha_i/2)/\cos(\gamma_i)$$
$$b_i = 2*dcc*\tan(\beta/2)/\cos(\gamma_i). \qquad (3)$$

Therefore, equation (1) becomes:

$$\frac{dcc}{\cos(\gamma_i)} = \frac{dct}{\cos(\gamma_i)} - \frac{dct*\tan(\alpha_i/2)}{\cos^2(\gamma_i)}$$

$$= \frac{dct}{\cos(\gamma_i)} * \left(1 - \frac{\tan(\alpha_i/2)}{\cos(\gamma_i)}\right)$$

$$= \frac{dct}{\cos(\gamma_i)} * \left(\frac{\cos(\gamma_i)-\tan(\alpha_i/2)}{\cos(\gamma_i)}\right). \qquad (4)$$

Substituting equation (4) into equation (3):

$$b_i = \frac{2*dct*(\cos(\gamma_i)-\tan(\alpha_i/2))*\tan(\beta/2)}{\cos^2(\gamma_i)}$$

Thus, the photography expansion factor for the ith level, $(PEF)_i$, is:

$$(PEF)_i = \frac{2*\pi*h*dct*\tan(\alpha_i/2)/\cos(\gamma_i)}{2*h*dct*(\cos(\gamma_i)-\tan(\alpha_i/2))*\tan(\beta/2)/\cos^2(\gamma_i)}$$

$$(PEF)_i = \left(\frac{\pi}{\tan(\beta/2)}\right) * \left(\frac{\cos(\gamma_i)*\tan(\alpha_i/2)}{\cos(\gamma_i) - \tan(\alpha_i/2)}\right)$$

In conclusion, the photography expansion of the number of nuts on the jth tree is:

$$(PE)_j = \frac{\pi}{\tan(\beta/2)} * \sum_{i=1}^{p} \left(\frac{\cos(\gamma_i)*\tan(\alpha_i/2)}{\cos(\gamma_i)-\tan(\alpha_i/2)} * N_{ij}\right)$$

where N_{ij} is the fruit or nut count for the ith level of the jth tree. Note that since the image width is not understated, the photography expansion will not be overstated.

EXAMPLE 2: For the third tree let $\beta = 13^o$, $\gamma_1 = 30^o$, $\gamma_2 = 45^o$, $\alpha_1 = \alpha_2 = 30^o$, $N_{13} = 10$ and $N_{23} = 20$.

The photography expansion of the nut count is:

$$(PE)_3 = \frac{\pi}{.1148} * \sum_{i=1}^{2} \left(\frac{\cos(\gamma_i) * \tan(\alpha_i/2)}{\cos(\gamma_i) - \tan(\alpha_i/2)} * N_{ij}\right)$$

$$= 27.3657 * \left(\frac{\frac{\sqrt{3}}{2} * \frac{1}{\sqrt{3}} * (10)}{\frac{\sqrt{3}}{2} - \frac{1}{\sqrt{3}}} + \frac{\frac{\sqrt{2}}{2} * \frac{1}{\sqrt{3}} * (20)}{\frac{\sqrt{2}}{2} - \frac{1}{\sqrt{3}}}\right)$$

$$= 27.3657\ (17.3 + 63.3)$$

$$\doteq 2206$$

In summary, using Approach II to determine the photography expansion the angle of inclination or declination at each level, the nut count at each level, the angle traversed from one edge of the canopy to the opposite canopy edge at each level and the horizontal angle of the camera must be found.

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(1) Gleason, Chapman P., A Comparison of Several Regression Models for Forecasting Pecan Yields, Research and Development Branch, Research Division, Statistical Reporting Service, U. S. Department of Agriculture, Washington, D.C., 1974.

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