Tobacco

ECONOMICS
RESEARCH
REPORT

AN ECONOMIC ANALYSIS OF ALTERNATIVE SYSTEMS FOR HARVESTING AND BULK CURING FLUE-CURED TOBACCO

ROBERT MAY
and
JOE S. CHAPPELL

ECONOMICS RESEARCH REPORT NO. 19
DEPARTMENT OF ECONOMICS
NORTH CAROLINA STATE UNIVERSITY AT RALEIGH
ERR-19 JANUARY, 1972

AN ECONOMIC ANALYSIS OF ALTERNATIVE SYSTEMS FOR HARVESTING AND BULK CURING FLUE-CURED TOBACCO

Robert May
and
Joe S. Chappell

Economics Research Report No. 19
Department of Economics
North Carolina State University
Raleigh, North Carolina
January 1972

ABSTRACT

The major purpose of this study was to quantify factors affecting the total cost of harvesting, curing and market preparation of flue-cured tobacco. Data were obtained from seventeen farmers located in eight Eastern North Carolina counties during the summers of 1968-69. Labor usage, fuel and electricity usage were quantified for eight alternative harvesting systems, all of which utilized bulk curing systems.

Labor requirements per 100 pounds of cured tobacco were inversely related to stalk position; i.e., lower stalk position had higher labor usage per 100 pounds. The walking-field racking system used significantly less labor than any other system and this difference ranged from .41 to 4.83 man-hours per 100 pounds for the mechanical-barn racking and riding-barn racking systems, respectively.

Initial and annual overhead costs were computed for these eight systems for operations varying from 3 to 40 acres harvested annually. Wage rates were varied from $1.30 to $3.00 per hour in this analysis.

Three mechanical harvesting systems were added to the observed systems to evaluate the feasibility of mechanical harvesters with increased initial costs and reduced labor requirements. At an $11,000 initial cost for the harvester, with a 50 percent reduction in labor usage to 2.00 man-hours per 100 pounds, a break-even wage of $3.36 per hour exists between the walking-field racking system and the mechanical harvesting-barn racking system at 25 acres harvested annually and a $2.07 per hour break-even wage rate at 40 acres harvested annually.

With initial cost of harvesters approaching $15,000 each, a considerable increase above 1971 levels in wage rates will be necessary to economically justify the adoption of mechanical harvesting equipment.

TABLE OF CONTENTS

AN ECONOMIC ANALYSIS OF ALTERNATIVE SYSTEMS FOR HARVESTING AND BULK CURING FLUE-CURED TOBACCO

Robert May and Joe Chappell*

I
INTRODUCTION

The economic pressures of higher wage levels and increased availability of nonagricultural jobs has steadily reduced the labor force available to the tobacco farmer to harvest his crop. The rapid industrial growth of the primary flue-cured tobacco growing area, the Southeastern United States, over the past fifteen years has presented year-round job opportunities not previously available. The migration of agricultural workers to other sections of the country has been an additional drain on the labor supply for harvesting tobacco.

Extension of the minimum wage law to agriculture in 1966 through amendments to the Fair Labor Standards Act affected all tobacco farmers. Even though many tobacco farmers were exempt because of low labor usage, increased wages paid by larger farmers raised the average wage level. Specifications of these amendments are presented by the U. S. Department of Labor (1966).

However, changes in the tobacco program during the 1960's were probably more important on production practices by tobacco farmers than the minimum wage law. The Lease and Transfer Program (Public Law 87-200)

---

*Former Research Assistant, Department of Economics, North Carolina State University; Associate Professor, Department of Economics, North Carolina State University, Raleigh, N. C., respectively.

(1962), the Acreage-Poundage Marketing Quota Program (Public Law 89-12) (1965) and the change in marketing regulations by the U. S. Department of Agriculture that allowed complete loose-leaf sales of tobacco have greatly altered opportunities of production and harvesting open to tobacco farmers.

Objectives

The specific objectives of this study were:

1. To measure labor, fuel, and electricity requirements for alternative mechanized tobacco harvesting-curing systems.

2. To analyze the requirements of the alternative systems--labor, operating, and fixed costs.

3. To determine the least-cost harvesting technology for selected volumes of tobacco at various wage rates.

4. To determine the break-even wage rates between the alternative systems for selected volumes of tobacco.

Description of Systems Evaluated

Seventeen farmers in eight counties in Eastern North Carolina agreed to participate in the study in 1968 and 1969. The farmers who participated met the following criteria: (1) were planning to use one of the selected systems; (2) were willing to assist in keeping accurate records; and (3) were within a daily driving distance of Raleigh. Counties included in in the study were Bertie, Edgecombe, Franklin, Harnett, Johnston, Nash, Sampson, and Wake.

Information was recorded on one barn of tobacco each week by individual stalk position during the harvesting season. Measurements were made on fuel and electricity usage on those farms that had separate meters and fuel tanks for an individual barn. Labor data for priming, hauling, barning, and market preparation were recorded by research assistants who were present when actual operations were conducted. Each barn of tobacco was tagged for identification in obtaining accurate market weights.

Although no attempt was made to gather data on the total tobacco acreage by farm, it was determined that tobacco acreage on the farms participating in the study varied from four to forty-three acres.

Essentially, six different harvesting systems were studied, all utilizing bulk curing. Each of the systems used commercial harvesting and curing equipment except for the home-built trailers used with the walking systems. All harvesting equipment was operated by farm workers at their desired work speeds.

Table 1 presents a brief description of the systems evaluated in this study.

Walking-Barn Racking System (WBR). Walking primers removed the tobacco from the stalk by hand similar to a conventional harvesting system. The primers or croppers placed armfuls of leaves into trailers pulled through the field in a skip row by a small tractor. It is a common practice to skip every fifth or seventh row to allow the tractor and trailers to move through the field without damaging the tobacco plants. Row spacing varied from 40 to 48 inches. After the trailer was filled with tobacco, it was towed to the curing barn. The tobacco was taken from the trailer by the barn crew who placed the leaves into bulk racks. A loading platform was used to assist in this operation. The rack was closed by forcing tines through the leaves. These tines were secured to the top part of the bulk rack. The filled rack was then transferred from the loading form to the bulk barn by members of the barn crew. Steel rails on the sides of each room in the barn served as a slide to permit filling the barn from rear to front. The leaves hang in a vertical position in the barn although they were loaded into the bulk rack in a horizontal plane.

Walking-Field Racking System (WFR). This harvesting system used walking primers like the previous system. However, with this system, the trailers also serve as the loading form. Each primer deposits his armful of tobacco leaves directly into the bulk racks located on the trailer. The top part of the bulk rack was placed into position by the priming crew.

The tractor drivers loaded the racks into the bulk barn with the assistance of electric chain hoists or inclined slides positioned at the front of the bulk barns. Electric hoists were used by some of the farmers using the walking-barn racking system.

Table 1. Composition of harvesting crew by tasks for selected harvesting systems

System	Harvester driver	Primers	Tractor drivers	Rack loaders[a]	Total crew size
		(number of people)			
WBR	--	4	2	3	9
WFR	--	4	2	0	6
RFR	1	4	1	2-3[b]	8-9
RBR	1	4	1	3	9
MBR	1	0	1-2	3	5-6
MFR	1	0	1-2	2	4-5

[a]Tractor drivers load the racks into the barn for field racking systems whereas rack loaders perform this task for barn racking systems.

[b]The driver of a self-propelled harvesting aide may also be a member of the racking crew.

Riding-Field Racking System (RFR). Primers with this sytem of harvesting ride on a four-row harvesting aid; these units may be either self-propelled or tractor drawn. Each primer placed a small handful of leaves between two belts directly above and slightly forward of his seat. The belts moved the leaves up and over to the center of the harvesting aid where they were placed into the bulk racks by the racking crew. Another member of the field racking crew closed the rack and hung it into a trailer. Self-propelled aids carried these trailers suspended from the rear of the aid whereas the trailers were towed behind the tractor pulled harvesting aids.

As suggested in Table 1, the driver of the self-propelled field racking harvesting aid may assist in the racking of the leaves. Also the tractor drivers loaded the filled racks of tobacco into the bulk curing barns.

Riding-Barn Racking System (RBR). A tractor towed or self-propelled priming aid was used with this system. Each primer placed the tobacco leaves into trays or packs directly in front of him on the priming aid. These trays or packs, when filled, were removed to a trailer to be transported to the curing barn to be placed into curing racks by the barn crew.

Machine-Barn Racking System (MBR). A self-propelled machine powered by an air-cooled engine used spiraled rubber wiper defoliators to remove tobacco leaves from the stalk. The defoliators are tilted upward with the forward portion being higher than the rear portion. The degree of tilt was adjustable to change the amount of swath removed by each pass through the field. The spiraled rubber defoliators rotated so that each tobacco leaf was broken from the stalk with a direct downward blow from the defoliators.

The driver was located at the front of the harvester, close to ground, beside the row of tobacco being primed. Priming height was easily adjustable with a hydraulic valve. Easy maneuverability of the harvester was provided by power steering and individual rear wheel brakes.

Leaves broken from the stalk fell on belts which elevated them as they moved toward the rear of the harvester where they fell into bins. The bins were emptied into pallets carried by the three-point hitch of a small farm tractor for movement to the rack loaders at the curing barn. A slight modification of this system was observed in the summer of 1971, in which the leaves were deposited into a small trailer carried on the harvester which was towed to the curing barn when filled. The leaves from this system are not oriented. Thus the leaves must be oriented prior to or at the completion of curing before they can be sold.[1] One manufacturer of mechanical harvesters produced a harvester designed to orient the leaves. The racking took place at the curing barn similar to other barn racking systems.

Machine-Field Racking System (MFR). The machine-field racking harvesting system utilized a self-propelled mechanical harvester that used the same defoliating head as the previously described system. However, the belt conveyance system on this machine elevated the tobacco vertically to an upper deck above the tobacco stalks where the tobacco fell into a bulk rack in a loading form. After each rack was filled, it was transferred to a platform or frame made especially to hold the racks in a vertical

[1]With the system observed in 1968-69, producers did not orient the leaves prior to sale. Current marketing regulations require orientation of leaves to avoid NO G grades.

position. The racks were moved to the frame by hand or by a hydraulic cylinder. When the platform was loaded, it was lowered to a heavy pallet mounted on the rear of a medium sized farm tractor for movement to the curing barn.

The Bulk Curing Barn

Two types of bulk curing barns were available commercially in 1969--a three-room prefabricated barn and a two-room mobile barn. Both types of barns were available in two-tier or three-tier models. Also available were components of these barns which were used to convert a conventional barn into a bulk curing barn.

Rack capacity for a 1969 model mobile barn varied from 84 to 126 racks. Prefab barn capacity varied from 84 to 150 racks. All of the available models were used by one or more farmers during the study.

Bulk curing barns used forced hot air for curing tobacco. An oil or gas furnace provided the necessary heat. A propeller or squirrel cage fan driven by an electric motor forced the heated air through the tightly packed tobacco. Temperature was controlled by a thermostat during the 130-150 hours normal curing cycle.

Steel grain floors were standard equipment in all bulk barns. Many options were available to assist in the loading, curing, and ordering operations. These included an automatic advance temperature controller, an automatic humidity controller, and an electric chain hoist with boom, trolley and mounting brackets. A fogging attachment that helped in ordering tobacco was also available.

II

DATA SOURCES AND ANALYTICAL PROCEDURES

Farm data recorded on each of the six systems by stalk position for 1968 and 1969 were used for the analysis. These measurements include labor times and weight per barn for all observations with fuel and electricity consumption along with fan and furnace hours for some of the observations where circumstances permitted.

All labor observations were recorded as the total number of hours for each task for each barn of tobacco. Barn sizes varied between locations; thus, all labor data have been standardized to man-hours per hundred pounds of cured tobacco. Labor tasks include priming, hauling, barning and market preparation time. Statistical analysis of labor productivity excluded market preparation due to a wide range of times caused by farmers following two barn unloading and sheeting options. Some farmers removed the tobacco from the barn, tied it in bundles of 12-20 pounds and packed it down in a storage barn to be sheeted at a later date for market, while others sheeted the tobacco directly from the barn. An average time for those sheeting directly from the barn was used in the budget analysis.

Analysis of variance (ANOVA) was used to test for significance (in man-hours per 100 pounds) between systems, stalk positions, and location of the racking operation as well as for determining a prediction equation using dummy variables. Comparison of system means was accomplished by using "F" and "t" tests.

Labor Productivity

Table 2 shows the combined farm data for 1968 and 1969. Five systems were observed in 1968 and four systems in 1969 for a total of 113 observations with one barn of tobacco comprising an observation. Unequal observations between and within systems resulted from farmers switching systems during the harvesting season. These changes resulted from mechanical breakdowns, weather conditions, changes in labor personnel and labor preferences as well as shifts in farmer preferences.

Table 2. Harvest time for alternative harvesting systems, bulk curing, 1968-1969

Type of system	No. of observations	Priming	Hauling	Barn	Total harvest	Market preparation	Total hours	Avg. barn wt.	Wt. per rack
				(man-hours per hundredweight)				(pounds)	
Walking - barn rack	46	2.18	.88	1.47	4.53	.82	5.35	1,515	14.73
Walking - field rack	20	2.12	.95	0	3.07	.41	3.48	1,319	16.19
Riding - field rack	30	5.34		0	5.34	.80	6.14	1,298	13.00
		(Priming and Hauling)							
Riding - barn rack	5	3.70	1.00	3.20	7.90	.61	8.51	1,087	13.36
Machine - field rack	6	5.30	1.55	0	6.85	1.20	8.05	907	12.40
Machine - barn rack	6	.70	1.41	1.37	3.48	.76	4.24	1,007	14.93

The small number of observations for the mechanical systems resulted from nondelivery of equipment, weather and plant conditions, and breakdowns. The 1968 harvest season began with five farmer operated mechanical harvesters scheduled to operate in Eastern North Carolina. However, numerous problems arose which greatly hampered obtaining acceptable observations. During the 1969 harvest season, only two mechanical harvesters operated and only one of those successfully.

The combined labor data in man-hours per hundredweight by stalk position, system, and task are presented in Table 3. Labor productivity increased as the harvest moved up the stalk and the weight per tobacco leaf increased. The WBR system used 2.71 man-hours per hundredweight for priming leaves at the lower stalk position, 2.05 man-hours per hundredweight at the middle stalk position and 1.86 man-hours per hundredweight at the upper stalk position. All data in Table 3 are means for the number of observations indicated.

Statistical Analysis

Labor data were recorded for four harvest and post-curing tasks. Total harvest time included priming, hauling, and barning hours. The addition of market preparation time to total harvest time gives total time for the harvesting-market preparation labor.

Statistical analysis has been limited to those labor tasks that make up total harvest time.

A comparison of total harvest labor using farm data by system is shown in Table 4. An "F" test was used to test the hypothesis of equal variances. Only the tests of variances for WBR versus MBR showed a rejection of the hypothesis of equal variances at the 5 percent level. A "t" test was used to test the null hypothesis of no significant difference between mean harvest times among systems. A system in the top row of Table 4 differs from a system in the left-hand column by the amount shown. Riding-field racking uses .81 man-hours per hundredweight more labor than the WBR system. The differences are statistically significant at the 1 percent level with the exception of those between MFR and RFR which are significant at the 5 percent level.

Table 3. Labor productivity for selected harvest systems by stalk position, 1968-1969

System	No. of observations	Priming	Hauling	Barn	Total harvest time	Sheeting	Total time
		(man-hours per hundredweight)					
Walking-barn racking							
Stalk position							
Lower	14	2.71	1.10	1.58	5.39	.93	6.33
Middle	16	2.05	.82	1.45	4.32	.85	5.17
Upper	16	1.86	.74	1.39	3.99	.68	4.67
Walking-field racking							
Stalk position							
Lower	5	2.64	1.33	0	3.97	.51	4.48
Middle	8	1.94	.80	0	2.74	.37	3.11
Upper	7	1.96	.85	0	2.81	.41	3.22
Riding-field racking							
Stalk position							
Lower	13	5.74	.83	0	6.57	.82	7.39
Middle	10	4.11	.51	0	4.62	.70	5.32
Upper	7	4.14	.50	0	4.64	.84	5.48
Riding-barn racking							
Stalk position							
Lower	4	3.60	1.09	3.50	8.19	.59	8.78
Middle	1	4.13	.64	1.97	6.74	.69	7.43
Upper	0	--	--	--	--	--	--
Machine-field racking							
Stalk position							
Lower	2	5.07	1.71	0	6.78	1.36	8.14
Middle	3	5.61	1.63	0	7.24	1.06	8.30
Upper	1	4.82	.97	0	5.79	1.29	7.08
Machine-barn racking							
Stalk position							
Lower	2	.88	1.76	1.76	4.40	.86	5.26
Middle	2	.66	1.31	1.89	3.86	.74	4.60
Upper	2	.57	1.15	1.15	2.87	.68	3.55

Table 4. Means of total harvest labor and significant differences between systems

System	Labor (man-hours per cwt.)	RBR	MFR	RFR	WBR	MBR	WFR
Riding-barn racking	7.90	--	1.06**	2.56**	3.37**	4.42**	4.83**
Machine-field racking	6.85		--	1.50*	2.31**	3.36**	3.77**
Riding-field racking	5.34			--	.81**	1.86**	2.27**
Walking-barn racking	4.53				--	1.05**	1.46**
Machine-barn racking	3.48					--	.41**
Walking-field racking	3.07						--

*Significant at the 5 percent level.

**Significant at the 1 percent level.

Prediction Equation for Walking and Riding Systems

A multiple regression equation used data for the walking and riding systems. The results are in Table 5. The RBR system, lower stalk position, represented the base of 9.68 man-hours per hundredweight. The intercept shifters in the model were b_1 through b_4.[2] The fifth variable accounted for differences in rack weights by stalk position. The coefficient of determination for the equation was .7026 with a standard error of the estimate equal to .816. Each of the five variables was statistically significant at the 1 percent level.

The weights per rack by stalk position for all observations of the study were 12.15, 15.34, and 15.82 pounds, respectively. Thus, a WFR system at the middle stalk position would use 2.80 man-hours per hundredweight of labor. This labor time was obtained by subtracting amounts for walking primers (1.85), field racking (1.42), middle stalk position (.90), and .1764 times weight per rack of 15.34 (2.71) from the base of 9.68 man-hours per hundredweight.

[2] A description of intercept shifters with regression analysis is presented by Ben-David and Tomek (1965).

Table 5. Regression of total harvest man-hours per hundredweight of cured tobacco on selected dummy and independent variables

$$y = a_1 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$$

where

y = total harvest man-hours per hundredweight of cured tobacco

a_1 = intercept

x_1 = 1 if walking primers; 0 otherwise

x_2 = 1 if field racking; 0 otherwise

x_3 = 1 if middle stalk position; 0 otherwise

x_4 = 1 if upper stalk position; 0 otherwise

x_5 = weight per rack in pounds

Variable	df	Sequential SS	b values	Prob > $\|t_b\|$
Intercept			9.6833	.0001**
x_1	1	59.7049	-1.8468	.0001**
x_2	1	53.9416	-1.4178	.0001**
x_3	1	11.5562	-0.9008	.0006**
x_4	1	36.2662	-0.8991	.0011**
x_5	1	21.7862	-0.1764	.0001**

R^2 = .7026

Standard error of the estimate = .816

**Significant at the 1 percent level.

Fuel and Electrical Consumption

Fuel usage was measured on those curing barns with individual tanks. Liquified petroleum gas was burned at a rate of 18.38 gallons per hundredweight of cured tobacco. Number two fuel oil consumption amounted to 16.39 gallons per hundredweight. Electricity was used at a rate of 37.46 kilowatt hours per hundredweight for a five horsepower motor. The rates of consumption of fuel and electricity are mean values over all observations where measurements were recorded.

Fuel and electrical consumption measured during 1968 and 1969 has been converted to a per hundredweight standard for use as an overall mean covering all barn sizes and stalk positions. Additional measurements were made on 89 barns of tobacco for fan and furnace hours. The mean fan hours per barn for the 89 observations was 143.6. The measured mean kilowatt-hour usage for all measured operations was 37.46 kilowatt-hours per hundredweight. This electrical consumption figure will be used in the budget calculations.

Comparison of Data with Previous Studies

The labor data on the six systems presented in the first four tables are based on farm data. Since the farmers chosen for the study were not a random sample, it is worthwhile to compare data obtained from this study with that of previous studies for similar tasks. Priming and hauling tasks from previous studies would be comparable to those for a walking-barn racking system.

Chumney and Toussaint (1957, p. 11) reported a priming time per 1,000 leaves of .400 man-hours while Chappell and Toussaint (1965, p. 10) found a priming time of .346 man-hours per 1,000 leaves with a standard deviation of .079. Both of these were on the farm studies involving walking primers. Bradford (1968, pp. 27, 32) observed a priming time of 2.23 man-hours per hundredweight with a coefficient of variation equal to 17.4. Transforming this priming time to man-hours per 1,000 leaves gives .384 with a standard deviation of .0388.[3]

---

[3] Bradford's study had a mean priming time of 2.23 man-hours per hundredweight with 129,000 leaves per acre for a yield of 2,230 pounds. Thus it took 58 leaves to make one pound of tobacco or an average leaf weight of .01728 pounds over all stalk positions.

Priming time for WBR for this study was 2.18 man-hours per hundredweight based on a 2,000-pound yield with 116,000 leaves per acre. Converted to man-hours per 1,000 leaves, this gives .376 with a standard deviation of .107. A "t" test between the Chappell and Toussaint, Bradford, and this study showed no significant difference between means for priming time at the 5 percent level. Of course, it was necessary to assume for these statistical comparisons that the mean leaf weight from Bradford's tests was correct and applicable to this study.

Hauling time for several previous studies is also available, but the standard deviations are lacking and this prevents running statistical tests. However, a comparison of times and weights is available. Chumney and Toussaint (1957, p. 11) found a hauling time of 17.0 hours for 2,000 pounds of cured tobacco. Coutu and Mangum (1960, pp. 14-15) used a figure of 17.5 man-hours per ton of tobacco per acre. Hauling time for WBR was .88 man-hours per hundredweight or 17.6 man-hours per 2,000 pounds. Thus, these three studies show essentially the same hauling times for equal amounts of tobacco.

III
BUDGET ANALYSIS

Labor requirements by tasks were presented in the previous section; now fuel, electricity, barn and harvesting equipment requirements along with their costs will be quantified so that budgets can present variable, fixed and total costs by system for selected volumes of tobacco and alternative wage rates. Cost information was obtained from manufacturers, dealers, farmers, and fuel and power suppliers. When an item of equipment was not available commercially, engineering cost estimates were used.

The expansion from six to eight harvesting-curing systems in this chapter results from the availability of harvesting equipment for the RBR and RFR systems in either tractor drawn or self-propelled models. Labor requirements are the same but initial investment costs are higher for self-propelled units than for the tractor drawn models. Four mechanical harvesting systems were added to the eight observed systems to further evaluate the potential of complete mechanical harvesting. Three of these additional systems encompass engineering data for harvesting labor requirements and appreciably higher initial costs of mechanical harvesting.

Variable Costs

Variable costs included all operating costs that were incurred when the tobacco was harvested and cured. Variable costs were divided into two categories, nonlabor operating costs and labor costs.

Nonlabor operating costs included electricity and fuel for the curing operation plus the operating costs for the tractors and/or self-propelled harvesters. A power company rate of 1.35 cents per kilowatt-hour was used in computing electrical costs. This service rate declines on a sliding scale to 1.35 cents per kilowatt-hour after 750 kilowatt-hours of electricity have been used. Fuel costs were calculated at 16 cents per gallon for LP gas. Number 2 fuel oil cost was estimated at 16 cents per gallon. However, all budget computations are based on using LP gas since fuel oil curing units initially cost $160-$212 more than comparable btu capacity gas furnaces. The estimated operating cost for very small tractors and self-propelled harvesters was 42 cents per hour while a medium size tractor costs were 64 cents per hour.[4]

Variable and fixed costs for the tractors were based on hauling hours data per hundredweight of cured tobacco for each system from the farm observations in Table 2. This method of calculating work hours for each piece of machinery appeared to be realistic since crew size varied between farms, such that actual work hours within each system covered a wide range for hauling time.

One small tractor was used with the systems using a self-propelled harvester except for the two mechanical harvesters. The MFR system used a medium size tractor with a rear mounted pallet to transport the platform filled with bulk racks from the rear of the harvester to the curing barn. The MBR system used two small tractors with small pallets enclosed on three sides to move the tobacco to the loading area outside the barn. Two small tractors were used with all other systems not using a self-propelled harvester.

It was assumed that a farmer using any of the twelve systems already owned the number and proper sizes of tractors needed to operate the particular system he used. Based on this assumption, only a cost per hour was charged to the tractors for the time in use during tobacco operations.

Labor costs comprised another portion of variable costs. The calculations of labor costs used total harvest man-hours per hundredweight from Table 2 except for the WFR and RBR systems. Harvest data showed WFR to use less labor for priming than WBR by .06 man-hours per hundredweight and to use only .07 man-hours per hundredweight more labor for the hauling operation. Thus, adjustments were made for the WFR system by deleting observations from one farm. The adjusted figures for WFR showed priming time at 2.33 man-hours per hundredweight, hauling time at 1.04 man-hours per hundredweight with total harvest time of

---

[4]A tractor with less than 35 h.p. is very small and a tractor with 50-64 h.p. is medium size according to Saunders et al. (1969, p. 37).

3.37 man-hours per hundredweight. Thus, the WFR system uses .15 man-hours per hundredweight more labor for priming and .16 man-hours per hundredweight more labor for hauling than the WBR system. This appears to be more realistic since in the WFR system the primers load and close the bulk racks and the tractor drivers must load the barn unassisted by any other barn crew. In the budget analysis, labor requirements for the WFR system were 2.33 man-hours per hundredweight of labor for priming and 1.04 man-hours per hundredweight of labor for hauling.

Table 2 shows actual labor usage of 7.90 man-hours per hundredweight for the RBR system. Due to the small number of observations and the absence of upper stalk position observations, the prediction equation from Table 5 was used to obtain an estimated labor time of 6.53 man-hours per hundredweight of labor.[5]

The farm data for market preparation in Table 2 range from a mean of .41 man-hours per hundredweight of labor with WFR to 1.20 man-hours per hundredweight with MFR. Due to differences in barn removal and sheeting operations among producers, an estimated time of .6 man-hours per hundredweight of labor was used to reflect this element of labor. The .6 man-hours per hundredweight of labor is a weighted mean of all farmers who used direct barn sheeting with the walking and riding systems. A market preparation time of 1.2 man-hours per hundredweight was used for the mechanical systems as more time is needed to straighten the leaves so that the tobacco will meet current market regulations.[6]

Fixed Costs

Bulk Barns

Fixed or capital costs were computed for five sizes of commercial bulk curing barns. The initial costs of the bulk curing barns were based on an average of 1969 manufacturers' F.O.B. plant prices.

---

[5] An average rack weight by stalk position for all 113 observations was used in computing the labor requirements for RBR.

[6] According to Splinter (1968, p. 23), 138 percent more time was needed to grade and market nonaligned tobacco than aligned tobacco.

Table 6 shows the investment cost for each of the five sizes of standard bulk barns. Also included are annual fixed costs and an estimated life of a barn. A prefabricated two-tier bulk barn ready for curing would cost $4,757 with an annual fixed cost of $699. Annual fixed costs were based on a life of 15 years with a zero salvage value, repairs at 2 percent of the initial cost, interest at 8 percent on 1/2 the initial investment and insurance and taxes at 2 percent of the initial cost. Thus, annual fixed costs were calculated to be 14.67 percent of the initial investment.[7]

Bulk Barn Capacity

Whereas many sizes of bulk curing barns were available, it was necessary to standardize capacity for each of the five sizes so that the least-cost combination could be used in computing budgets.

Determination of two-tier barn capacity for six cures was based on the average weight per rack by cure from the farm data. Three-tier barn capacity was formulated using only two-thirds capacity for the first two cures and full capacity for the last four cures.[8] Full rack capacities for the five barn sizes in Table 7 were calculated using 84, 84, 102, 126, and 150 racks, respectively. The barn capacity was then estimated to the nearest tenth of an acre based on a yield of 2,000 pounds per acre. Average weights per rack by cure over all observations were as follows:

Cure	Average weight per rack of cured tobacco (pounds)
1	11.36
2	12.93
3	15.16
4	15.51
5	16.16
6	15.54
Weighted average	14.35

[7] Assuming a useful life of 25 years for a barn results in an annual fixed cost of 12 percent of the initial investment.

[8] Manufacturers recommend using the third tier only for middle and upper stalk tobacco.

Table 6. Investment costs for standard bulk barns

Loading area	Identification	Initial cost[a]	Annual cost[b]	Estimated life
		(dollars)		(years)
Under 440 sq. ft.	Prefab - two tier	4,186	614	15
Under 440 sq. ft.	Mobile - two tier	4,654	682	15
Above 500 sq. ft.	Prefab - two tier	4,757	699	15
Above 640 sq. ft.	Mobile - three tier	5,386	798	15
Above 740 sq. ft.	Prefab - three tier	5,611	823	15

[a]Based on FOB plant price plus transfer cost to farm, erection costs and electrical connections. Standard bulk barn ready to cure includes assembled racks, steel floor, 5 h.p. electric motor, gas furnace, automatic temperature controller (manual advance) and a wet/dry bulb thermometer. Foundation costs are based on using no footing, perimeter foundation consisting of two layers of cement blocks for the prefab barn and one layer cement blocks for the mobile barn.

[b]Annual cost computed as follows: Depr. $= \frac{\text{Initial cost}}{\text{Estimated life}}$

Repairs = 2 percent of initial cost (I.C.)
Insurance and taxes = 2 percent of initial cost (I.C.)
Interest on investment $= \frac{\text{I.C.}}{2}$ x 8 percent.

Table 7. Bulk barn capacity and fixed cost per pound of cured tobacco for selected acreages

Selected acreages	Acres capacity	Bulk barn size[a] Two tier: Prefab under 440 sq. ft.	Two tier: Mobile under 440 sq. ft.	Two tier: Prefab above 500 sq. ft.	Three tier: Mobile above 640 sq. ft.	Three tier: Prefab above 740 sq. ft.	Fixed cost per pound[b] (dollars)
Acres capacity		3.6	3.6	4.4	4.9	5.9	
3	3.6	(1)					.1023
5	5.9					(1)	.0823
7.5	8.0	(1)		(1)			.0875
10	10.3			(1)		(1)	.0761
15	15.4	(1)				(2)	.0753
20	20.6			(2)		(2)	.0761
25	25.0			(3)		(2)	.0749
40	41.3					(7)	.0720

[a]Number of each size barn used in cost computations is enclosed in parentheses.

[b]Annual fixed cost per pound is computed for 3 acres by dividing the annual fixed cost of $614 by the volume of 6,000 pounds.

Utilizing the information on annual fixed barn costs (Table 6) and bulk barn capacity, a fixed cost per pound of cured tobacco was calculated using the least-cost combination of barn sizes.

Table 7 shows bulk barn capacity and fixed cost per pound for the selected volumes of tobacco. The least-cost combination of barns for 10 acres would be one with 4.4 acres capacity and one with 5.9 acres capacity giving a total capacity of 10.3 acres with a fixed cost per pound of 7.61 cents.

The acres capacity of each barn are shown directly under the loading area in Table 7. The cheapest combination of barns progresses toward the use of all three-tier units as acreages become larger. A mobile, two-tier barn was never selected because it costs $68 more annually than an equivalent size prefab barn. Of course, the cost calculations do not consider possible advantages of owning a mobile barn such as resale value, movability, and ease of installation which could outweigh the extra annual cost of approximately 1 cent per pound.

Harvesting Equipment

Capital costs of harvesting equipment were also based on commercial equipment available using 1969 manufacturers' price lists and farmer invoices. Engineering cost estimates were used for those items not available commercially. The equipment listed in Table 8 for each system was assumed to be the items needed for one complete operating unit except for the tractors needed to pull trailers and priming aides and to lift pallets. Saunders et al. (1969, p. 32) calculated fixed cost for small and medium size tractors to be $.68 and $1.61 per hour, respectively, based on an annual usage of 600 hours.

Equipment for the riding and walking systems had an estimated life of 10 years with zero salvage value. The mechanical systems had an estimated life of 5 years with zero salvage value.[9] A major unknown factor in determining the life of the mechanical harvesters is obsolescence.

[9] A similar situation of zero salvage value exists with grain combines. Many junk dealers will only purchase combines after they have been taken apart and separated into groups of metals.

Table 8. Investment costs and specifications for harvesting equipment

System	Item	Initial cost		Annual cost[a]	Estimated life
		(dollars)			(years)
*Walking-barn racking	4 trailers @ $50 each	200			
	1 loading platform	53	253	50.60	10
*Walking-field racking	4 trailers @ $55 each	220	220	44.00	10
*Riding-field racking	Tractor drawn aide	1875			
	3 special trailers @ $325 each	975	2850	570.00	10
**Riding-field racking	Self propelled aide	4095			
	3 special trailers @ $325 each	975	5070	1014.00	10
*Riding-barn racking	Tractor drawn aide	975			
	3 trailers @ $50 each	150			
	1 loading platform	53	1178	235.60	10
**Riding-barn racking	Self propelled aide	2495			
	3 trailers @ $50 each	150			
	1 loading platform	53	2698	539.60	10
**Machine-field racking	Harvester	8900[b]			
	1 heavy pallet	100	9000	2700.00	5
**Machine-barn racking	Harvester	6000[b]			
	2 pallets @ $72 each	144			
	1 loading platform	53	6197	1858.70	5

*Tractor drawn.

**Harvester self-propelled, trailers or pallets tractor drawn.

[a]Annual cost computed as follows: $\text{Depr.} = \frac{\text{Initial cost}}{\text{Estimated life}}$
Repairs = 5 percent of initial cost
Insurance and taxes = 1 percent of initial cost
Interest on investment = $\frac{\text{I.C.}}{2}$ x 8 percent.

[b]Variable initial costs assumed for purposes of evaluating alternative systems.

No information is available on the actual life of a mechanical harvester operating for more than two years under field conditions.

Investment costs and equipment specifications are presented in Table 8 along with annual fixed costs. A riding-field racking tractor drawn harvesting aide costs $1,875. Three special trailers at $375 each raise the initial equipment investment to $2,850. Annual fixed costs for the walking and riding systems amount to 20 percent of the initial investment based on a 10-year life.

The annual fixed costs for the mechanical systems are 30 percent of the initial investment based on a 5-year life. Increasing the life expectancy to 7 and 10 years reduces the annual fixed costs to 24.29 percent and 20 percent of the initial cost, respectively.

Estimated Total Harvesting-Curing Market Preparation Costs of Selected Systems

Using all fixed and variable cost data, budgets were computed for 3, 5, 7.5, 10, 15, 20, 25 and 40 acres of tobacco. The selected acreages or volumes of tobacco were chosen since approximately 99 percent of the tobacco allotments in North Carolina are 25 acres or less.[10]

Twenty-five acres of tobacco was considered to be the capacity for each system except the mechanical harvesters. Each mechanical harvester was estimated to be capable of harvesting 40 acres. Therefore, two complete sets of equipment for all walking and riding systems would be needed to harvest 40 acres.

Variable costs for labor, tractor and/or harvester operating costs, fuel and electricity for curing as well as fixed costs of tractors, harvesters, equipment and bulk barns were combined for each system for selected sizes of acreages. Wage rates were varied from $1.30 to $3.00 per hour.

Identification of Alternative Tobacco Harvesting Systems

Table 9 contains the identification numbers, abbreviations, harvesting and sheeting labor requirements per 100 pounds of cured

---

[10] Based on information provided in a USDA publication (U. S. Department of Agriculture, 1968).

Table 9. Identification of alternative tobacco harvesting systems, labor requirements and equipment expenses

System number	Abbre-viation	Labor[a]			Equipment	
		Harvest	Sheeting	Total	Annual	Initial cost
		(man-hours per hundredweight)			(dollars)	
1	WBR*	4.53	.60	5.13	51	253
2	WFR*	3.37	.60	3.97	44	220
3	RFR*	5.34	.60	5.94	570	2,850
4	RFR	5.34	.60	5.94	1,014	5,070
5	RBR*	6.53	.60	7.13	236	1,178
6	RBR	6.53	.60	7.13	540	2,698
7	MFR	6.85	1.20	8.05	2,700	9,000
8	MBR	3.48	1.20	4.68	1,858	6,197
9	MBR	3.48	.60	4.08	2,758	9,197
10	MFR	2.00	.60	2.60	3,300	11,000
11	MBR	1.40	.60	2.00	3,358	11,197
12	MBR	.80	.60	1.40	3,358	11,197

*Tractor drawn trailers or aides.

[a]Labor requirements for Systems 1-9 obtained from current study. Labor requirements for System 10 obtained from Splinter _et al_. (1968). Labor requirements for Systems 11 and 12 assumed for illustrative purposes.

leaf, initial costs and annual costs for the 12 systems evaluated in this study. All of the mechanical barn racking systems (MBR) require loading platforms and trailers or pallets in addition to the harvester. Harvesting labor requirements include leaf removal, placing into the bulk racks, transporting the filled racks of tobacco to the bulk barns and hanging the filled bulk racks into the curing barns.

Costs per 100 Pounds - $1.30 Wage Rate

System 2 (WFR) resulted in the lowest level of costs per 100 pounds up to 40 acres of tobacco harvested annually (Table 10). At 40 acres per year, system 12 (MBR), with harvest labor requirements of .80 man-hours per 100 pounds, resulted in approximately equal costs of $17 per 100 pounds with system 2. Notice the disadvantage of observed mechanical harvesting systems 7 and 8 relative to systems 1, 2 and 3 at this wage rate and at all acreages considered in this study. System 10 which uses a mechanical harvester with an initial cost of $11,000 and which requires 2.6 man-hours of labor per 100 pounds of tobacco to harvest and prepare for market resulted in a cost more than $2 per hundred pounds higher than the least cost system (at 40 acres). This difference totaled more than $1,600 annually.

At 25 acres annual volume, system 3 (RFR) resulted in lower costs per 100 pounds of cured tobacco than any of the observed mechanical systems.

Costs per 100 Pounds - $2.50 Wage Rate

System 2 was the least cost system through 20 acres harvested annually and only $.47 per 100 pounds more expensive than system 12 (MBR) at an annual volume of 25 acres (Table 11). Notice the decrease in cost per 100 pounds as volume increased from 3 to 40 acres for any system; i.e., from $25.48 to $21.59 for system 2 (WFR). Part of this decrease in cost was attributed to equipment annual fixed costs but most of it was associated with the estimated fixed costs per pound of bulk barn sizes. System 11 (MBR) budgeted with a 20 percent reduction in harvest labor from 1967 levels and without orienting the leaves prior to the sale of tobacco illustrated the potential adoption of a mechanical

Table 10. Estimated total costs of selected harvesting systems, dollars per hundredweight, at wage rate of $1.30 per hour

Acres							
3	5	7.5	10	15	20	25	40
2[a]	2	2	2	2	2	2	2
20.72[b]	18.42	18.80	17.58	17.43	17.47	17.33	17.06
1	1	1	1	1	1	1	12
22.16	19.82	20.17	18.95	18.78	18.82	18.67	17.13
5	5	5	5	3	3	12	11
27.98	24.40	24.14	22.39	21.78	21.38	19.94	18.06
3	3	3	3	5	12	11	1
32.08	26.28	24.90	22.81	22.13	21.74	20.87	18.41
6	6	6	6	6	5	3	10
32.70	27.10	25.82	23.57	22.81	22.01	20.97	19.22
4	4	4	4	4	4	4	8
39.12	30.35	27.49	24.66	22.89	22.13	21.50	20.90
8	8	8	8	12	6	5	3
52.58	38.19	32.51	28.28	24.45	22.43	21.77	20.97
9	9	12	12	8	11	10	9
66.80	46.41	36.87	30.13	25.10	22.67	21.98	21.24
12	12	9	11	11	8	6	5
71.92	47.54	37.73	31.06	25.38	23.63	22.04	21.61
11	11	11	9	10	10	8	4
72.85	48.47	37.80	32.00	26.43	23.75	22.58	21.72
10	10	10	10	9	9	9	6
73.13	49.12	38.64	32.01	27.32	25.10	23.60	22.03
7	7	7	7	7	7	7	7
73.19	53.19	44.71	39.07	34.49	32.32	30.84	28.53

[a]System number.

[b]Cost--dollars per hundredweight.

Table 11. Estimated total costs of selected harvesting systems, dollars per hundredweight, at wage rate of $2.50 per hour

Acres							
3	5	7.5	10	15	20	25	40
2[a]	2	2	2	2	2	12	12
25.48[b]	23.19	23.56	22.35	22.19	22.24	21.62	18.81
1	1	1	1	1	12	2	11
28.32	25.98	26.33	25.10	24.94	23.42	22.09	20.46
5	5	3	3	12	1	11	2
36.53	32.96	32.03	29.93	26.13	24.98	23.27	21.59
3	3	5	5	11	11	1	10
39.21	33.40	32.69	30.95	27.78	25.07	24.83	22.34
6	6	6	4	3	10	10	1
41.26	35.66	34.38	31.79	28.90	26.87	25.10	24.57
4	4	4	12	10	3	3	9
46.24	37.48	34.62	31.81	29.54	28.51	28.10	26.14
8	8	8	6	4	8	8	8
58.19	43.80	38.13	32.13	30.02	29.25	28.19	26.52
9	12	12	11	5	4	9	3
71.70	49.22	38.55	33.46	30.69	29.25	28.49	28.10
12	11	11	8	8	9	4	4
73.60	50.87	40.20	33.89	30.72	30.00	28.62	28.85
11	9	10	10	6	5	5	5
75.25	51.30	41.76	35.13	31.36	30.57	30.33	30.16
10	10	9	9	9	6	6	6
76.25	52.24	42.63	36.89	32.22	30.99	30.60	30.58
7	7	7	7	7	7	7	7
82.85	62.85	54.57	48.73	44.15	41.98	40.50	38.13

[a]System number.

[b]Cost--dollars per hundredweight.

harvesting system at wage rates of $2.50 per hour. Some very efficient operations during the summer of 1971 were reported to achieve harvesting labor requirements of this magnitude.

The effect of higher wage rates on the least cost systems and the level of costs are depicted in Appendix Tables 1-4 for wage rates of $1.50, $1.75, $2.00 and $3.00 per hour, respectively.

As wage rates were increased, the mechanical harvesting systems 10, 11 and 12 became much more competitive with the hand systems 1, 2 and 3. However, a wage rate of $2.50 per hour was required together with 25 acres of tobacco harvested annually before either of the mechanical harvesting systems was least cost. Thus for the immediate future, hand harvesting systems result in lower total harvesting costs than currently available mechanical harvesting systems. System 12 (MBR) which probably reflects the minimum level of labor requirements possible with whole leaf harvesters and at 40 acres annual capacity, with a wage rate of $2.50 per hour, represented less than $3.00 per 100 pounds lower cost than the walking-field racking system.

Table 12 summarizes the joint effects of acreage and wage rates. With a wage rate of $1.30 per hour, system 2 (WFR) is the cheapest system. At a wage rate of $2.00 per hour, system 2 is cheapest up to 25 acres annual volume but system 12 is cheapest at 40 acres. System 12 is the lowest cost system at 20 acres annual volume at a wage rate of $3.00 per hour.

Estimated total costs of system 3 decrease from $28.95 per 100 pounds at 5 acres annual volume at a wage of $1.75 per hour to $23.64 per 100 pounds at 40 acres (Table 13). Estimated total costs of system 3 increase slightly more than $10 per 100 pounds as wage rates increase from $1.30 to $3.00 per hour. Increased wages have more effect on the costs of system 3 than on either system 9 or 12. This reflects the higher labor requirements of system 3 relative to both systems 9 and 12.

System 10 (MFR) results in costs per 100 pounds of $52.41 higher than those of system 2 at a wage rate of $1.30 per hour and 3 acres harvested annually (Table 14). Data in this table can be used to compare a hand harvesting system with a mechanical harvesting, field racking system. System 10 is more expensive than system 2 for all comparisons except at $3.00 per hour wages and 40 acres annual volume harvested.

Table 12. Ranking and cost per 100 pounds of least cost system at selected wage rates and annual volumes harvested

Wage rate	Acres							
	3	5	7.5	10	15	20	25	40
($/hr.)	(dollars per hundredweight)							
1.30	2	2	2	2	2	2	2	2
	20.72	18.42	18.80	17.58	17.43	17.47	17.33	17.06
1.50	2	2	2	2	2	2	2	12
	21.52	19.22	19.59	18.38	18.22	18.27	18.12	17.41
1.75	2	2	2	2	2	2	2	12
	22.51	20.21	20.58	19.37	19.22	19.26	19.11	17.76
2.00	2	2	2	2	2	2	2	12
	23.50	21.20	21.57	20.36	20.21	20.35	20.10	18.11
2.50	2	2	2	2	2	2	12	12
	25.48	23.19	23.56	22.35	22.19	22.24	21.62	18.81
3.00	2	2	2	2	2	12	12	12
	27.47	25.17	25.54	24.33	24.18	24.12	22.32	19.51

Table 13. Illustrative effect of alternative wages and annual volumes harvested on costs of selected systems

System	Wage rate	Acres harvested per year			
		5	10	20	40
	($/hr.)	(dollars per hundredweight)			
3 RFR	1.30	26.28	22.81	21.38	20.97
	1.75	28.95	25.48	24.05	23.64
	3.00	36.37	32.91	31.48	31.07
9 MBR	1.30	46.41	32.00	25.10	21.24
	1.75	48.24	33.83	26.94	23.08
	3.00	53.34	38.93	32.04	28.18
12 MBR	1.30	47.54	30.13	21.74	17.13
	1.75	48.17	30.76	22.37	17.76
	3.00	49.92	32.51	24.12	19.51

Table 14. Differences in costs per hundred pounds between system 10 (machine field racking) and system 2 (walking field racking) at selected wage rates and annual volumes harvested[a]

Wage rate	Acres							
	3	5	7.5	10	15	20	25	40
($/hr.)	(dollars per hundredweight)							
1.30	52.41	30.70	19.84	14.43	9.00	6.28	4.65	2.16
1.50	52.13	30.42	19.57	14.15	8.73	6.00	4.38	1.93
1.75	51.79	30.08	19.23	13.81	8.37	5.66	4.04	1.54
2.00	51.45	29.74	18.89	13.47	8.03	5.22	3.70	1.20
2.50	50.77	29.05	18.20	12.78	7.35	4.63	3.01	0.75
3.00	50.08	28.67	17.53	12.10	6.67	3.96	2.33	(0.17)[b]

[a]Cost of system 10 minus cost of system 2.

[b]Parentheses denote negative difference.

With a wage rate of $2.00 per hour, the cost disadvantage of system 10 relative to system 2 decreases from approximately $30 per 100 pounds to less than $4 per 100 pounds at 5 and 25 acres annually.

The initial cost of mechanical harvesters evaluated in this study ranged from $6,000 to $11,000. The lower value reflected the suggested cost of the experimental harvester observed during 1968-69. The $9,000 cost of the harvester used with system 7 represented the 1968 cost levels for harvesters which embraced racking in the field. The cost was increased to $11,000 for the mechanical harvesters to reflect 1969-70 price levels.

Sales prices of 1972 model mechanical harvesters are expected to approach $14,000. With a $14,000 initial cost and annual overhead costs totaling 30 percent, the fixed costs amount to $4,200 per year. This represents an $842 increase above the annual costs of systems 11 and 12.

What change in estimated total costs and feasibility of mechanical harvesting occurs at this higher initial cost? Estimated total costs are increased slightly more than $2 per 100 pounds at an annual volume of 20 acres and approximately $1.05 per 100 pounds at an annual volume of 40 acres. With a wage rate of $1.50 per hour, total costs for system 12 (MBR) are increased from $22.02 to $24.12 per 100 pounds and system 12 is more costly than any of the hand harvesting systems at 20 acres annual volume. The additional overhead costs of $1.05 per 100 pounds reflecting the potential 1972 harvester prices increase total costs from $17.41 to $18.46 for system 12, thus resulting in slightly higher costs per 100 pounds than system 2 (WFR).

The cost differential of $4.30 per 100 pounds between system 12 and system 2 is reduced to $3.26 at a wage rate of $3.00 per hour and 40 acres harvested annually. Thus higher initial costs of mechanical harvesters result in higher estimated total costs and reduce the cost advantage of mechanical harvesting systems at wage rates of $2.00 and more per hour.

IV
ANALYSIS OF BREAK-EVEN WAGES

An additional way to evaluate alternative systems is to calculate break-even wage rates. Using this technique, a wage rate is computed by a comparison of annual overhead and nonlabor operating costs for two systems together with the amount of labor used by each system. In a situation in which both systems use identical quantities of labor and nonlabor operating costs are identical, then the system with lower annual overhead costs of equipment should be chosen.[11] Whenever one system has lower nonlabor operating costs and lower annual overhead costs together with lower labor requirements, this system is lower in cost than any other system in comparison. This section evaluates break-even wage rates for the twelve systems at 25 and 40 acres annual volume.

Table 15 depicts break-even wage rates for an annual volume of tobacco harvested of 25 acres. Notice the peculiarity of system 2 (WFR) in comparison with systems 1-9 in that walking-field racking is always cheaper to use. Wage rates of $4.75 per hour are required to equalize the cost per 100 pounds between system 10 (MFR) and system 2. A break-even wage rate of $1.77 per hour or higher is required to adopt any of the mechanical harvester systems in comparison with system 1, walking-barn racking. Recall that systems 11 and 12 utilize labor requirements appreciably below those observed in this study. Thus at this volume of operation, it is unlikely that mechanical harvesting of tobacco will replace efficient hand harvesting systems observed in this study at farm wage levels likely to occur in the immediate future. These are average wage rates for an entire harvesting-sheeting crew and are not solely for priming labor. Typically, wages for primers are 30-50 percent higher than wages paid to tractor drivers and barn crew members; i.e., with a barn crew wage of $1.50 per hour, primers wages approximate $2.00 per

---

[11] Pasour, Nichols, and Bradford (1969).

Table 15. Break even wages--25 acres harvested annually

	6	5	4	3	2	1	8	9	10	11	12
							(dollars per hour)				
7	*	*	*	*	*	*	*	.03	.22	.22	.20
6	-	a	.80	.05	*	*	1.08	1.45	1.22	1.10	.98
5		-	1.31	.56	*	*	1.32	1.65	1.35	1.22	1.09
4			-	a	*	*	1.34	1.88	1.37	1.19	1.03
3				-	*	*	2.04	2.35	1.63	1.42	1.23
2					-	b	b	b	4.75	3.36	2.59
1						-	8.03	5.16	2.65	2.11	1.77
8							-	3.00	1.39	1.12	.91
9								-	.73	.58	.45
10									-	.19	.10
11										-	c
12											-

*System in column has both lower labor and capital requirements, therefore, always adopt.

[a]Both systems have same labor and system in column has lower capital requirement--adopt system with lower capital requirements.

[b]System in row has both lower labor and capital requirements--never adopt system in column.

[c]Both systems have same capital requirements and system in column has lower labor requirement--adopt system with lower labor requirements.

hour. Given the composition of a walking-barn racking system crew, the average wage rate would be approximately $1.72 per hour. Alternative wage rates for specific tasks together with data presented in Table 1 can be used to determine average wage rates for each system evaluated. These average wage rates can then be compared with the break-even wages computed in Table 15.

As the annual volume is increased to 40 acres, break-even wage rates are reduced (Table 16). Recall that 40 acres was assumed to be the capacity of a mechanical harvester and 25 acres the assumed capacity of hand systems. Thus, two sets of hand harvesting equipment are used at 40 acres annual volume. The break-even wage system 3 (RFR) and system 5 (RBR) is $.70 per hour. Similarly, the break-even wage rate between system 10 (MFR) is less than the current farm minimum wage for all systems except 1 and 2. Only system 2 is cheaper than system 11 (MBR) at wages at or below current minimum wage rates. At average wage rates of $1.60 per hour and higher, system 12, a very efficient mechanical harvesting system with initial costs of the harvester of $11,000, is the least cost system at 40 acres annual volume.

Thus, unless annual volumes approach 40 acres and labor requirements of mechanized harvesting systems approach the levels of systems 11 and 12 (1.4 to 2.0 man-hours per 100 pounds), harvesting systems utilizing hand primers will be lower in total costs at wage rates near current levels. Higher initial costs of mechanical harvesters serve to increase the break-even wage rates above those of Tables 15 and 16. That is, with 25 acres annual volume harvested and an initial cost of the mechanical harvester of $14,000, the break-even wage between system 3 (RFR) and system 10 (MFR) is increased from $1.63 to $2.17 per hour. Other comparisons can be made using data in Tables 8 and 9.

Table 16. Break even wages--40 acres harvested annually

	6	5	4	3	2	1	8	9	10	11	12
					(dollars per hour)						
7	*	*	*	*	*	*	*	.02	.14	.14	.12
6	-	a	1.00	.06	*	*	.40	.68	.61	.56	.50
5		-	1.63	.70	*	*	.71	.94	.78	.70	.63
4			-	a	*	*	*	.49	.48	.42	.37
3				-	*	*	.71	1.09	.81	.70	.61
2					-	b	b	b	2.93	2.07	1.59
1						-	4.88	3.16	1.58	1.30	1.09
8							-	1.88	.87	.70	.57
9								-	.46	.36	.28
10									-	.12	.06
11										-	c
12											-

*System in column has both lower labor and capital requirements, therefore, always adopt.

[a]Both systems have same labor and system in column has lower capital requirement--adopt system with lower capital requirements.

[b]System in row has both lower labor and capital requirements--never adopt system in column.

[c]Both systems have same capital requirements and system in column has lower labor requirement--adopt system with lower labor requirements.

V
SUMMARY

The major purpose of this study was to quantify the factors thought to affect the total cost of harvesting, curing, and market preparation of flue-cured tobacco using bulk curing barns. Emphasis was directed toward gathering data from actual farming operations in Eastern North Carolina for six alternative harvesting-curing systems. The six harvesting systems considered were (1) walking-barn racking; (2) walking-field racking; (3) riding-field racking; (4) riding-barn racking; (5) machine-field racking; and (6) machine-barn racking. The specific objectives of the study were (1) to measure labor, fuel, and electricity requirements for the selected harvesting-curing systems; (2) to analyze requirements of the systems--labor, operating, and fixed costs; (3) to determine the least-cost harvesting technology for selected volumes of tobacco at various wage rates, and (4) to determine the break-even wage rates between the alternative systems for selected volumes of tobacco.

The statistical analysis of total harvest labor data revealed a statistical difference at the 1 percent level between labor requirements of lower and middle, and lower and upper stalk positions. The analysis also showed that the walking systems used significantly less labor (at the 1 percent level) than the riding systems. No significant difference between field and barn racking was detected in the multiple regression analysis. However, test of individual mean differences revealed this situation was due to MFR using more labor than MBR while WFR and WBR used less labor than RFR and RBR, respectively.

A test of individual mean differences showed that WFR used less labor than RBR by 4.83 man-hours per hundredweight, less labor than MFR by 3.77 man-hours per hundredweight, less labor than RFR by 2.27 man-hours per hundredweight, less labor than WBR by 1.46 man-hours per hundredweight and less labor than MBR by .41 man-hours per hundredweight. Machine-barn racking used less labor than RBR, MFR, RFR, and WBR by 4.42, 3.36, 1.86 and 1.05 man-hours per hundredweight, respectively. Walking-barn racking used less labor than RBR, MFR, and RFR by 3.37, 2.31, and

.81 man-hours per hundredweight, respectively. Riding-field racking used less labor than RBR by 2.56 man-hours per hundredweight. Machine-field racking used 1.06 man-hours per hundredweight less labor than RBR. Each of these mean differences is statistically significant at the 1 percent level. Riding-field racking used 1.50 man-hours per hundredweight less labor than MFR. This mean difference is statistically significant at the 5 percent level.

However, the total cost data, together with consideration of other externalities, present the actual situation facing a tobacco grower at the present time. The walking systems have the lowest initial cost. Walking-field racking used the least amount of labor. However, it must be kept in mind that while these two walking systems are low in cost when compared to other systems, they require the use of able-bodied labor for all tasks.

The riding systems have higher investment costs and use more labor than the walking systems. Nevertheless, these systems offer growers an opportunity to use a physically weaker class of labor; i.e., women, children, and older men.

The eight observed systems were augmented by four mechanical harvesting systems which differed by initial costs, harvesting labor requirements and by variations in market preparation labor requirements. Initial investment and annual overhead costs were computed for bulk curing barns and related equipment for 12 harvesting systems. Annual costs were standardized for various annual acreages harvested by selection of the least-cost combination of bulk barn sizes. Annual cost per pound of tobacco of bulk barns varied from \$.1023 to \$.0720 as acreage ranged from 3 to 40 acres, respectively.

With wages at \$1.50 per hour, system 2 (WFR) is cheapest for all acreages budgeted from 3 to 25 acres and is only 47 cents per 100 pounds more costly than system 12 (MBR) at 40 acres harvested annually. As wage rates increase to \$1.75 and \$2.00 per hour, the mechanical harvesting system becomes more competitive with the hand primed system regardless of whether they use riding or walking primers. As wage rates reach \$3.00 per hour, system 12 is lowest in costs per 100 pounds at volumes of 20 acres harvested annually.

Break-even wage rates were computed for the 12 systems at annual acreages harvested of 25 and 40 acres. System 2 (WFR) is equal in cost with system 10 (MFR) at a wage rate of $4.75 per hour. Increasing the annual volume harvested to 40 acres reduces the break-even wage rates as the mechanical harvesting systems are used at or near capacity while two complete sets of riding and walking equipment must be utilized. Mechanical harvesting systems, 10-12, have break-even wage rates of less than $1.60 per hour when compared with all systems except system 2.

The acceptance of marketing nonaligned leaves offers a significant potential for reducing costs; i.e., from $.78 to $1.20 per 100 pounds at wage rates of $1.30 to $2.00 per hour, respectively. Improved handling and processing techniques by tobacco companies could result in the elimination of a major drawback to mechanization; i.e., relaxing the present marketing regulation on nonoriented tobacco.

An analysis of costs involved in harvesting and curing suggests that rapid adoption of mechanical harvesting of flue-cured tobacco isn't likely to occur in the near future. Rather large increases in current wage levels would be expected to lead to adoption of mechanical harvesting of flue-cured tobacco at an accelerated pace.

LIST OF REFERENCES

Ben-David, S. and W. G. Tomek. 1965. Allowing for slope and intercept changes in regression analysis. Agricultural Economics Research No. 179, Department of Agricultural Economics, Cornell University, Agricultural Experiment Station, Ithaca.

Bradford, G. L. 1968. An economic analysis of the costs of producing flue-cured tobacco and cost production variable relationships. Unpublished Ph.D. thesis, Department of Economics, North Carolina State University, Raleigh. University Microfilms, Ann Arbor, Michigan.

Chappell, J. S. and W. D. Toussaint. 1965. Harvesting and curing flue-cured tobacco with automatic tying machine, bulk curing and the conventional method: Labor requirements, costs and prices received. A. E. Information Series No. 123, Department of Economics, North Carolina State University, Raleigh.

Chumney, W. T. and W. D. Toussaint. 1957. Machine or hand harvesting tobacco. A. E. Information Series No. 57, Department of Economics, North Carolina State College, Raleigh.

Coutu, A. J. and F. A. Mangum. 1960. Farm management manual. Agricultural Economics Miscellaneous Publication No. 1, Department of Agricultural Economics, North Carolina State College, Raleigh.

Pasour, E. C., Jr., T. E. Nichols, Jr., and G. L. Bradford. 1969. Applying economic principles in replacing or purchasing agricultural equipment. Economics Information Report No. 10, Department of Economics, North Carolina State University, Raleigh.

Saunders, F. B., J. O. Wise, W. C. McArthur, J. R. Allison, and R. J. Amick. 1969. Farm machinery costs in Georgia. Research Report 45, College of Agriculture Experiment Stations, University of Georgia, Athens.

Splinter, W. E. 1968. Engineering developments in harvesting and market preparation system. Agricultural Policy Institute Series 29, School of Agriculture and Life Sciences, North Carolina State University, Raleigh.

Splinter, W. E., C. W. Suggs, and E. C. Howell. 1968. Field operation of a mechanical harvester for tobacco. Tobacco Science 12:95-104.

U. S. Department of Agriculture. 1968. Distribution of 1968 tobacco allotments by size groups. ASCS, Policy and Program Appraisal Division, Washington, D. C.

U. S. Department of Labor. 1966. Hired farm workers under the Fair Labor Standards Act as amended in 1966. Wage and Hour and Public Contracts Publication 1161. U. S. Government Printing Office, Washington, D. C.

A P P E N D I X

Appendix Table 1. Estimated total costs of selected harvesting systems, dollars per hundredweight, at wage rate of $1.50 per hour

Acres							
3	5	7.5	10	15	20	25	40
2[a]	2	2	2	2	2	2	12
21.52[b]	19.22	19.59	18.38	18.22	18.27	18.12	17.41
1	1	1	1	1	1	1	2
23.19	20.85	21.20	19.97	19.81	19.85	19.70	17.86
5	5	5	5	3	12	12	11
29.40	25.83	25.56	23.82	22.96	22.02	20.22	18.46
3	3	3	3	5	3	11	1
33.27	27.46	26.08	23.99	23.56	22.57	21.27	19.44
6	6	6	6	4	11	3	10
34.13	28.53	27.25	25.00	24.08	23.07	22.16	19.79
4	4	4	4	6	4	10	8
40.30	31.54	28.68	25.85	24.23	23.31	22.50	21.84
8	8	8	8	12	5	4	9
53.18	39.12	33.45	29.21	24.73	23.44	22.68	22.06
9	9	12	12	11	6	5	3
67.62	47.22	37.15	30.41	25.78	23.86	23.20	22.16
12	12	11	11	8	10	6	4
72.20	47.82	38.20	31.46	26.04	24.27	23.47	22.91
11	11	9	10	10	8	8	5
73.25	48.87	38.55	32.53	26.95	24.57	23.51	23.03
10	10	10	9	9	9	9	6
73.65	49.64	39.16	32.81	28.14	25.92	24.41	23.45
7	7	7	7	7	7	7	7
74.80	54.80	46.32	40.68	36.10	33.93	32.45	30.14

[a]System number.

[b]Cost--dollars per hundredweight.

Appendix Table 2. Estimated total costs of selected harvesting systems, dollars per hundredweight, at wage rate of $1.75 per hour

Acres							
3	5	7.5	10	15	20	25	40
2[a]	2	2	2	2	2	2	12
22.51[b]	20.21	20.58	19.27	19.22	19.26	19.11	17.76
1	1	1	1	1	1	12	2
24.47	22.13	22.48	21.25	21.09	21.13	20.57	18.85
5	5	5	3	3	12	1	11
31.19	27.61	27.35	25.48	24.45	22.37	20.98	18.96
3	3	3	5	12	11	11	10
34.75	28.95	27.57	25.60	25.08	23.57	21.77	20.39
6	6	6	6	5	3	10	1
35.91	30.39	29.03	26.78	25.34	24.05	23.15	20.72
4	4	4	4	4	4	3	8
41.79	33.02	30.16	27.33	25.57	24.80	23.64	23.01
8	8	8	8	6	10	4	9
54.68	40.29	34.62	30.38	26.01	24.92	24.17	23.08
9	12	12	12	11	5	8	3
68.64	48.17	37.50	30.76	26.28	25.22	24.68	23.64
12	9	11	11	8	6	5	4
72.55	48.24	38.70	31.96	27.21	25.64	24.98	24.39
11	11	9	10	10	8	6	5
73.75	49.37	39.57	33.18	27.59	25.74	25.25	24.81
10	10	10	9	9	9	9	6
74.30	50.29	39.81	33.83	29.16	26.94	25.43	25.23
7	7	7	7	7	7	7	7
76.81	56.81	48.33	42.69	38.11	35.94	34.47	32.16

[a] System number.

[b] Cost--dollars per hundredweight.

Appendix Table 3. Estimated total costs of selected harvesting systems, dollars per hundredweight, at wage rate of $2.00 per hour

Acres							
3	5	7.5	10	15	20	25	40
2[a]	2	2	2	2	2	2	12
23.50[b]	21.20	21.57	20.36	20.21	20.35	20.10	18.11
1	1	1	1	1	1	12	11
25.75	23.41	23.76	22.54	22.37	22.41	20.92	19.46
5	5	3	3	12	12	1	2
32.97	29.39	29.05	26.96	25.43	22.72	22.26	19.84
3	3	5	5	3	11	11	10
36.24	30.43	29.13	27.38	25.93	24.07	22.27	21.04
6	6	6	6	11	3	10	1
37.69	32.09	30.81	28.56	26.78	25.54	23.80	22.00
4	4	4	4	4	10	3	9
43.27	34.51	31.65	28.82	27.05	25.57	25.13	24.10
8	8	8	12	5	4	4	8
55.85	41.46	35.79	31.11	27.12	26.28	25.65	24.18
9	12	12	8	6	8	8	3
69.66	48.52	37.85	31.55	27.80	26.91	25.85	25.13
12	9	11	11	10	5	9	4
72.90	49.26	39.20	32.46	28.24	27.01	26.45	25.88
11	11	10	10	8	6	5	5
74.25	49.87	40.46	33.83	28.38	27.43	26.76	26.60
10	10	9	9	9	9	6	6
74.95	50.94	40.59	34.85	30.18	27.96	27.03	27.02
7	7	7	7	7	7	7	7
78.83	58.82	50.34	44.70	40.12	37.95	36.48	34.17

[a]System number.

[b]Cost--dollars per hundredweight.

Appendix Table 4. Estimated total costs of selected harvesting systems, dollars per hundredweight, at wage rate of $3.00 per hour

Acres							
3	5	7.5	10	15	20	25	40
2[a] 27.47[b]	2 25.17	2 25.54	2 24.33	2 24.18	12 24.12	12 22.32	12 19.51
1 30.88	1 28.54	1 28.89	1 27.67	12 26.83	2 24.22	2 24.07	11 21.46
5 40.10	3 36.37	3 35.00	12 32.51	1 27.51	11 26.07	11 24.27	10 23.64
3 42.18	5 36.52	5 36.26	3 32.91	11 28.78	1 27.42	10 26.40	2 23.81
6 44.82	6 39.22	4 37.59	11 34.46	10 30.85	10 28.18	1 27.39	1 27.13
4 48.72	4 40.45	6 37.95	5 34.52	3 31.88	3 31.48	8 30.53	9 28.18
8 60.53	8 46.14	12 39.25	4 34.76	4 32.99	8 31.59	9 30.53	8 28.86
9 73.75	12 49.92	8 40.47	6 35.70	8 33.06	9 32.04	3 31.07	3 31.07
12 74.30	11 51.87	11 41.20	8 36.23	5 34.26	4 32.23	4 31.59	4 31.82
11 76.25	9 53.34	10 43.07	10 36.43	9 34.26	5 34.14	5 33.89	5 33.73
10 77.55	10 53.84	9 44.67	9 38.93	6 34.93	6 34.56	6 34.16	6 34.15
7 86.88	7 66.87	7 58.39	7 52.76	7 48.18	7 46.00	7 44.53	7 42.22

[a]System number.

[b]Cost--dollars per hundredweight.

Agricultural Experiment Station

North Carolina State University
at Raleigh

J. C. Williamson, Jr., Director of Research

Bulletins of this station will be sent free to all citizens who request them.