Tobacco

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AN ANALYSIS OF LABOR USE FOR ALTERNATIVE FLUE-CURED TOBACCO HARVESTING AND CURING SYSTEMS

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PREFACE

Bob Davis' thesis, "An Economic Analysis of Labor Use for Alternative Flue-Cured Tobacco Harvesting and Curing Systems," provides the basis for this bulletin. The authors wish to thank the Agricultural Stabilization and Conservation Service Office Managers and farmers contacted in the 14 study counties. Professors W. D. Toussaint, D. M. Hoover, J. G. Sutherland, J. S. Chappell, J. G. Allgood, R. K. Perrin and C. H. Little offered their assistance and comments during the study.

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ABSTRACT

The most profitable harvesting and curing system for flue-cured tobacco and the amount of farm labor required for various wage rates for hired labor were analyzed in this study. Labor use was estimated both for individual farms and for the study area.

Data were collected in Census Subregion 17, North Carolina, to describe four farm situations and eight alternative harvesting-curing systems for tobacco that represented a wide range of capital-labor ratios. The most profitable harvesting-curing systems were determined for each farm situation for wage rates for hired labor varying from 1967 levels to a maximum of $4.00 per hour. The analysis was conducted for two lengths of run. In the short run, adequate conventional curing barns were assumed to be present on the farms. In the long run, all curing facilities were assumed to be variable.

At 1967 wage rates, the results were the same for both lengths of run for each farm. At higher wages some differences in results for the two lengths of run were noted. Substitution of several alternative systems for the most profitable system had little effect on net revenue in many cases.

The impact of the adoption of the mechanical harvesting, bulk curing system on labor use in the study area was estimated. With complete adoption the quantity of labor could be reduced 40 percent. The time period estimated for adoption of this system by 91 percent of the farmers varied from 15 to 60.5 years from 1967 depending upon the lag and the harvester price assumed. If farm numbers continue to decline at the present rate, farm size could be sufficiently large for mechanical harvesters to be profitable. Also, if the reduction in the number of farm workers continues at the same rate, the impact of adoption on the labor market may be slight.

AN ANALYSIS OF LABOR USE FOR ALTERNATIVE FLUE-CURED TOBACCO HARVESTING AND CURING SYSTEMS

Bob Davis and Loren A. Ihnen*

INTRODUCTION

The implications of substituting harvesting and curing machinery for labor in tobacco production are examined in this study. Although flue-cured tobacco has been a very labor intensive crop in the past, there are indications that it will be less so in the future. Traditionally, tobacco has been hand harvested and prepared for curing by a crew of 14 to 20 laborers. Generally, only field tillage operations have been highly mechanized. Therefore, about 75 percent of the 400 to 500 man-hours of labor required to produce an acre of tobacco has been used for harvesting, curing, and marketing (Bradford, 1968).

Tobacco farmers who do not have large families or several families of farm workers residing on the farm or available nearby must search for and hire relatively large quantities of labor during the harvesting, curing, and marketing stages of production. The costs of farm labor have been rising over time, both absolutely and relative to other inputs (U. S. Department of Agriculture, 1968a). As of 1967, minimum wage coverage was extended by Congress through amendments to the Fair Labor Standards Act to many hired workers on larger farms (U. S. Department of

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Labor, 1966). If effective, an increase in minimum wage standards will raise labor costs and change relative factor prices. Thus, farmers will have incentives to substitute other inputs for labor, particularly capital in the form of machinery. With changes in relative wages for different types and qualities of labor as well as relative factor prices, the inducements for factor substitution will be especially great for labor intensive crops such as tobacco.

Several harvesting and curing systems, each with different labor and capital requirements, are being sold to farmers and used in the tobacco fields. The kinds of machinery systems that are most profitable on different sizes of tobacco farms and, therefore, most likely to be adopted by farmers will depend, among other things, upon the level of farm wages and the costs of alternative machines. Also, the system or systems adopted by farmers will determine the size of the adjustments in the organization of individual farms and in the labor market in flue-cured tobacco production areas.

Objectives

The specific objectives of the study are:

(1) To determine the optimal organizations and quantities of labor used for selected flue-cured tobacco farm situations with selected alternative machinery systems and wage rates. To achieve this objective, linear programming models were constructed for individual farm situations, and the most profitable tobacco harvesting and curing systems were determined for varying labor prices.

(2) To estimate the aggregate quantity of labor used in the 14-county study area with alternative rates of adoption of machinery on flue-cured tobacco farms. The procedure for satisfying this objective is a simple aggregation of optimal linear programming results based on tobacco acreage for the study area.

Study Area

The study was conducted in the 14-county Piedmont and Coastal Plain area designated by the Department of Commerce as Census Subregion 17 (figure 1). The counties involved are Edgecombe, Franklin, Greene, Harnett, Johnston, Lee, Lenoir, Nash, Pitt, Sampson, Wake, Warren, Wayne,

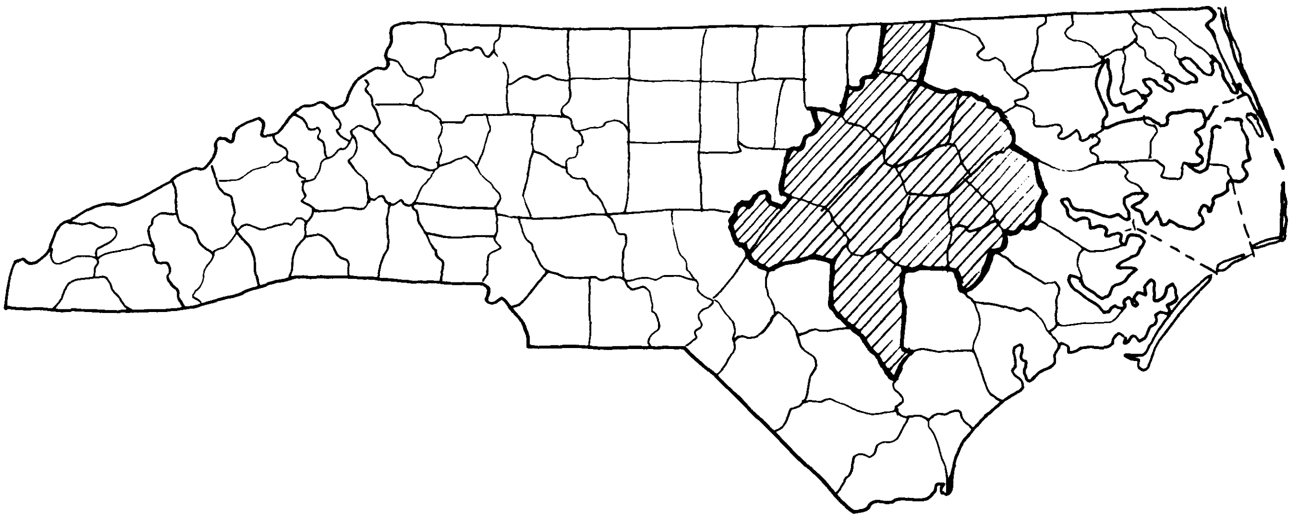

Figure 1. The 14-county study area

and Wilson. Most of the counties are agricultural counties with a predominance of tobacco farms. The area lies primarily in the Coastal Plain with the fall line, which separates the Coastal Plain and Piedmont, running roughly north and south through Nash and Wilson counties before turning west and going through Johnston, Harnett, and Lee (Lee, 1955). This area was chosen because of its relative homogeneity and its importance in the state in the production of flue-cured tobacco. North Carolina produces more flue-cured tobacco than all the other producing states combined, and, historically, farmers in the study area have grown about 40 percent of North Carolina's flue-cured tobacco (U. S. Department of Agriculture, 1967a).

PROCEDURE

A description of the method of analysis employed, the assumptions made, and the data sources used in the study are presented below.

Farm Size

Farms of different sizes generally do not have the same cost structure and organization (Madden, 1967) or respond the same way to adoption of new techniques (Griliches, 1957). To account for these differences, four different farm sizes were selected for analysis of alternative harvesting and curing systems for tobacco. The sizes selected were: (1) small farms with 10 to 49 acres of cropland, (2) average farms with 50 to 99 acres of cropland, (3) medium farms with 100 to 219 acres of cropland, and (4) large farms with 220 acres or more of cropland. Farms with less than 10 acres of cropland were not considered to be commercial operations because such farms generally have less than 3 acres of tobacco so that, for most wage levels, the only feasible harvesting-curing systems would be hand harvesting and conventional curing or purchase of custom harvesting services. Cropland was chosen as a measure of farm size because of the variability of crop acres to total acres of land. Many farms in the study area had woodland and pasture; however, the proportion of cropland to total land changes from farm to farm, and most of the noncropland produces relatively little income.

An estimate of the distribution of farms that fell in the four selected size groups was obtained from two farmer surveys conducted in the 14-county study area.[1] The first survey was conducted in the spring

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[1] Other data sources such as the Census of Agriculture and the Agricultural Stabilization and Conservation Service county office records were not used. The census definition of a farm was not consistent with the one employed in this study. For census purposes, sharecroppers are included in the set of farmers (U. S. Bureau of the Census, 1968, p. xx). However, sharecroppers are generally laborers receiving a share of the crop as wages. They perform very few, if any,

of 1965 and provided data for 1964 farm organization and structure. The second was taken in February and March 1968 to provide data for 1967. The same sample was used for both surveys and was a stratified random area sample utilizing equal sized strata with proportional allocation (Monroe and Finkner, 1959).[2]

The 1964 data were used in this study in designing the questionnaire for the later survey. In 1968 no questions were asked about crops other than tobacco, corn, soybeans, and cotton because, in the 1964 survey, these were the only crops for which the estimated mean acreages for all farms did not approach zero.[3] In addition, in 1964, very few farmers had both livestock and tobacco enterprises. Therefore, questions regarding livestock enterprises were omitted.

The 1967 data on farm practices and management units were sorted into each of the four farm size groups chosen for analysis, and arithmetic means were calculated for the organizational characteristics of each farm (table 1). The mean acreages of total land, cropland, and tobacco in table 1 for each size of farm were used as constraints in the analyses. The mean tobacco acreage was calculated for each farm situation by

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of the management tasks regularly done by farmers. Thus, for this study all the land farmed by sharecroppers was allocated to the farmer, not the sharecropper. Under this procedure there are fewer farms than there would be if the census definition of a farm had been followed. Unfortunately, there is no way to distinguish sharecroppers from farmers with census data.

The ASCS farms do not always include all the land managed by one individual because of renting. Many landlords retain ASCS contract numbers and deal with the ASCS county offices as though they were running their farms when in fact the farms have been rented out and the landlords make no management decisions concerning the farming operations.

[2]This sample design had been used earlier for a survey of farms in 7 of the 14 counties in the study area (Pasour *et al.*, 1959). The sample drawn by Pasour *et al.* was included as part of the sample for this study. The survey taken in 1965 and again in 1968 was composed of two independent samples. The first sample included the one drawn by Pasour *et al.*, but it was augmented with an additional sampling unit per segment as an out-migration adjustment. The second sample was new. It was drawn in the remaining seven counties using the same methods employed by Pasour *et al.* Thus, the first independent sample had three segments per stratum, the second had two, and the sampling ratio was different for each sample.

[3]Copies of the questionnaires used in 1964 and 1968 can be obtained from the authors.

Table 1. Number of survey farms, mean acreages and percent rented per farm for land and selected crops by size of farm, Census Subregion 17, North Carolina, 1967

Item	Farm Size			
	Small	Average	Medium	Large
Farms (number)[a]	120	95	61	18
Total land				
Acres	52.0	111.7	205.6	654.3
Rented in (percent)	32.7	41.3	45.8	34.9
Cropland				
Acres	30.1	69.6	143.2	369.6
Rented in (percent)	47.4	53.8	57.0	52.3
Tobacco				
Quota per farm (pounds)	10,614.4	18,640.7	31,872.3	64,726.4
Acres[b]	5.28	9.27	15.86	32.20
Rented in (percent)	69.1	65.5	62.1	50.1
Corn				
Acres	11.0	26.9	61.2	159.9
Rented in (percent)	54.4	66.5	57.3	62.0
Soybeans				
Acres	3.5	11.6	26.7	85.4
Rented in (percent)	52.4	58.4	72.6	52.5
Cotton				
Acres	0.9	1.6	1.8	8.2
Rented in (percent)	31.2	38.0	39.9	49.9

[a]There were 17 farms with fewer than 10 acres of cropland that were excluded from the analysis.

[b]The tobacco acreage figures were derived from the poundage quotas by assigning a yield of 2,010 pounds per acre to all farms.

dividing the poundage quota by the yield per acre (2,010 pounds) assumed for the study. The 2,010-pound yield was the average for all farms in the 14 counties during 1965, 1966, and 1967 (U. S. Department of Agriculture, 1965, 1966, 1967b).

The alternative crops considered in the analysis for each farm situation were tobacco, corn, soybeans, and Blueboy wheat. Although most farms had cotton, the acreage per farm was so low (table 1) that the crop was excluded from the analysis. Blueboy wheat was a new variety introduced in 1966 that could double wheat yields on farms in the study area. Therefore, the new wheat variety would compare favorably with corn and soybeans in terms of net revenue per acre, and it was included as an alternative crop even though very little was grown in 1967.

Tobacco Harvesting and Curing Systems

Eight systems were selected as alternatives for harvesting and curing tobacco. Three require bulk curing barns, while five systems use conventional barns. The systems selected cover the range of alternative methods of harvesting and curing tobacco in use by farms and offered for sale by machinery companies.

Each harvesting-curing system was given a short name for discussion purposes (table 2) and will be referred to hereafter by that name.

Harvesting and Curing Operations

The operations that must be performed in a flue-cured tobacco harvesting and curing system are: (1) harvesting ripe tobacco leaves, (2) preparing tobacco for curing by placing the leaves in bulk racks or tying them on sticks, (3) loading the barn with sticks or racks of tobacco, and (4) curing and marketing.

Harvesting of tobacco can be accomplished in three ways. First, tobacco can be harvested by hand by workers called primers who walk down the rows in the field breaking off ripe tobacco leaves. The tobacco is usually planted in a skip row pattern with every fifth row left fallow so that a sled or trailer can be pulled through the field and the primers can place harvested tobacco on the sled. Filled sleds are taken to the barn where further operations are performed. Second, with a priming aid,

Table 2. Flue-cured tobacco harvesting and curing systems selected for analysis

System name	Harvesting method	Methods of preparing tobacco for curing	Curing method
Hand	By hand while walking, put tobacco on sled	Tie tobacco on sticks by hand at barn	Conventional curing barn
Tying	By hand while walking, put tobacco on sled	Tie tobacco on sticks by machine at barn	Conventional curing barn
Aide-tying	By hand while riding, put tobacco in bins	Tie tobacco on sticks by machine at barn	Conventional curing barn
Aide	By hand while riding, hand tobacco to persons tying	Tie tobacco on sticks by hand on priming aide	Conventional curing barn
Self-propelled aide	By hand while riding, put tobacco in chain clips	Tie tobacco on sticks by hand on priming aide	Conventional curing barn
Hand-bulk	By hand while walking, put tobacco on sled	Fill bulk racks by hand at barn	Bulk curing barn
Aide-bulk	By hand while riding, put tobacco between belts	Fill bulk racks by hand on priming aide	Bulk curing barn
Mechanical harvester	Mechanically harvests leaves, put tobacco between belts	Mechanically fills bulk racks on machine, hand clamped	Bulk curing barn

the primers travel through the field on a machine sitting on seats suspended between rows of tobacco and harvest ripe leaves by hand as the machine travels down the row. Most priming aides have four seats for primers, and four rows of tobacco are harvested per time through the field. Once harvested, tobacco is either placed on a trailer and taken to the barn for further operations or is prepared for curing by laborers riding on the priming aide.

Third, tobacco that is mechanically harvested is broken from the stalk by spiraled rubber wipers or steel knives attached to a movable head. Once set to the correct height, the head straddles the tobacco stalk with one wiper or knife on each side of the stalk and removes all the leaves on the stalk at that height. As the machine goes down the row, harvested leaves are conveyed by belts to a turntable where they are placed in bulk racks. Full racks are stored preparatory to being taken to the barn.

Tobacco is prepared for curing by either tying it on sticks or placing it in bulk racks. However, the operations can be performed either solely by hand or with the aid of a machine and can be done either at the barn or on a harvesting machine. Once the tobacco has been placed on sticks or in bulk racks, it is put in the barn. When filled, the barn is closed, and the tobacco is cured. (See Bennett et al. (1964) for a discussion of curing techniques.)

Machines

Six of the alternative harvesting-curing systems require a machine in addition to a tractor. For example, the automatic tying machine is used to tie tobacco on sticks during curing preparation. The tying machine is used at the conventional curing barn usually with one end placed inside the barn door. After tobacco has been tied onto a stick by the machine, the stick is conveyed into the barn and hung for curing. A stick of tobacco can be tied three to four times faster with a tying machine than by hand. The machine ties a stick in 15 to 20 seconds, whereas almost 60 seconds are needed to tie tobacco by hand.

There are several kinds of priming aides used to harvest tobacco. One type of tractor-drawn priming aide is often used in conjunction with an automatic tying machine. On this priming aide there is a bin or pallet directly in front of each primer's seat where harvested tobacco leaves are deposited. This priming aide requires a five-man harvesting crew--four primers and a leaf mover. The leaf mover is necessary to keep harvested tobacco pushed forward in the bins or pallets. Otherwise, frequent stops would be necessary so the primers could push the tobacco forward to keep it from falling on the ground. When the bin or pallet is full, the machine is stopped and the tobacco is placed on a trailer attached to the rear of the priming aide. When the trailer is full, it is taken to the tobacco barn where the tobacco is tied onto sticks.

Another type of tractor-drawn priming aide used with conventional curing barns contains a crew that prepares the tobacco for curing as it is harvested. The priming aide has four seats facing forward, as on the previously described priming aide, and four seats facing the rear where people tying tobacco on sticks are stationed. As each primer harvests a handful of tobacco leaves, it is given to the person seated facing him. The recipient then ties it on a tobacco stick. When a stick is full, it is placed on a trailer or pallet attached to the rear of the priming aide. The priming aide need not stop except to obtain an empty pallet or trailer. When enough tobacco has been harvested to fill a barn, the crew goes to the barn and hangs the tobacco for curing.

A similar tractor-drawn priming aide is used in conjunction with bulk barns. As primers harvest a handful of tobacco, they place it between two belts rather than handing the tobacco to someone. The belts deposit the tobacco in a bin near the center of the priming aide. Workers take the tobacco from the bin and fill bulk curing racks. Filled racks are placed in a special trailer attached to the rear of the machine. When filled, the trailer is hauled to a bulk barn and the racks are slid into the barn by the tractor driver.

The self-propelled priming aide used with conventional curing barns has seats for the primers suspended below a high deck. The primers place harvested leaves into clips on a chain conveyor that elevates the tobacco to the deck. The persons tying tobacco on sticks are seated on the deck and remove the leaves from the chain. Filled sticks are stacked on a pallet at the rear of the deck. When the pallet is full, it is lowered to ground level, and the tobacco is unloaded and transported to the barn for hanging. This priming aide was introduced in the 1950's (Chumney and Toussaint, 1957).

The mechanical harvester is a one-row, self-propelled machine with a deck. After the leaves are mechanically harvested and placed in bulk curing racks, the racks are put in a pallet at the rear of the harvester. When the pallet is full, it is lowered to ground level where it is removed by tractor and transported to a bulk barn. The racks are taken from the pallet by the tractor driver and a helper and placed in the barn for curing. Leaves harvested with this machine are cured in a non-oriented or random fashion and have to be straightened with the lamina all pointing in one direction before the tobacco will be graded at the market.

The costs of the various machines and the tobacco budgets used in this study are presented in Davis and Chappell (1969), while curing barn costs and budgets for corn, wheat, and soybeans are contained in Appendix A.

Labor

Crew size for the harvesting-curing systems was assumed to vary from 5 to 20 people, depending upon the system (table 3). Each system, except the mechanical harvester, was assumed to use four people as primers for harvesting tobacco. The composition of the rest of the crew for each harvesting-curing system is determined by the particular operations involved.

Performance data for the mechanical harvester were obtained from field trials conducted by Splinter and Suggs on a farm near Angier, North Carolina, in 1967, from Splinter et al. (1960 and 1968) and from Splinter and Suggs (1966 and 1968). Performance data for priming aides including crew size, composition and wages paid were obtained during the summer of 1967. They were collected by visiting fields where priming aides were in use, interviewing the farmers and recording performance data. This information was obtained by 44 visits to farms that were selected via purposive sampling from lists provided by machinery dealers. Price and performance data for automatic tying machines were obtained from Chappell and Toussaint (1965). The crew sizes for hand harvesting systems were synthesized from the 1967 farmer

Table 3. Crew size and composition for selected tobacco harvesting and curing systems, Census Subregion 17, North Carolina

System	Crew size	Composition of crew			
		Primers	Drivers	Tying or racking	Other[a]
Hand-bulk	10	4	2	4	-
Aide-bulk	9	4	2	3	-
Mechanical harvester	5	-	2	2	1
Hand	20	4	2	12	2
Tying	14	4	2	5	3
Aide-tying	15	4	2	5	4
Aide	11	4	2	4	1
Self-propelled aide	11	4	2	4	1

[a]Includes various jobs not easily categorized such as the man to help load at the barn with the mechanical harvester, people hanging tied sticks in the barn when this job is not done by the whole crew, and various strenuous tasks such as moving tobacco in the field from where it is tied or racked to a trailer or pallet so that it can be hauled to the barn.

survey data and from hourly requirements as given in Bradford (1968), North Carolina Agricultural Extension Service (1965) and Chappell and Toussaint (1965). Crew sizes for all other systems considered were those most commonly observed during field visits.

In addition to varying crew sizes, individual systems use different kinds of labor for harvesting and curing tobacco. Hand harvesting while walking is a difficult task that requires able-bodied men or older boys. However, women, teenagers, and older persons can work as primers while riding on priming aides because less effort is required for the task (Suggs and Wilson, 1954).[4] Women usually tie tobacco on sticks or place it in bulk racks, although men generally are employed on the mechanical harvester for racking. Children are used in the hand system to hand tobacco from the trailers or sleds to the people tying it on sticks.

[4]Of the 44 observations made of priming aides during the summer of 1967, 10 crews had women over 16 years of age as primers, and 11 crews had teenage boys under 16 as primers. However, for the 21 crews involved, only 39 of the 84 priming crew members were women or young people under 16, the remainder were men over 16.

Wages used in the study were the most common rates reported by farmers for each task for 1967. No differences were found in average wages paid for the same job by size of farm or for different harvesting-curing systems.[5] Weighted average wages were calculated for each size of farm for each harvesting-curing system. They were calculated for each size of farm because there were differences in the hours worked by the farm operator and by hired labor. One hour of operator labor was assumed to be required for supervision of each 20 hours of hired labor. The operator, therefore, could work less as a laborer on large farms because his total work and supervisory time could not exceed the amount of time available to him. The resulting wages for the larger two farm situations were slightly different than those for the smaller two farm situations (table 4).

One of the objectives in this study requires that wages be varied over a range of values. A weighted average for each farm, rather than wages by task, was used to reduce the computational burden in variable wage programming. For a detailed description of the tasks performed by hired labor, the distribution of tasks between operator and hired labor by size of farm, and a description of the method for calculating weighted wages see Davis and Chappell (1969).

Farm Use of Harvesting and Curing Systems

Based on the 1967 survey in the 14-county study area, a wide range of harvesting systems was used by farmers, both within a given farm size class and between classes (table 5). The tobacco acreage harvested with systems requiring some type of machine increased with farm size. The hand system was used on nearly 83 percent of the tobacco acreage on small farms and on only 54 percent of the acreage on large farms. Only two of the farmers surveyed used bulk curing barns in 1967, and they harvested by hand. One of these farmers put the tobacco on conventional tobacco sticks rather than in bulk racks and cured it in his bulk barn. All the other farmers surveyed used conventional curing systems in 1967.

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[5]The foregoing statement does not mean that all farmers paid the same wages or that all laborers were equally efficient. Such factors vary among individual farms (Chappell and Toussaint, 1965 and Bradford, 1968). However, the statement does hold for the averages computed for the four farm situations.

Table 4. Weighted wage rates for each harvesting and curing system and for crops, by farm size, Census Subregion 17, North Carolina, 1967

Item	Farm Size			
	Small	Average	Medium	Large
	(dollars per hour)			
Hand-bulk	1.06	1.06	1.04	1.04
Aide-bulk	1.07	1.07	1.06	1.06
Mechanical harvester	1.04	1.04	1.06	1.06
Hand	.94	.94	.94	.94
Tying	.99	.99	.98	.98
Aide-tying	.99	.99	.98	.98
Aide	.98	.98	.97	.97
Self-propelled aide	.93	.93	.93	.93
Tobacco preharvest operations	.90	.90	.88	.88
Corn	--	--	1.00	1.00
Soybeans	--	--	1.00	1.00
Wheat	--	--	1.00	1.00

Linear Programming Models

Each farm situation was described by a linear programming model that incorporated the main features of the farm size under consideration. The objective was to construct linear programming models so that the cropping patterns and tobacco harvesting systems obtained in the solutions to the models for each farm situation with 1967 weighted wages would agree reasonably well with those actually in use on the majority of the farms in the study area. If this objective was achieved, the predictive ability of the models concerning the optimal tobacco harvesting-curing systems at higher wages probably would be enhanced. The linear programming models constructed for each farm situation were similar and are discussed as a group.

Constraints

Within each programming model acres of cropland and tobacco poundage were constrained to the mean values obtained from the survey quota (table 1). The other nonzero restrictions placed on the models were for hours of operator labor, which were the same for all sizes of farms

Table 5. Total acres and percent of tobacco harvested using various systems on sample farms, Census Subregion 17, North Carolina, 1967

Item	Farm size				Total for all farms
	Small	Average	Medium	Large	
Acres of tobacco harvested with each of the following systems:[a]					
Hand	449.25	605.79	614.76	305.04	1974.84
Aide-tying	-	-	-	58.51	58.51
Aide	29.77	15.40	-	27.65	72.82
Tying	12.54	69.94	96.00	56.59	235.07
Self-propelled aide	51.91	112.02	217.23	119.23	500.39
Total acres of tobacco	543.47	803.15	927.99	567.02	2863.31[b]
Total number of tobacco farms	101	85	60	17	271[c]
Percent of tobacco acreage harvested with each of the following systems:[a]					
Hand	82.66	75.42	66.25	53.80	68.97
Aide-tying	-	-	-	10.32	2.04
Aide	5.48	1.92	-	4.88	2.54
Tying	2.31	8.71	10.34	9.98	8.21
Self-propelled aide	9.55	13.95	23.41	21.02	17.48
Total	100.00	100.00	100.00	100.00	100.00[b]

[a]Two farmers in 1967 had one bulk curing barn each in addition to several conventional curing barns and did not state the acreage of tobacco bulk cured. One of these farmers put conventional tobacco sticks in his bulk barn rather than bulk racks. Therefore, the hand harvested and bulk-cured tobacco was treated as conventional-cured tobacco in the above analysis.

[b]On sample farms with less than 10 acres of cropland, 21.68 acres of this tobacco was harvested by the hand system and was included for completeness, even though such farms were not considered in any other part of the analysis.

[c]The 271 farms include 8 sample tobacco farms with less than 10 acres of cropland.

(see Appendix B). The constraints consisted of a breakdown of operator labor into eight monthly groupings[6] and a restriction on total operator labor.

Activities

The production alternatives for each farm situation were: one way to produce and eight ways to harvest, cure, and market flue-cured tobacco; the possibility of hiring labor for each of the ways of producing, harvesting, curing, and marketing tobacco; the possibility of growing corn, Blueboy wheat, and soybeans; and for the two largest sizes of farms, the possibility of hiring labor for the Blueboy wheat, corn, and soybeans enterprises.

The demand curves facing the farmer for both products and inputs were assumed to be perfectly elastic. North Carolina product prices for 1967 as reported by the U. S. Department of Agriculture (1968b) were used in constructing the activities. Input prices and input-output data used in constructing activities were obtained from the farmer survey made in the study area, from the survey of tobacco priming aides made in the summer of 1967, from Bradford (1968), Chappell and Toussaint (1965), North Carolina Agricultural Extension Service (1965) and from unpublished material collected by Chappell in 1968. Budgets were developed from these data (see Davis and Chappell (1969) and Appendix A), and the linear programming activities were constructed from the budgets.

Objective Function

The values for the objective function were net returns to land, labor, management, capital and tobacco allotment (where applicable) for each of the tobacco harvesting-curing activities, Blueboy wheat, corn and soybeans. For the hired labor activities, the hourly weighted wage rates were used, The annual ownership costs of tractors and the preharvest variable costs for tobacco preharvest operations were used in the objective function for those activities.

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[6]The eight monthly groupings were: January-March, April-May, June, July, August, September, October, and November-December.

Length of Run

Two lengths of run were considered in the analysis, and length of run was based on one factor, availability of conventional tobacco curing barns. In the short run, conventional curing barn capacity was assumed to be available in sufficient quantity for each farm situation, and no ownership costs were assessed for conventional barns. In the long run, no curing facilities were assumed to exist for any of the farm situations so that those required had to be purchased. Thus, the farmer had to bear annual ownership costs for curing barns in the long run whether those chosen were conventional or bulk barns. Two alternative objective functions were used for each programming model, one for the short run and one for the long run.

Sensitivity Analysis

To obtain solutions for any one model or size of farm, for example, the small farm, wages were set at the 1967 average ($0.90 to $1.07 per hour, depending upon the tobacco system). Then, after the optimal solution was obtained at 1967 wages, new solutions were obtained by changing wages continuously for hired labor for all eight harvesting-curing systems and the alternative crops. As wages were increased from 1967 levels to an upper limit of $4.00 per hour, new solutions were obtained whenever wages increased sufficiently to cause another tobacco harvesting-curing system to become optimal. The solutions at these new wage rates give not only the optimal tobacco harvesting-curing method, but also the amount of labor required by that method and the other crops planted to the remaining cropland on the farm as well as the amount of labor used for other crops.

OPTIMUM TOBACCO HARVESTING-CURING SYSTEMS

An analysis of the solutions obtained from the linear programming models constructed for each of the four farm situations is undertaken in this section. For each size of farm, an analysis of the solutions for both the short-run and long-run models is made for wages at the 1967 base level and for wages varied from the 1967 level to $4.00 per hour.

Short-Run Results

To reiterate, the short-run model was based on the assumption that, for each size of farm, annual ownership costs for conventional curing barns were zero, but positive annual ownership costs were charged for bulk barns.

Farm Organization

The optimal farm organizations obtained with linear programming seem to closely approximate the actual organizations of the survey farms. The crops grown on the optimal farms were tobacco, which was produced to the extent allowed by government regulation, and corn (table 6). No survey farms grew only two crops, but corn in the linear programming solutions could be considered as a proxy for the various feed grains and soybeans actually produced on farms in the area. The resources required to produce soybeans, small grains and other substitutes for corn and the net returns obtained from the substitute enterprises are similar. (See, for example, Appendix A, tables 3, 5 and 7.) Also, the actual crop enterprises grown on any particular farm may be more diversified to spread the risks associated with a crop failure or reduced revenue because of unfavorable environmental and economic conditions. The linear programming models were not constructed to allow for such risks. While a more detailed programming model could be constructed from which solutions more closely approximating actual cropping patterns probably could be obtained, the model might not provide a more precise description of the tobacco harvesting-curing systems in use.

Table 6. Maximum profit short-run farm organization, four farm sizes, 1967 wage rates, Census Subregion 17, North Carolina

Description	Farm size			
	Small	Average	Medium	Large
Harvesting-curing system	Aide	Aide	Tying	Self-propelled aide
Crops grown:				
Flue-cured tobacco, acres[a]	5.28	9.27	15.86	32.20
Corn, acres	23.5	58.0	123.4	329.3
Labor use:				
Flue-cured tobacco, total labor	1,711	3,006	4,932	10,109
Hours hired	1,298	2,280	4,223	9,276
Hours worked by operator	413	725	709	833
Corn, total labor	122	302	1,136	3,032
Hours hired	-	-	999	2,668
Hours worked by operator	122	302	137	364
Total labor, hours	1,833	3,308	6,068	13,141
Farm income, dollars per year[b]	4,562	8,628	15,954	35,782
Gross farm sales, dollars per year	9,436	18,375	34,048	77,634

[a]Does not include idle land in skip rows. A pattern of planting 4 and skipping 1 row was assumed for all farm sizes.

[b]Farm income is defined as return to operator labor and management, land, crop allotments and farm operating capital.

Corn labor requirements are substantial on the large model farm where more than 300 acres is produced (table 6). On small and average farms, not all labor for corn was specified in the table because corn was assumed to be custom harvested and hauled to market. The costs of labor for the tasks performed by custom operators were included in the custom rate charged. Therefore, hours of labor for custom work were omitted from the hired labor section of table 6.

The optimal tobacco harvesting-curing systems employed the following amounts of labor per acre:[7] 324 hours for the aide system, 311 hours for the tying system, and 314 hours for the self-propelled aide.

Most of the tobacco labor for the model farms would be provided by hired workers, regardless of the size of farm analyzed (table 6), because of the assumptions made with respect to allocation of the operator's time and because no family or exchange labor was assumed to be available. For the model farms, such a procedure was deemed more desirable than the alternative method of assuming that an arbitrary portion of the work was done by unpaid family or exchange workers. There seemed to be several weaknesses in using the alternative method: (1) the opportunity cost of family labor probably is near the hired wage level; (2) in actual practice the amount of unpaid labor used on farms is highly variable depending upon individual family situations, and (3) the farm income figures presented in the tables of the study would be more difficult to interpret. At present, farm income is a return to operator labor and management, land, crop allotments and farm operating capital. If the alternative method were used, farm income would also represent a return to varying amounts of unpaid family labor.

A relatively small quantity of available total operator labor was used on small and average farms (table 6). Total operator labor use was low because the programming constraints imposed an upper bound of 260 hours per month on operator labor during the highly intensive labor-using months of the summer, even though the annual amount available was 2,818 hours per year (Appendix B, table 1). These constraints apply

[7]The figures contain both hired and operator labor for preharvest as well as harvesting and postharvest operations, including operator supervisory labor.

not only to the time the operator spends supervising hired labor but also to his own work time. The proportion of time allocated to these two activities varies among the model farms. As farm size increases, so does the proportion of the operator's time spent supervising hired labor. On actual farms, the operator may spend less time as a supervisor and more as a laborer. In addition, he may work more hours during peak-load periods and hence during the year than that shown in table 6.

One situation in which the operator may work more hours than that indicated in the linear programming solutions is where labor is exchanged with other farmers. Timeliness is not too critical during the transplanting and harvesting of 5.28 acres of tobacco because these operations can be performed in a very short time period, such as 1 or 1 1/2 days. The remainder of the week can thus be used by the farmer in performing tasks on an exchange basis with neighboring small farmers. Thus, suppose three small farmers agree to exchange labor. With three farmers and their families working together as a 12- to 15-man crew, there would be little need for supervision or for hiring labor. The crew would work on one farm one day and on the other two farms on successive days. The farmers would have enough labor available to perform the work indicated above and farm income would be supplemented by the cost of the hired labor shown in table 6, which amounts to about $1,300 for the small farm.

Another alternative available to small farmers is to transplant and harvest the tobacco with their own family labor, i.e., with a smaller sized crew than that assumed in the budgets for this study. For example, the farmer may require 3 days to harvest the tobacco rather than 1 or 1 1/2 days. However, by taking more time, he and his family remain employed and do not have to hire labor, thus increasing farm income by about $1,300. Farmers who choose to use only family labor will probably use only the hand system for harvesting and curing tobacco because it is the most flexible in terms of crew size requirements. The harvesting-curing systems that require machinery also tend to require a fixed crew size. The flexibility of the hand system may explain the wide use on small farms in the study area in 1967 relative to the rather limited use of the optimal aide system obtained from the programming results (table 5).

Farmers on average farms could also exchange labor or work with a smaller crew than that assumed for this study. However, they might also hire some labor, because the time required to harvest 9.27 acres of tobacco on each of three farms could be sufficient to cause problems of untimeliness, particularly during a wet harvesting season.

For each farm situation programmed, only one harvesting-curing system was optimal, while an array of harvesting-curing systems was observed in use during 1967 (table 5). The optimal systems for each farm situation were actually used on some farms of the same size in 1967, but the majority of farms did not use them. Other systems, primarily the hand system, were utilized to harvest the major share of the tobacco acreage. Thus, the costs of going from the actual to the optimal systems need to be examined.

If the actual system in use on the majority of tobacco farms of a particular size requires a larger quantity of labor and less machinery than the optimal harvesting-curing system, then the increased costs of the labor could reduce net revenue more than the annual ownership costs of the machinery used with the optimal system, and the actual system would be less profitable. For example, the hand system consistently reduces annual revenue for each farm when compared to the optimal systems (table 7). The aide system substitutes low cost machinery for labor on small and average farms. On the medium farm, annual ownership costs per acre for machinery have declined so that the tying system is optimal. The tying system requires less labor than the aide system, and the savings in labor costs coupled with relatively low machinery costs made the tying system optimal. For the large farm, the self-propelled aide system was optimal because the combination of labor and machinery costs was lower than for all other systems.

One might expect to see an array of tobacco harvesting-curing systems in use on farms because of differences in labor productivity and hence wages paid from farm to farm (Bradford, 1968). In addition, differences in managerial skills of farm operators are also likely to exist. Such factors singly or in combination could account for different labor costs than those used in this study.

Hopper (1968) noted that farmers generally try only those new techniques or inputs that significantly raise farm income. Those

Table 7. Income loss by farm size in the short run from using nonoptimal activities, 1967 wage rates, Census Subregion 17, North Carolina[a]

Item	Farm size: Small	Average	Medium	Large
	(dollars per year)			
Tobacco harvesting-curing systems:				
Hand	- 117	- 305	- 625	- 1,865*
Aide	--	--	- 2	- 384
Tying	- 145	- 93	--	- 153
Aide-tying	- 300*	- 276	- 237	- 518
Self-propelled aide	- 289*	- 181	- 26	--
Hand-bulk	- 609**	- 559*	- 1,302*	- 2,619*
Aide-bulk	-1,006**	- 941**	- 1,693**	- 2,975*
Mechanical harvester	-3,296**	-3,391**	- 3,200**	- 3,853**
Wheat	- 269	- 636	- 1,762	- 2,776
Soybeans	- 297	- 731	- 2,043	- 2,819
Income from optimal activities	4,562	8,628	15,954	35,782
5 percent deviation in income	228	431	798	1,789
10 percent deviation in income	456	863	1,595	3,578

[a]The entries in the table should be interpreted as follows: (1) For tobacco harvesting-curing systems the figures represent the annual loss in income that would occur if the nonoptimal systems were used on all the tobacco acreage on the farm. (2) For wheat and soybeans the figures represent the annual loss in income that would occur if those enterprises were grown on all nontobacco land on the farm (i.e., 23.5, 58.0, 123.4, or 329.3 acres).

*Systems outside a 5 percent deviation in income.

**Systems outside a 10 percent deviation in income.

investments that increase income slightly, such as 3 to 5 percent, are not undertaken usually because the effect of such investments is difficult to separate from yearly fluctuations in income attributable to weather and other uncontrollable variables. Given the variance of the means for the input-output data used in constructing budgets for the programming model, a 5 percent variation in income may not be very large. Thus, for purposes of this study, tobacco harvesting-curing systems leading to reductions in income falling within 5 percent of the optimal farm income could be considered as no different from the optimal system. Since only three tobacco harvesting-curing systems in use on actual farms fall outisde a 5 percent variation in optimal farm income (table 7) and, given the earlier explanation for a variety of harvesting-curing systems in use, the programming results seem reasonable.

Alternative Wage Rates

Currently wages are above 1967 levels and will probably follow a rising trend in future years. Farm wage rates in the United States have increased more than 200 percent since 1950. Only the price of farm real estate has increased at a more rapid pace than wages (U. S. Department of Agriculture, 1968a). Thus, it is important to examine the sensitivity of the optimal solutions obtained for each farm situation as wages increase. Wages were varied continuously from 1967 levels to $4.00 per hour and the changes in optimal tobacco harvesting-curing systems noted for each size of farm (table 8).

For all except the large farm, the most profitable solution for harvesting and curing tobacco was quite stable as labor costs increased. Wages had to increase more than 50 percent above 1967 levels before some other harvesting system became more profitable. For large farms, once the tying system became optimal, the solution was also stable for a wide range in wages. For all farm sizes only two systems--aide and tying--were consistently profitable below wages of $2.00 per hour for the short run. The mechanical harvester was not a feasible alternative except on the large farm. For medium and large farms, tobacco was no longer a profitable enterprise for wage levels slightly above $3.80 per hour and farm income was much lower than that achieved at 1967 average wage rates. However, if tobacco had been grown and harvested by some (nonoptimal) system, income would have been even lower (table 9). For example, for the medium farm, income would have been reduced about $17 if one acre of tobacco had been grown and harvested with the mechanical system at $3.83 wages. The income reduction was presented on a 1-acre basis rather than on an annual basis because only linear programming shadow prices were available for use in making the loss determinations for the nonoptimal systems for each of the various wage rates.[8]

[8] Partial budgeting can be used to calculate the short-run breakeven wage rates for each farm situation. However, since this kind of budgeting

Table 8. Most profitable short-run farm organizations for alternative wage rates by size of farm, Census Subregion 17, North Carolina

Description	Size of farm: Small		Average			Medium			Large			
Wage rate per hour	1967 average	$2.64	1967 average	$1.62	$1.82	1967 average	$2.44	$3.83	1967 average	$1.11	$2.12	$3.88
Harvesting-curing system	Aide	Hand-bulk	Aide	Tying	Hand-bulk	Tying	Hand-bulk		Self-propelled aide	Tying	Mechanical harvester	
Crops grown:												
Flue-cured tobacco, acres[a]	5.28	5.28	9.27	9.27	9.27	15.86	15.86	-	32.20	32.20	32.20	-
Corn, acres	23.5	23.5	58.0	58.0	58.0	123.4	123.4	143.2	329.3	329.3	329.3	369.6
Labor use:												
Flue-cured tobacco, total labor	1,711	1,348	3,006	2,868	2,368	4,932	4,076	-	10,109	10,044	7,084	-
Hours hired	1,298	958	2,280	2,159	1,683	4,223	3,408	-	9,276	9,158	6,340	-
Hours worked by operator	413	390	725	709	685	709	668	-	833	886	744	-
Corn, total labor	122	122	302	302	302	1,136	1,136	1,318	3,032	3,032	3,032	3,402
Hours hired	-	-	-	-	-	999	999	1,160	2,668	2,668	2,668	2,994
Hours worked by operator	122	122	302	302	302	137	137	158	364	364	364	408
Total labor, hours	1,833	1,470	3,308	3,170	2,670	6,068	5,212	1,318	13,141	13,076	10,116	3,402
Farm income, dollars per year[b]	4,562	2,375	8,628	7,101	6,667	15,954	8,196	2,066	35,782	33,698	21,620	5,791

[a]Does not include idle land in skip rows. A pattern of planting 4 and skipping 1 row was assumed.

[b]Farm income is defined as return to operator labor and management, land, crop allotments and farm operating capital.

Table 9. Short-run income loss for one acre, nonoptimal harvesting-curing systems, alternative wage rates, four farm sizes, Census Subregion 17, North Carolina

Item	Harvesting-curing systems							
	Hand	Tying	Aide-tying	Aide	Self-propelled aide	Hand-bulk	Aide-bulk	Mechanical harvester
	(dollars)							
Small farm--one acre loss in income for wages of:								
1967 average	- 22.08	- 27.37	- 56.79	--[a]	- 54.65	-115.27	-190.60	-624.23
2.64 per hour	-129.47	- 4.06	- 43.38	0[b]	- 44.15	--	- 67.99	-454.44
Average farm--one acre loss in income for wages of:								
1967 average	- 32.88	- 10.01	- 29.78	--[a]	- 19.54	- 60.23	-101.48	-365.63
1.62 per hour	- 80.18	--	- 23.58	0[b]	- 20.31	- 10.32	- 48.29	-297.14
1.82 per hour	- 94.72	0[b]	- 24.78	- 2.63	- 20.71	--	- 37.17	-279.69
Medium farm--one acre loss in income for wages of:								
1967 average	- 39.39	--[a]	- 14.92	- 0.13	- 1.67	- 33.24	- 57.88	-152.91
2.44 per hour	-154.63	0[b]	- 24.56	- 22.56	- 13.02	--	- 17.86	- 67.48
3.83 per hour	-326.70	- 71.50	-105.23	-113.67	- 87.16	0[b]	- 13.41	- 17.27
Large farm--one acre loss in income for wages of:								
1967 average	- 57.92	- 4.76	- 16.10	- 11.91	--[a]	- 81.32	- 92.38	-119.63
1.11 per hour	- 71.98	--	- 12.48	- 11.29	0[b]	- 62.91	- 71.86	- 93.18
2.12 per hour	-147.44	0[b]	- 19.53	- 26.03	- 5.82	- 9.77	- 15.54	--
3.88 per hour	-418.23	-148.70	-179.42	-199.08	-151.22	- 70.61	- 71.11	0[b]

[a]Indicates optimal system.

[b]Indicates the system being replaced by an optimal system.

Long-Run Results

With the assumption that all curing facilities must be replaced in the long run, viz., the costs of both conventional and bulk barns are variable, the results obtained were still similar to those for the short run.

Farm Organization

The most profitable harvesting-curing systems for flue-cured tobacco and the associated farm organizations are identical in the long run to those obtained for the short run (table 6). Only the farm incomes obtained were different, and they were less than the short-run incomes by the amount of the annual ownership costs of the conventional curing barns. In addition, the long-run loss in annual income that would occur through use of nonoptimal harvesting-curing systems was calculated for 1967 wage rates (table 10). Note that the annual loss in income was identical to that obtained for the short run for nonoptimal conventional harvesting-curing systems and for wheat and soybeans (compare table 7 with table 10). The loss in income calculated for nonoptimal bulk harvesting-curing systems for the long run was about half as large as that computed for the short run, except for the mechanical harvester system.

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treats all labor as homogeneous, there is no assurance that the results will be the same as those obtained with linear programming. For the small farm the breakeven wage, w, between the aide system and the hand-bulk system can be calculated by solving the following equation for w. $197.0\ w + 187.11 = 131.5\ w + 357.08$ where 197.0 and 131.5 are hours of total labor per acre, and 187.11 and 357.08 are net revenue per acre for the aide and hand-bulk systems, respectively (Appendix B table 1). The result is $2.60 which is only 4 cents lower than the answer obtained with programming. For the average farm, the breakeven wage rate between the aide and tying systems is $1.51 while that between the tying and hand-bulk systems is $1.82. These wage rates compare with the $1.62 and $1.82 per hour rates obtained with programming (table 9). For the medium farm the breakeven wage rate between the tying and the hand-bulk systems is $2.27 while the programming breakeven wage is $2.44. For the large farm, the breakeven wage rates between the self-propelled aide and the tying system is $2.17, while that between the tying system and the mechanical harvester is $2.28. These figures compare with $1.11 and $2.12 breakeven wages obtained by programming. Thus, while some results are very close, others are not.

Table 10. Income loss by farm size in the long run from using nonoptimal activities, 1967 wage rates, Census Subregion 17, North Carolina[a]

Item	Farm size			
	Small	Average	Medium	Large
	(dollars per year)			
Tobacco harvesting-curing systems:				
Hand	- 117	- 305	- 625	- 1,865*
Aide	--	--	2	- 384
Tying	- 145	- 93	--	- 153
Aide-tying	- 300*	- 276	- 237	- 518
Self-propelled aide	- 289*	- 181	- 26	--
Hand-bulk	- 350*	- 171	- 527	- 1,197
Aide-bulk	- 747**	- 553*	- 918*	- 1,553
Mechanical harvester	-3,038**	-3,003**	- 2,425**	- 2,431*
Wheat	- 269	- 636	- 1,762	- 2,776
Soybeans	- 297	- 731	- 2,043	- 2,819
Income from optimal activities	4,303	8,240	15,178	34,360
5 percent deviation in income	215	412	759	1,718
10 percent deviation in income	430	824	1,518	3,436

[a]See footnote a, table 7.

*Falls outside a 5 percent variation in income.

**Falls outside a 10 percent variation in income.

Alternative Wage Rates

The farm organizations for alternative wage rates in the long run were similar to the short-run farm organizations obtained when wages were varied from the 1967 average to $4.00 per hour. However, the wage rates at which the farm organizations changed from one tobacco harvesting-curing system to another were generally lower for long-run farm situations (table 11).

For most farm sizes the hand-bulk system became optimal at relatively low wage levels, and once it became profitable the solution was no longer very sensitive to changes in wages. The mechanical harvester system would be profitable only on the large farm if wage rates were relatively high.

For each of the optimal solutions obtained for alternative wage rates, the loss in income that would occur if a nonoptimal harvesting-curing system were used on 1 acre of tobacco was computed (table 12). The linear programming shadow prices used to represent the losses that would occur in the long run are identical to those computed for the short-run farm situations for conventional harvesting-curing systems for the same wage rates (tables 9 and 12).

Implications for Quantity of Labor Used

Based on these results, it appears that there will be no large reduction in the quantity of labor used per acre for tobacco harvesting-curing operations as wages increase in the short run. While the optimal harvesting-curing systems do require less labor than the hand system in use on the majority of tobacco farms in 1967, the optimal systems (and those that are nearly optimal or reduce costs less than 5 percent of total revenue) do not drastically lower the amount of labor employed. Most of the labor savings that occur with the optimal systems result from use of a smaller crew than that required for the hand system. Such systems substitute relatively simple machinery for crew members, but they do not radically change the method of accomplishing the tasks performed.

In the long run, bulk curing systems are more profitable and the potential for reducing the quantity of labor used is greater than for the short run. However, the hand-bulk system is the most profitable of the bulk systems, and it is also the most labor-intensive of the bulk systems.

Table 11. Most profitable long-run farm organizations for alternative wage rates by size of farm, Census Subregion 17, North Carolina

Description	Size of farm											
	Small		Average		Medium			Large				
Wage rates per hour	1967 average	$1.88	1967 average	$1.14	1967 average	$1.49	$3.83	1967 average	$1.11	$1.47	$1.83	$3.87
Harvesting-curing system	Aide	Hand-bulk	Aide	Hand-bulk	Tying	Hand-bulk		Self-propelled aide	Tying	Hand-bulk	Mechanical harvester	
Crops grown:												
Flue-cured tobacco, acres[a]	5.28	5.28	9.27	9.27	15.86	15.86	-	32.20	32.20	32.20	32.20	-
Corn, acres	23.5	23.5	58.0	58.0	123.4	123.4	143.2	329.3	329.3	329.3	329.3	369.6
Labor use:												
Flue-cured tobacco, total labor	1,711	1,348	3,006	2,368	4,932	4,076	-	10,109	10,044	8,306	7,084	-
Hours hired	1,298	958	2,280	1,683	4,223	3,408	-	9,276	9,158	7,531	6,340	-
Hours worked by operator	413	390	725	685	709	668	-	833	886	775	744	-
Corn, total labor	122	122	302	302	1,136	1,136	1,318	3,032	3,032	3,032	3,032	3,402
Hours hired	-	-	-	-	999	999	1,160	2,668	2,668	2,668	2,668	2,994
Hours worked by operator	122	122	302	302	137	137	158	364	364	364	364	408
Total labor, hours	1,833	1,470	3,308	2,670	6,068	5,212	1,318	13,141	13,076	11,338	10,116	3,402
Farm income, dollars per year[b]	4,303	3,103	8,240	7,829	15,178	12,388	2,066	34,360	32,276	28,012	24,236	5,791

[a]Does not include idle land in skip rows. A pattern of planting 4 and skipping 1 row was assumed.

[b]Farm income is defined as return to operator labor and management, land, crop allotments, and farm operating capital.

Table 12. Long-run income loss for one acre, nonoptimal harvesting-curing systems, alternative wage rates, four farm sizes, Census Subregion 17, North Carolina

Item	Harvesting-curing systems							
	Hand	Tying	Aide-tying	Aide	Self-propelled aide	Hand-bulk	Aide-bulk	Mechanical harvester
	(dollars)							
Small farm--one acre loss in income for wages of:								
1967 average	- 22.08	- 27.37	- 56.79	--[a]	- 54.65	-66.32	-141.65	-575.28
1.88 per hour	- 84.47	- 14.02	- 48.78	0[b]	- 52.59	--	- 71.03	-481.36
Average farm--one acre loss in income for wages of:								
1967 average	- 32.88	- 10.01	- 29.78	--[a]	- 19.54	-18.41	- 59.66	-323.81
1.14 per hour	- 51.22	- 6.41	- 27.05	0[b]	- 25.74	--	- 39.93	-304.13
Medium farm--one acre loss in income for wages of:								
1967 average	- 39.39	--[a]	- 14.92	- 0.13	- 1.67	-33.24	- 57.88	-152.91
1.49 per hour	- 85.84	0[b]	- 18.28	- 9.14	- 11.21	--	- 20.90	-101.83
3.83 per hour	-375.60	-120.40	-154.13	-162.57	-136.06	0[b]	- 13.41	- 17.27
Large farm--one acre loss in income for wages of:								
1967 average	- 57.92	- 4.76	- 16.10	- 11.91	--[a]	-37.17	- 48.23	- 75.49
1.11 per hour	- 71.98	--	- 12.48	- 11.29	0[b]	-10.09	- 21.65	- 52.12
1.47 per hour	- 98.62	0[b]	- 14.97	- 16.49	- 2.23	--	- 7.82	- 16.13
1.83 per hour	-145.05	- 19.18	- 36.83	- 41.20	- 17.51	0[b]	- 6.84	--
3.87 per hour	-462.38	-192.85	-223.57	-243.23	-195.37	-70.61	- 71.11	0[b]

[a]Indicates optimal system.

[b]Indicates system being replaced by optimal system.

The mechanical harvester would be the least cost system only on the large farm if wage rates were $1.83 per hour which is about double the 1967 wage rate.

In an earlier study of the harvesting, curing, and marketing stages of tobacco production, Cockroft (1960) concluded that the least-cost tobacco harvesting and curing systems in the long run were hand harvesting and bulk curing for tobacco acreages between 1.5 and 6 acres and a tractor-drawn priming aide and bulk curing in the 6- to 54-acre range. However, the results of the present study are not directly comparable with those obtained by Cockroft. The prices of bulk barns have essentially doubled in money terms since 1959-60. The 77-rack bulk barn used in the Cockroft study was estimated to cost only $2,150 whereas the 84-rack bulk barn used in this study cost $4,131 (Appendix A table 2). Cockroft estimated the average price of labor as 70 cents per hour in 1960. The weighted average market price was 98 cents in 1967. Perhaps a more significant difference in input requirements between the two studies was in labor coefficients. When the labor hours for harvesting and curing were converted to hours per hundredweight of tobacco to eliminate differences in yield per acre, the hand harvesting, bulk curing system required 5.1 hours per hundredweight in the Cockroft study and 5.6 in the present study, while harvesting with a tractor-drawn priming aide and bulk curing was estimated to require 3.6 hours per hundredweight by Cockroft and 5.4 in the present study. Part of the difference in labor coefficients was probably due to the assumptions made with respect to ground speed of the machinery. Cockroft assumed that the effective ground speed of the 4-row tractor drawn priming aide was .54 MPH. For this study the effective ground speed observed was .37 MPH. In addition, crew composition was different with the higher ground speed being attained with crews composed entirely of men. The 1967 survey results indicate that all-man crews are rare. Because Cockroft considered three alternative methods of preparing tobacco for market, he analyzed marketing costs in a separate section from harvesting and curing costs. No comparable investigation was conducted in this report. Hence marketing costs were included with those for harvesting and curing.

In summary, the differences in input coefficients and factor costs between 1960 and 1967 seem to have limited the applicability of the results of the Cockroft study.

ADOPTION OF MECHANIZATION AND LABOR USE

The previous discussion was focused upon the relative profitability of each of eight harvesting-curing systems for tobacco for individual farm sizes at various wage levels. In this section, special emphasis is devoted to analyzing the effects of adoption by farmers of the mechanical harvester system for tobacco on aggregate labor use.

The analysis proceeds as follows. First, adoption of the mechanical harvester system under 1967 conditions is discussed. Also, the conditions required for the mechanical harvester to be profitable are assumed to exist and the effects on labor use of immediate adoption are examined. Second, changes in those variables that would increase the profitability of the mechanical harvester are considered. Third, adoption of the mechanical harvester is discussed under conditions of a time lag assuming each of the following situations: Wages for labor increase to $1.83 per hour while harvester price remains at $12,500; and wages increase to $1.47 per hour while the harvester price falls 21 percent. For these situations a logistic time path of adoption is considered. The above analysis is based on assumptions that are relatively favorable to the adoption of a mechanical harvester system for tobacco.

Because adoption of the mechanical harvester may not occur immediately, the extent of adoption of other tobacco harvesting-curing systems with rising wage rates is also considered.

The section ends with a consideration of the trends in farm numbers in the study area taken from census data and farmer survey data. Based on these trends, the projected decline in farm numbers and the time required for this decline are compared with the projected farm numbers with adoption of the mechanical harvester and the time required for adoption.

Immediate Adoption

To the extent that the model farms and the conditions assumed in this study are appropriate, the prospects for widespread adoption of the mechanical harvester system appear rather dim at 1967 wage rates, even on large farms.

Although adoption of the mechanical harvester is relatively unprofitable under these conditions, the machine may very well become a profitable alternative for tobacco farmers as circumstances change.

Assume the situation exists such that the mechanical harvester system is profitable for farmers now. Assume further that all farmers adopt the machine immediately. Under these circumstances the quantity of labor used on tobacco farms in Census Subregion 17 would decline. The question, of course, is by what amount. In determining the quantity of labor saved by the mechanical harvester system for the study area, the following procedure is used. First, the size distribution and general characteristics of farms in the area are assumed to be identical to those obtained in the survey of tobacco farms conducted in the area in early 1968 (table 1). Second, the amount of labor required per acre for each of the harvesting-curing systems is specified [table 5 and Davis and Chappell (1969), tables 2 to 23]. Then, a weighted system is constructed based on the proportion of tobacco acreage actually harvested on sample farms with each of the various systems. The hours per acre from the weighted system are then compared to those required for the mechanical harvester system and the quantity of labor saved noted.

In using the above approach, the hours per acre for the weighted system were calculated to be 348.9 (table 13). When compared with the 210.2 hours per acre for producing, harvesting, curing, and marketing tobacco with the mechanical harvester, about 40 percent less labor is required per acre with the mechanical system.[9] Therefore, under conditions such that all farmers would adopt the mechanical harvester system, farmers would employ 40 percent fewer hours of labor in tobacco.

The quantity of labor used in the study area could be reduced more than that indicated from adoption of the mechanical harvester system if

[9]The comparison made here does not depend upon the programming results. It is simply the weighted average system actually found in use on farms in the study area versus the mechanical harvester system.

Table 13. Labor requirements per acre for selected tobacco systems, Census Subregion 17, North Carolina[a]

Item	Hours per acre
Tobacco systems used in survey:[b]	
Hand	370.0
Aide-tying	304.3
Aide	311.8
Tying	297.7
Self-propelled aide	299.6
Weighted average for above tobacco systems[c]	348.8
Mechanical harvester system	210.2
Saving with mechanical harvester system over weighted average system	138.7

[a]Source: Davis and Chappell (1969, tables 2 to 23). The figures in this table do not include operator supervisory labor.

[b]These systems were those in use on actual farms surveyed in the study area. See table 5.

[c]Weighted average was obtained by multiplying the percent of acres harvested on sample farms for each of the above systems by the hours per acre for that system (the numbers which appear in the last column of table 5) and summing.

the combination of crops in the area were changed, agriculture in the area were reduced, or the harvester were changed so that it required less labor.

Alternative Adoption Rates

The two cases of zero and complete adoption of the mechanical harvester system are somewhat extreme. In the first case, conditions were assumed to remain as they were in 1967, and adoption was not profitable. The second case is the opposite extreme where the system was adopted instantaneously. In this section the effects of alternative adoption rates for mechanical harvesters are examined. However, before anyone will adopt the machine, it must be profitable. Any number of factors could have an effect on the profitability of the mechanical harvester. Some of the more important ones are machine quality and price, the price of labor, the size distribution of farms, custom work, changes in the farm in which tobacco is marketed, and money invested in other harvesting systems.

After a machine has been on the market, improvements are often made in some of its parts or in the design of mechanisms that improve its quality. Such improvements will probably be made in the mechanical harvester and bulk curing system once it has been on the market long enough for farmers and manufacturers to learn where its present faults and weaknesses lie. An improvement in machine quality will lower its cost to the producer. Hence wage levels for which the mechanical harvester is profitable on the large farm could apply to smaller farms. In addition, the machine could be profitable at even lower wages on large farms.

Another item that could make the mechanical harvester more profitable is a reduction in its price and, hence, a reduction in annual ownership costs per acre for all farm sizes. The price reduction could come about for two reasons. First, because the mechanical harvester is a new commodity. As Stigler (1966, p. 173) says,

> ...new commodities fall in price more rapidly through time than do the prices of established goods, and the more rapid fall is due to the large increase in volume. Once the reduction of the commodity has achieved a substantial scale, these economies are exhausted and the traditional cost curves of infinite production runs become appropriate.

Second, new entrants into an industry where firms are making profits will begin competing with the original manufacturers with the result being lower prices. Ball-point pens are a good example of a commodity whose price was lowered because of new entries into the industry (Whiteside, 1951).

If the real wage rate for labor increases, whether it is caused by a shift to the left in the farm supply curve for labor, given the demand, or a shift to the right in the farm demand curve, given the supply, or by a shift in both curves (see, for example, Gisser, 1965), the mechanical harvester could eventually become a profitable alternative for tobacco farmers, as shown earlier.

Alternatively, if tobacco were accepted on the market in a different form, i.e., as random oriented leaves rather than in the current form where the leaves are ordered with the lamina all pointing one way, then labor costs of straightening the leaves would be avoided. The machine would in effect be less costly to operate, but there may be an added cost of processing random leaf due to the possibility of more foreign material in the tobacco.

Once the historical size distribution of farms and the age distribution of farmers are known, the particular size groups that are expanding and those that are shrinking and possible trends in their rates of change can be estimated. Thus if there are few young entrants into the industry, at some future date a large number of exits will occur due to death and retirement. Assuming all land remains in agriculture, there would be a substantial reduction in the number of farms and an increase in size. Large farms and farms growing in size would be expected to adopt machinery faster than other farms, other things equal. If older farmers, those above 55, were concentrated in one size group, such as the large farms, then the adoption of machinery may not be rapid because the expected investment returns stream may be too short. If there were not a large cost of information so that the transactions costs of selling used machines were small, then the salvage value of the machines may be large enough that these older farmers would invest anyway. In addition, the availability of custom machine services could effectively eliminate problems associated with the farm size and age distribution of farmers. However, purchasers of custom services bear the risk of loss of timeliness of operations if there is a waiting period for contracting for and acquiring the services on the day they are needed. The supply of custom services probably increases as adoption of the machine increases, assuming that large farms adopt first, and then operators of smaller farms adopt and sell custom services.

To the extent that a large percentage of farmers have invested in automatic tying machines, priming aides, and conventional curing barns, then they may be less likely to sell, trade or junk that equipment for mechanical harvesters. If the programming results are applicable, farmers are likely to invest in harvesting aides and tying machines now because they are profitable. If a mechanical harvester system unexpectedly becomes most profitable within a short time period, owners of other harvesting equipment could suffer capital losses on used machines and annual ownership costs or rental rates would decline. Hence, current investment in other harvesting systems represents a slowdown or dragging influence on the adoption of a mechanical harvester.

Projection of Wage Rates

North Carolina wage rates for farm labor, excluding room and board, have risen from 49 cents per hour in 1950 to $1.13 in 1968 (Appendix C table 1). The money wage data were deflated by the Parity Index to change them to real terms and in 1967 dollars increased from $.65 to $1.09 per hour. The real wages were plotted against time and lines were fitted to three different sets of observations (Appendix C figure 1).[10] During the last 5 years real wages increased about one and one-half cents per hour per year. Since this rate of increase was the most rapid and hence the most favorable for adoption of the mechanical harvester, it was selected as the basis for projections.

An Hourly Wage of $1.83. The $1.83 per hour wage rate, as discussed earlier, is the rate at which the mechanical harvesting system became profitable on large farms assuming 1967 conditions, i.e., costs of items based on 1967 prices. The length of time necessary for farm wage rates in North Carolina to reach $1.83 per hour was determined by projecting the line fitted to the last 5 years data. Thus, if wage rates continue to rise as they have in the last 5 years, real wages will reach $1.83 in 1982.[11] This estimate does not include the time period necessary for the actual adoption process to take place, but represents the time for the machinery to become profitable. Before the time required for

[10]The data sets were: (1) the entire 19 observations for the period 1950 to 1968, (2) data for the last 10 years, and (3) data for the last 5 years. The first two sets produce lower estimates of the rate of increase in real wages and hence require longer time periods for wages to increase to any given level when used as a basis for projections (Appendix C figure 1). Hence, any estimate of adoption times made using projections from these data sets would be longer.

[11]In contrast, the projections to $1.83 using data for the periods 1950-68 and 1957-68 give 45 and 27 years, respectively.

adoption is discussed, changes in other variables that might make the harvester profitable in a shorter period of time will be considered.

Mechanical Harvester Price Reduction. One such variable is the price of the mechanical harvester. If the price does decline in the immediate future, due to an increase in the supply of the machine, then the wage rate necessary to make the harvester profitable will be less, and the time required to reach that wage will also be less than that needed to reach a higher wage.

Thus, if the money wage levels for the large farm are taken from table 12, the price decline necessary for the mechanical harvester to be profitable (break even) can be calculated for each of these wage rates because the annual ownership costs of the mechanical harvester were computed as a fixed percentage of the purchase price (Davis and Chappell, 1969, table 4). The break-even price for the harvester is quite variable depending upon the length of run and the wage rate chosen (table 14). The wage rates presented in table 14 are the wage rates where the most profitable harvesting system changed from one kind to another on the large farm. Of course, the price of the mechanical harvester necessary to make it profitable for other wage rates can be calculated and a curve derived from the points so that a schedule is made of wage rates and machine prices for the large farm for both lengths of run (figure 2).

However, for the long run, only the $1.47 wage requires a price drop of less than half the current price of the machine (table 14). In this case the price must decline about 21 percent.

An Hourly Wage of $1.47. The $1.47 wage rate was chosen for further examination because it represents a wage and a mechanical harvester price which might be attained in several years. North Carolina wage rates are projected to reach $1.47 per hour by 1975.[12] Therefore, if mechanical tobacco harvesters are manufactured in sufficient

[12]Projections using data for 1950-68 and 1957-68 give 15 and 26 years, respectively.

Table 14. Break-even mechanical harvester prices for selected wage rates on the large farm in the long and short run[a]

Wage rates	1967 price of harvester	Reduction in price necessary for harvester to be profitable	Price at which harvester would be profitable
(dols. per hour)		(dollars)	
		Long run	
1967 weighted wage	12,500	12,286	214[b]
1.11	12,500	8,482	4,018
1.47	12,500	2,625	9,875
1.83	12,500	0	12,500
		Short run	
1967 weighted wage	12,500	19,471	--
1.11	12,500	15,164	--
2.12	12,500	0	12,500

[a]Source: Tables 7, 9, 10, and 12.

[b]These figures calculated as follows: Annual amount that costs exceed total revenue at 1967 wages = 2,430.88 (table 10). Annual fixed costs of the mechanical harvester = 2,473.21. 2,473.21 - 2,430.88 = 42.33. 42.33 ÷ 19.78569 (the percent that fixed costs are of the purchase price) = 213.94 or 214 as the new purchase price at 1967 weighted wages for which the mechanical harvester is profitable.

quantity such that the price declines about 21 percent, they could become profitable on large farms in the long run as early as 1975.[13]

[13]Recall that the long run was defined so that the annual ownership costs of all tobacco barns had to be paid by the farmers.

An alternative approach is to assume a change in the technology of the mechanical harvesting system. Assume the harvester was redesigned and could be operated with a two-man crew. One man would operate the harvester in the tobacco field, and the other would take harvested leaves from the field and put them in the bulk barn. Under such an arrangement, harvesting time would be reduced 60 percent and total hours per acre would be reduced 12.2 percent. The harvester would be profitable on the large farm in the short run at wage rates of $1.77 per hour and in the long run at wages of $1.38 per hour. In both cases the two-man harvester would replace the tying system.

When compared to the weighted system of table 13, the two-man harvester would reduce labor use about 47 percent. While a two-man machine is not currently available in the market place, this example illustrates the effect a technological advance can have on costs and hence on projections.

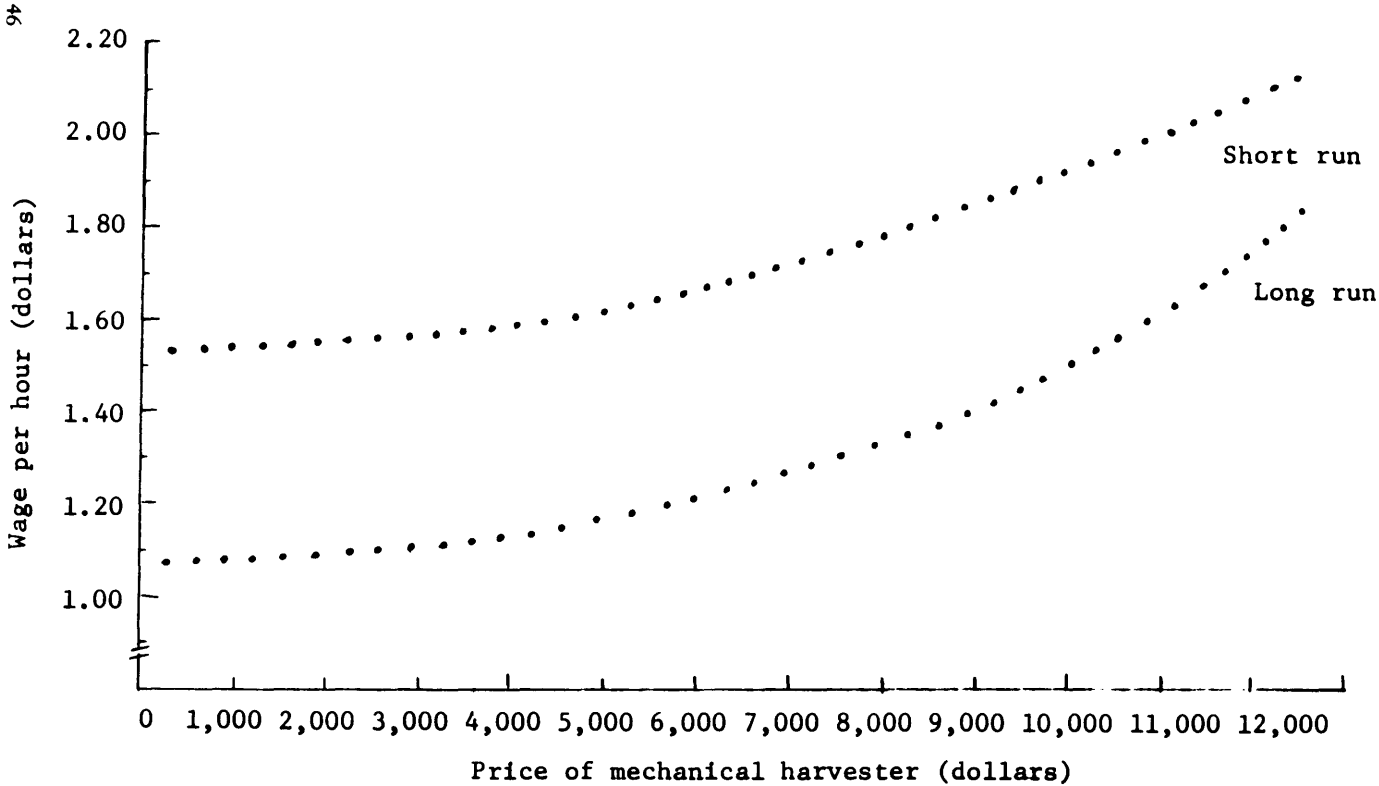

Figure 2. Break-even mechanical harvester prices and hired farm labor wage rates in the long and short run on the large farm

Rates of Adoption of Mechanical Harvesters

Ordinarily there may be several time lags in the development and adoption of a new process or technology. First, there is the lag between the inception of an idea and the time funds are appropriated for research to develop a workable model. There is an additional lag in development of the model and a third lag in going from research model to manufactured product. Finally, there is a time lag associated with obtaining information about the new product. Such lags usually stand for a number of unspecified forces. The first three lags will not be considered in this study because the mechanical harvester system has already been manufactured.

The final lag, however, will be considered in more detail. Buyers (farmers in the case of a tobacco harvester) have to learn of the existence of the product and the circumstances under which it is profitable before they will decide to adopt it. Based on previous studies of adoptions of agricultural innovations, initially only a few producers will adopt the mechanical harvester (Beal and Rogers, 1960). If the machines prove profitable and can be integrated into the production process relatively easily, other farmers will be induced to try them, and the adoption will continue at some rate until most of the farmers use the machines.

A general adoption pattern like that described above was followed by farmers for a new technology introduced to agriculture during the first half of the twentieth century--hybrid corn (Griliches, 1957). In the case of hybrid corn, Griliches found that the rate of adoption by farmers could be described by a logistic function, $P = \frac{K}{1 + e^{-(a+bt)}}$, where P = the percent planted to hybrid corn, K = the ceiling or equilibrium value, a = constant of integration which positions the logistic on the time axis, b = rate of growth coefficient, and t = time. Fishelson (1968) has shown that the percentage of farmers adopting hybrid corn in the five Corn Belt states (Ohio, Indiana, Illinois, Iowa, and Missouri) in any 1 year varied from 0.3 to 19.0 (table 15). Thus, if the logistic for the five Corn Belt states were applied to mechanical tobacco harvesters to describe the rate of adoption by farmers, 87.5 percent would adopt during the 7-year period represented by years 6 through 12 (inclusive (table 15). Only 3.8 percent would adopt during the first

Table 15. Adoption rates assumed for the mechanical tobacco harvester[a]

Year	Proportion adopting in any one year	Cumulative proportion adopting[b]
1	0	0
2	.003	.003
3	.004	.007
4	.010	.017
5	.021	.038
6	.043	.081
7	.083	.164
8	.139	.303
9	.189	.492
10	.190	.682
11	.144	.826
12	.087	.913
13	.045	.958
14	.022	.980
15	.010	.990
16	.006	.996
17	.004	1.000

[a]Source: Fishelson (1968, Appendix A table 3).

[b]The cumulative adoption function is $P = \frac{1}{1 + e^{-(.76 + .796t)}}$ for the five Corn Belt states (Ohio, Indiana, Illinois, Iowa and Missouri). It would be different for other sets of states.

5 years while, during the last 5 years, 8.7 percent of the farmers would adopt the machine.

If tobacco farmers can be assumed to use either of two tobacco harvesting systems (the mechanical harvester system or the weighted system) (table 13), and the price of the mechanical harvester remains at $12,500, then the amount of time required for 91.3 percent of the farmers to turn away from the weighted system and adopt the mechanical harvester would vary from 22 to 27 years (table 16).

The projections were carried forward from the year 1967 and were obtained as follows. The length of time required for the mechanical harvester to become profitable is 15 years. From table 15, assume that 3.8 percent of the farmers adopt in the first 5 years and 87.5 percent in the next 7 years. Then 12 years are necessary to achieve 91.3 percent adoption once the machine is profitable. Thus, the total adoption time is 27 years. However, if 3.8 percent of the farmers adopt the machine while it is becoming profitable for the remainder of the population, then the adoption lag would be 7 years and total adoption time would be 5 years shorter.

If the price of the mechanical harvester were to decline by about 21 percent during future years, then real wages would only have to climb to $1.47 per hour before the machinery would be profitable. The mechanical harvester would be adopted by 91.3 percent of the farmers in 20 years. These estimates use the projections of 8 years from 1967 until the machine is profitable and 12 years for the adoption to take place once the machine is profitable (table 16).

If 5 years were subtracted from these estimates because the first 3.8 percent of the farmers adopted the mechanical system during the last 5 years of the real wage increase toward $1.47 per hour, then the system could be 91.3 percent adopted in as few as 15 years.

Expansion Rate of Other Systems

If the mechanical harvester system is not adopted by farmers in the immediate future as suggested in the preceding discussion, then the question of how the rate of use of other tobacco harvesting-curing systems will change over time is appropriate. Increases in the farm wage rate also affect the relative profitability of the other

Table 16. Time required for adoption of the mechanical harvester system at alternative wage rates[a]

Item	Wage rate $1.83	Wage rate $1.47
Years to reach break even	15	8
Adoption lag	7-12	7-12
Total years	22-27	15-20

[a]Source of projection data: Appendix C.

harvesting-curing systems. Therefore, those systems that were found to be profitable in the linear programming analysis would be expected to be adopted by tobacco farmers at wage rates between the 1967 weighted average and an hourly wage of $1.83 for which the mechanical harvester system becomes profitable in the long run.

Profitable Harvesting-Curing Systems

The profitable harvesting-curing systems obtained from the linear programming solutions for each model farm are aggregated into a weighted harvesting-curing system for each of several money wage rates. The proportion of total acres of tobacco planted by farms in a particular size category is used as the weighting factor to determine the average hours of labor per acre for the profitable harvesting-curing system for these farms.[14]

1967 Wage Rates. Based on the long-run linear programming solutions for the model farms at 1967 wages, estimated labor use would be 304.7 hours per acre (table 17). This estimate is 44.2 hours per acre less

[14]The total acres of tobacco planted by sample farms in each size category are: small farms, 543.47; average farms, 803.15; medium farms, 927.99; and large farms, 567.02 (table 5). Therefore, the proportion of the tobacco acreage planted on farms in each size category is .1913, .2826, .3266, and .1995 for small, average, medium, and large farms, respectively. In this section the acreage of tobacco planted on very small farms with less then 10 acres was excluded from the calculations because very small farms were excluded from the programming analysis. Therefore, the estimates obtained will be approximately 0.3 percent too low.

Table 17. Labor use for the most profitable harvesting-curing systems long-run linear programming results, 1967 wages[a]

Item	Farm size				Aggregate
	Small	Average	Medium	Large	
Most profitable harvesting system	Aide	Aide	Tying	Self-propelled aide	
Hours of labor per acre	311.8	311.8	297.7	299.6	
Weights	.1913	.2826	.3266	.1995	
Hours of labor per acre for weighted system[b]					304.7

[a]Source: Tables 10 and 13.

[b]Calculated by multiplying figures in each column together and then summing the products.

than the estimated actual labor use per acre for the weighted harvesting system calculated from farmer survey data for 1967 (table 13). Therefore, the programming results for higher wage rates also are likely to underestimate actual hours of labor employed.[15] If the programming results also underestimate aggregate labor used at higher wage levels by the same absolute amount as for 1967 wage levels (44.2 hours per acre), then estimates of reductions in labor use associated with wage increases will be unaffected.

[15]The amount of the bias would be the same if the short-run programming solutions for 1967 wages were compared with the farmer survey data because the optimal harvesting system for both lengths of run are identical. (See tables 7 and 10.) However, if the programming estimates of labor use at all wages are lower than actual hours of labor employed by some constant percentage rate, then there will be a consistent percentage error in the estimates of reductions in labor used based on the programming results. A greater error would occur if the programming results for high wage levels were an overestimate and the results for 1967 wages were an underestimate of actual labor use.

Other Wage Levels. When wages were increased from 1967 levels, the relative profitability of the harvesting-curing systems changed, and some systems were replaced by others with lower labor requirements. Thus, as wages rose, the hours of labor per acre required for the weighted tobacco system declined (table 18). No change occurred in the systems making up the aggregate for wages between $1.49 and $1.83 per hour where the mechanical harvester system became profitable.

The decline in the number of hours of labor per acre for the aggregate system from table 13 as wages rose from the 1967 base level to $1.49 per hour was 45.9 hours or 15 percent.

The wage elasticity of demand for farm labor when computed as an arc elasticity for the aggregate system as wages rose from 1967 levels ($0.98 per hour) to $1.49 per hour was -.39. The elasticity estimate as wages changed from $1.49 to $1.83 per hour and the mechanical harvester system became profitable was -1.01, while for the whole change from 1967 wage levels to $1.83 wages, the arc elasticity was -.61.[16] Hours of labor per acre were used as a measure of quantity in computing the elasticities. These elasticities presented here probably approximate those obtained for a constant output factor demand curve (Friedman, 1962). One would expect the wage elasticities of labor demand calculated from an unconstrained demand curve for the factor to be larger. Schuh (1962) obtained long-run wage elasticities of demand for hired farm labor of -.40 when measured at the mean and -.77 for 1957, using time series data for the United States. However, hired labor accounts for about 25 percent of the total farm labor force. Wallace and Hoover (1966) obtained a wage elasticity of demand estimate of -1.433 using cross-section data for the United States for 1959. Gisser (1967) assumed that the reciprocal of the demand elasticity for labor was -.50, which would make the elasticity equal to -2.0. Thus, the reduction in farm labor use calculated in this study may underestimate the changes that would occur in labor use with increasing wages and mechanization of tobacco harvesting in the long run.

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[16] If these elasticities are calculated from a base of 348.9 hours of labor per acre rather than 304.7 hours per acre, then wage elasticities for the intervals considered are -.34, -.85, and -.52, respectively.

Table 18. Labor use for the most profitable harvesting systems, long-run linear programming results, variable wage rates[a]

Item	Farm size				
	Small	Average	Medium	Large	Aggregate
Weights	.1913	.2826	.3266	.1995	
$1.11/hour wage rate:					
Hours/ac. for most profitable systems	311.8[b]	311.8	297.7[c]	297.7	
Hours/ac. for weighted system					304.4
$1.14/hour wage rate:					
Hours/ac. for most profitable systems	311.8	246.3[d]	297.7	297.7	
Hours/ac. for weighted system					285.8
$1.47/hour wage rate:					
Hours/ac. for most profitable systems	311.8	246.3	297.7	246.3	
Hours/ac. for weighted system					275.6
$1.49/hour wage rate:					
Hours/ac. for most profitable systems	311.8	246.3	246.3	246.3	
Hours/ac. for weighted system					258.8

[a]Source: Tables 8 and 13.

[b]Total hours per acre for aide system including tobacco preharvest operations.

[c]Total hours per acre for tying system including tobacco preharvest operations.

[d]Total hours per acre for hand-bulk system including tobacco preharvest operations.

Time Required for Adoption

If adoption of the aggregate systems was instantaneous once wages reached the break-even level, the time required for adoption would be a function of the rise in wages. If the projections of the North Carolina farm wage for the 1964-68 period were used, then the estimated number of years required for the full 15 percent reduction in the quantity of labor employed on tobacco farms would be eight.[17]

If the case of instantaneous adoption is modified to include a lag so that profitable harvesting-curing systems are adopted immediately by only a few farmers, then the time required for a 15-percent labor reduction will be extended by the amount of the lag. The length of the timespan necessary for adoption of any new technology depends upon its profitability. The more profitable it is, the shorter the timespan (Griliches, 1957). The adoption curve employed earlier with mechanical harvester systems (table 15) required about 6 years for adoption to go from 10 to 91 percent of the farms.[18] The data for the adoption curve are for the five Corn Belt states. If, however, the adoption curve for Iowa, where hybrid corn was adopted most rapidly, were used, then the time would be cut from 6 to 4 years (Griliches, 1957). Therefore, the time required for adoption of the aggregate harvesting system by 91 percent of the farmers would range from 12 to 14 years. If the price of the major equipment item used in these systems, bulk barns, falls in the future and wages rise, then the time period required to reach the break-even point would be shorter and adoption would be hastened.

Trends in Farm Numbers

The decline in labor use (and the implied reductions in the number of farms) estimated above for the 14-county study area under the

[17] The real wage rate would be $1.49/342 = $.4357. The years for which the projections hit a horizontal line at the $.4357 level are 1975, 1983, and 1994 for the 5-, 10-, and 19-year projections, respectively. When 1967 is subtracted from those years, then 8, 16, and 27 years are required to reach the break-even wage rate for the aggregate systems.

[18] The 10-percent starting point is used here because of the number of harvesting systems already in use by farmers in 1967.

assumption of mechanization and firm growth may or may not be reasonable in light of the past trends in farm numbers for the study area.

Census Data

The period 1950 to 1964 was chosen for an analysis of the changes in farm numbers for the study area as reported in the Census of Agriculture. The census year immediately preceding 1949 was a war year, 1945, and was, therefore, not considered. For the 14 counties studied, farm numbers declined by 34,003 from 1949 to 1964 (table 19), a reduction of 50.34 percent. The annual rate of decline in farm numbers for this 15-year period was 4.78 percent per year. The rate of decline in farm numbers per year for the most recent 5-year period reported, 1959-1964, was 5.08 percent.

If farm numbers continue to decline at a rate of 5 percent per year in the future, how many years will be required to attain the reduction in farm numbers and increase in farm size necessary for profitable operation of the mechanical harvester? To obtain this estimate, it is necessary to make some assumptions regarding the future number and size distribution of farms and also to estimate the number and size distribution of farms in 1967. Since the mechanical harvester was profitable only on the large farm, the simplest assumption to make is that all farms will adjust in size to become large farms, i.e., contain 32.20 acres of tobacco. Such a change in the farm size distribution would lead to a reduction in the number of tobacco farms from 16,327 in 1967 to 5,424.[19] Approximately 22 years, or until 1990, would be required to attain this increase in farm size and reduction in number.

[19] The 174,645 acres of tobacco reported for 1967 by ASCS (U. S. Department of Agriculture, 1967b) for the 14-county study area was multiplied by the proportion of small, average, medium, and large farms in the survey (table 18). The resulting acres of tobacco on small, average, medium, and large farms were divided by the mean tobacco acreage for each class of farm (5.28, 9.27, 15.86, and 32.20) to obtain the number of small, average, medium, and large farms, which were 6,324, 5,324, 3,597, and 1,082, respectively. Thus, the estimate of the total number of tobacco farms was 16,327. Then assume that the size distribution of farms observed from farmer survey data (table 5) no longer holds, and all farms become large farms with 32.20 acres of tobacco. In this case there would be 5,424 farms (174,645 ÷ 32.20).

Table 19. Number of farms in Census Subregion 17, North Carolina, 1949-1964[a]

Year	Number of farms
1949	67,542
1954	60,303
1959	42,958[b]
1964	33,539

[a]Source: U. S. Bureau of the Census (1952, 1956, 1967).

[b]There was a change in the definition of a farm used by the Census of Agriculture between the 1954 and 1959 surveys. As a result, part of the decline in the farm numbers is due to definitional change. For Census Subregion 17, the decrease due to definitional change was 1,390 farms.

An alternative assumption is that the number of large farms in the study area in 1967 remains constant and all the remaining farms shift into the medium size class, 15.86 acres of tobacco, with a corresponding decrease in farm numbers in the area from 16,327 to 9,897.[20] Such a change in farm size might be consistent with profitable use of the mechanical harvester if custom work and machine sharing were rather widespread. Again assuming a 5-percent annual rate of reduction in farm numbers, approximately 10 years, or until 1977, would be required to attain this increase in farm size and reduction in numbers.

How do these time estimates compare with estimates of years required for wage rates to rise sufficiently to make the mechanical harvester profitable? Assuming no decline in the price of the mechanical harvester, it will be 1982 before adoption of the harvester will be profitable based on wage rate projections (to $1.83 per hour) using wage data for the last 5 years (Appendix C). Thus, the projected increases in farm

[20]The tobacco acreage on the 1,082 large farms, 34,840 acres, is subtracted from the total acreage in the study area, 174,645 acres, and the remaining acreage, 139,805 acres, is divided by 15.86 acres per farm to estimate the number of farms in the medium size class, 8,815. Given this assumption regarding the size distribution of farms, the total number of farms in the study area would be 9,897 (8,815 + 1,082).

size required for profitable operation of the harvester may occur as rapidly as the wage rate increase required to make the harvester profitable relative to other harvesting-curing systems.

Age Distribution of Farmers

Another way to examine the decline in farm numbers would be to take the data on the age distribution of farmers obtained in the farmer survey for 1967 or the 1964 Census of Agriculture and assume no entry into the industry. Then the proportion of farmers reaching the retirement age of 65 in 1977 and 1990 could be used as an indication of the decline in farm numbers that might occur. The distributions of farm operators by age which were derived from the 1964 Census of Agriculture and the farmer survey for 1967 give slightly different estimates (table 20). If there were no entry, then 59 percent of the farmers in 1964 would remain on farms in 1977 but, by 1990, only 23 percent would be left. Using the farmer survey data, 61 percent of the current farmers would still be farming in 1977 but, by 1990, only 22 percent would be left.

The Census of Agriculture data thus show a 4.08-percent decline per year in farm numbers between 1964 and 1977 and a 5.74 percent decline per year between 1964 and 1990. The farmer survey data, however, are indicative of a more rapid rate of decline in farm numbers. The rate for the period 1967-1977 is 5.12 percent and the rate between 1967 and 1990 is 6.88 percent per year. Thus, while the age projections seem reasonable for 1977, they seem less so for 1990 because for the longer period of time the assumption of no entry appears to be very severe.

In summary, a projection of the decline in farm numbers of about 5 percent per year seems consistent with the historical trends in farm numbers and with the expected retirement rates of farm operators in the area. Such a rate of reduction in farm numbers would be consistent with adoption of the mechanical harvester between 1977 and 1990. If the reduction in the number of farm laborers occurs at the same rate as the reduction in farms, then the labor market effects of rapid displacement of large numbers of workers by mechanization may not be severe. This conclusion seems warranted because the adoption rate appears to be slow enough so that the current reduction in farm numbers in the area will have eliminated any excess supply of laborers by the time adoption becomes a reality.

Table 20. Percentage distribution of farm operators by age, Census Subregion 17, North Carolina, 1964 and 1967[a]

Year	Age of farm operator					
	Under 25	25-34	35-44	45-54	55-64	65+
	(percent)					
1964	2.58	11.22	24.08	30.84	21.41	9.86
1967	1.67	6.67	19.00	33.33	27.67	11.67

[a]Source: U. S. Bureau of the Census (1967) and primary data collected by the authors in 1968.

SUMMARY AND CONCLUSIONS

The harvesting, curing, and marketing stages of flue-cured tobacco production have historically been highly labor intensive. However, as the price of labor continues to increase, there is an incentive to mechanize these operations. The implications for substituting harvesting and curing machinery for labor in flue-cured tobacco production were examined in this study. The objectives of the study were: (1) to determine the optimal organizations and quantities of labor used for selected flue-cured tobacco farm situations with selected alternative machinery systems and wage rates; and (2) to estimate the aggregate quantity of labor used in the 14-county study area with alternative rates of adoption of machinery on flue-cured tobacco farms.

Because farms of different sizes do not always respond the same way to adoption of new techniques, four farm situations were specified for analysis. Sizes of farms selected were: (1) small farms with 10 to 49 acres of cropland, (2) average farms with 50 to 99 acres of cropland, (3) medium farms with 100 to 219 acres of cropland, and (4) large farms with 220 acres or more of cropland.

A distribution of farms that fell in the four selected size groups was obtained from two farmer surveys conducted in Census Subregion 17, North Carolina. The survey data were sorted into each of the four farm size groups, and arithmetic means were calculated for the organizational characteristics of each farm situation.

Eight tobacco systems were selected which covered the range of alternative harvesting-curing methods in use by farmers and offered for sale by machinery companies. Five systems were used in conjunction with conventional curing barns, while three systems required bulk curing barns. Crew size for the systems was assumed to vary from 5 to 20 people depending upon the system. Weighted average wage rates were calculated for each system for each size of farm.

Each farm situation was described by a linear programming model that incorporated the main features of the farm size under consideration.

Each model was constrained to the mean values obtained from survey data for acres of cropland and tobacco poundage quota. The other nonzero restrictions were for hours of operator labor, which were the same for each farm. The programming matrix for each farm contained several production alternatives, including eight ways to harvest, cure, and market tobacco, and the possibility of raising corn, soybeans, and Blueboy wheat in addition to tobacco. Also, there were labor hiring activities for each of the tobacco and grain enterprises. Wage rates of hired labor were varied, and the most profitable farm organization was noted for wages ranging from 1967 levels to $4.00 per hour for each farm. The analysis was conducted for two lengths of run. In the short run, adequate conventional curing barns were assumed to be present on the farms, but annual costs of bulk-curing barns would need to be added if they were to be used, because currently there are none. In the long run, all curing facilities were assumed to be variable.

At 1967 wage rates, harvesting-curing methods were the same for both lengths of run for each farm. At higher wages some differences in results for the two lengths of run were noted. The most profitable tobacco harvesting and curing method at 1967 wage rates for hired labor on small and average farms was the aide system.[21] On medium farms the tying system was most profitable, while the self-propelled aide system was optimal on large farms. All these systems require conventional curing barns, and are not very different from the systems in use on the tobacco farms surveyed. As wages were increased above 1967 levels, harvesting and curing systems that required less labor became profitable. In the short run, bulk curing systems were not profitable at wages below $1.82 per hour. In the long run, bulk curing systems became profitable on average farms when wages rose to $1.14 per hour, on medium farms at $1.49 per hour, and on large farms at $1.47 per hour. Wages had to rise to $1.88 per hour before bulk curing would be profitable on small farms in the long run. The priming aide, bulk curing system was not profitable at any of the wage rates considered. The mechanical harvesting, bulk curing system became profitable only on large farms at relatively high

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[21] See table 2 for description of systems.

wages for hired labor--$1.83 per hour in the long run and $2.12 per hour in the short run.

When the stability of the solutions was examined, several tobacco harvesting-curing systems were seen to be close substitutes for the optimal system at any given wage rate for each farm. That is, while the systems named above were optimal at the wages cited, several other systems could have been employed by farmers with very little loss in revenue. In the short run, where conventional curing barns were assumed to be on the farm, bulk curing systems did not pay except at high wage levels. However, none of the conventional curing systems were really unprofitable for some size of farm. While some systems were more profitable than others for specific farm sizes, all of the conventional curing systems analyzed will be used on tobacco farms if the programming results and accompanying sensitivity analyses are correct.

In the long run, where no curing facilities were assumed available so that whatever system was used required purchase of curing barns, bulk curing systems were profitable at much lower wage rates than was the case for the short run. The implication from these results is that farmers would find bulk curing barns a profitable alternative only if they found it necessary to replace existing conventional curing facilities. In that case, of the bulk curing systems analyzed, hand harvesting would be most profitable.

After considering the relative profitability of the alternative tobacco systems for individual farms of various sizes, attention was focused upon the study area as a whole and the impact on labor use that could be expected if the mechanized harvesting of tobacco were adopted by farmers. Several adoption rates of the mechanical harvester system were considered. Initially, adoption rates of the harvester with current prices of labor were examined, but under the assumptions made for the study no farmers would be expected to adopt the harvester. Next, adoption of the mechanical harvester was considered for the case where all farmers adopted the system instantaneously because of increased wages or price declines for the machine such that it was profitable. Under the assumption of instantaneous adoption of the harvester, the hours of labor hired in the area were expected to decline about 40 percent. Prediction of this type of adjustment assumes no changes in the mechanical harvesting system, types of crops grown or the intensity of agriculture in the area.

Other adoption rates for the mechanical harvester were also examined. Wage rates for hired labor were projected into the future using wage data for three periods, 1950 to 1968, 1959 to 1968, and 1964 to 1968. The time required for wages to reach $1.83 per hour, the level at which the mechanical harvester was profitable assuming all other prices remained at their 1967 levels, was determined for each wage projection. Using the shortest projection of wages and a logistic adoption time path, the mechanical harvester would be adopted by 91 percent of the farmers in 27 years using 1967 as a base. Similar time paths estimated for the other two projection rates of wages were 39 and 57 years.

The harvester price declines necessary for the mechanical harvester system to become profitable (break-even) at wages below $1.83 per hour were calculated. At a wage level of $1.47 per hour, the price of the mechanical harvester must decline 21 percent, a level that might be attained in several years. When projections of hired farm wages were made to $1.47 per hour, the time path of adoption was shortened to 20, 27, and 38 years for 91 percent adoption of the mechanical harvester using the logistic time path.

Because the lag for mechanical harvesters to be profitable was several years, the adoption of partially mechanized tobacco harvesting and curing systems by farmers was considered. A weighted harvesting system was calculated based on the most profitable systems obtained in the linear programming analysis for each of the four sizes of farms. The proportions of the total tobacco acreage grown on each size of farm were used as weights. The weighted system was calculated for 1967 wage rates and higher wages up to $1.83 per hour, the break-even wage for mechanical harvesters. As wages rose from 1967 levels to $1.83 per hour, farmers could reduce the estimated amount of harvesting and curing labor employed in tobacco in the study area by 15 percent by adopting the most profitable partially mechanized tobacco harvesting systems as obtained from the linear programming solutions.

Projections of the declines in farm numbers using 1964 Census of Agriculture data were found to be consistent with the length of time projected for farm wages to rise to \$1.83 per hour, the level where the mechanical harvester is profitable at 1967 prices.

The age distribution of farmers was also examined and the decline in the number of farmers was investigated assuming no new entrants into the industry. Using farmer survey data for the area, 61 percent of the farmers would be under 65 years old and hence still farming by 1977. According to 1964 Census of Agriculture data, 59 percent of the farmers would be under 65 by 1977. The above figures are consistent with a 5.12 annual rate of exit of farmers for the survey data and a 4.08 percent rate for the census data.

Thus, if farm numbers continue to decline at a rate of 5 percent and farm wages increase as projected, the number of farms left in the study area, and consequently farm size, will be such that the mechanical harvester system will be profitable in as few as 10 to 15 years if the price of the machine remains the same. The supply of agricultural laborers should be sufficient to harvest the crop. Day (1967) observed a 54-percent decline in the farm population during the decade 1950-1960 and a 62-percent decline from 1940-1960 in the Mississippi Delta as a result of technological change on Delta farms. If the current trend in farm numbers and sizes continues at the same rate, it will result in farm size cconsistent with the adoption of the mechanical tobacco harvester, and the realization of these changes could lead to a population change not unlike that observed by Day.

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APPENDICES

Appendix A

Enterprise Budgets

This section contains the budgets used to derive the coefficients for the activities in the linear programming models that do not appear in Davis and Chappell (1969). The first two tables contain annual ownership costs for curing barns. Davis and Chappell assumed a constant barn cost per pound of tobacco (2.1¢/lb. for conventional barns and 6.1¢/lb. for bulk barns) and did not specify barn costs on a per-barn basis. In this study, annual costs were estimated for one conventional and two bulk curing barns. Each farm situation was required to have a complement of curing barns, and annual barn costs were prorated per acre of flue-cured tobacco. This difference in treatment of curing barns changed costs slightly. Instead of $42.21 per acre for all farm situations, the annual costs of conventional curing barns became $48.95 for the small farm, $41.82 for the average farm, $48.90 for the medium farm, and $44.15 for the large farm. For bulk barns annual costs were $187.73 for the small farm, $121.89 for the average farm, $129.39 for the medium farm, and $122.86 for the large farm instead of $122.61 for all farm sizes. Also, Davis and Chappell present only tobacco budgets. Hence budgets are included in this section for corn, Blueboy wheat, and soybeans. The grain and soybean budgets for the small farm are presented in their entirety (Appendix A, tables 3 to 8), but only the modifications necessary to make the budgets applicable to the larger farms are presented (Appendix A, tables 9 and 10).

Appendix A Table 1. Investment and annual ownership costs for a conventional tobacco barn and equipment with 3-acre capacity[a]

Item	Life	Costs
	(years)	(dollars)
Investment costs:		
Tobacco curing barn	20	750.00
Low pressure gas curer	20	175.00
2700 tobacco sticks at 4 1/2 cents	10	121.50
Total		1,046.50
Annual costs:[b]		
Depreciation		
Barn and gas curer		46.25
Tobacco sticks		12.15
Total depreciation		58.40
Repairs on barn and gas curer		18.50
Interest		31.40
Taxes		20.93
Total		129.23

[a]Sources: Cost of curing barn was obtained from unpublished data acquired by Dr. J. G. Sutherland, Department of Economics, N. C. State University. Cost of gas curer was quoted in private communication with North Carolina Butane Gas Co., Raleigh, N. C., October 11, 1968. The gas tank is furnished by the company at no extra charge. The costs of tobacco sticks were obtained from FCX Farm and Garden Supplies, Raleigh, N. C., by private communication, October 11, 1968.

[b]The various annual costs were calculated as follows. Depreciation on the barn and gas curer was obtained as 5 percent of investment costs. Depreciation on the tobacco sticks was computed as 10 percent of investment costs. Repairs on the barn and gas curer were figured at 2 percent of investment costs. Interest and taxes were obtained as 3 and 2 percent of investment costs, respectively.

Appendix A Table 2. Investment and annual ownership costs for bulk tobacco barns and equipment[a]

Item	Bulk-curing barn capacity	
	3.85 acres	4.63 acres
Investment costs (dollars)	4,130.66	4,709.90
Years of life	20	20
Annual costs:[b] (dollars)		
Depreciation	206.53	235.50
Repairs	82.61	94.20
Interest	123.92	141.30
Taxes	82.61	94.20
Total	495.67	565.20

[a]Sources: 3.85-acre capacity curing barn prices were the arithmetic average of those quoted for 1967 by Powell Mfg. Co., Bennettsville, S. C., for 82 rack, 422 sq. ft. barn; Long Mfg. Co., Tarboro, N. C., for 96 rack, 432 sq. ft. mobile barn, and Harrington Mfg. Co., Lewiston, N. C. for 84 rack, 441 sq. ft. barn, while 4.63-acre capacity curing barn prices were the average of those quoted for 1967 by Powell Mfg. Co. for 100 rack, 514 sq. ft. barn and Harrington Mfg. Co. for 102 rack, 536 sq. ft. barn. The prices were for fully assembled barns with wood floor, gas furnace, 3 hp motor for 3.85-acre capacity (5 hp motor for 4.63-acre capacity) bulk curing racks, wet bulb, automatic temperature control and clock.

[b]Annual depreciation costs were computed as 5 percent of investment costs. See footnote b, Appendix A table 1 for calculation of repairs, interest and taxes.

Appendix A Table 3. Corn: Budget for one acre, small farm, Census Subregion 17, North Carolina

Item	Description	Price per unit	Amount
		(dollars)	
Shelled corn	90 bu.	1.20	108.00
Variable costs			
Fertilizer	6 cwt. 5-10-10	2.25	13.50
	120 lbs. Nitrogen	.10	12.00
Seed	12.2 lbs. Hybrid	.22	2.68
Weed control	2.5 lbs. Atrazine	2.85	7.12
	.5 lbs. 2, 4-D	1.06	.53
Tractor[a]	31 drawbar hp, 4.5 hours	.50	2.25
Custom harvesting	90 bu.	.16	14.40
Custom hauling	90 bu.	.05	4.50
Total			56.98
Annual ownership costs of other machinery			1.70
Total costs (except labor)			58.68
Returns			49.32

[a]For the average farm a 42-drawbar hp tractor is used with variable costs of $.71 per hour or $3.20 per acre. Returns are lowered to $48.37.

Appendix A Table 4. Corn: Labor and machinery budget, one acre, small farm, Census Subregion 17, North Carolina

Operation and date	Times over	Machinery Size	Use	Annual ownership costs Per hour	Per acre	31 draw-bar hp tractor use	Operator labor
			(hours)	(dollars)		(hours)	(hours)
Disking (Nov.)	1	7'	0.7	.30	.21	0.7	0.7
Break land (April)	1	3-14[a]	1.1	.46	.51	1.1	1.1
Disking (April)	1	7'	0.7	.30	.21	0.7	0.7
Harrowing (April)	1	9'[b]	0.4	.09	.04	0.4	0.4
Plant and fert. (May)	1	2 row	0.6	.58	.35	0.6	1.0
Weed control (May)	1	4 row	0.3	.21	.06	0.3	0.4
Cultivate, weed control and fert. (May)	1	2 row	0.7	.45	.32	0.7	0.9
Picking (Oct.)	1	Custom					
Hauling (Oct.)	1	Custom					
Total			4.5		1.70	4.5	5.2

[a]Moldboard plow.

[b]Section harrow.

Appendix A Table 5. Blueboy wheat: Budget for one acre, small farm, Census Subregion 17, North Carolina

Item	Description	Price per unit	Amount
		(dollars)	
Wheat	70 bu.	1.15	80.50
Variable costs			
Seed	1 bu.	4.00	4.00
Fertilizer	6 cwt., 5-10-10	2.25	13.50
	1.2 cwt. N, custom applied	10.00	12.00
Tractor[a]	2.4 hours, 31 drawbar hp	.50	1.20
Harvesting	Custom, one acre	7.00	7.00
Hauling	Custom, per bu.	.05	3.50
Total			41.20
Annual ownership costs of other machinery			1.42
Total costs (except labor)			42.62
Returns			37.88

[a]For the average farm a 42-drawbar hp tractor is used with variable costs of $.71 per hour or $1.70 per acre. Returns are lowered to $37.38.

Appendix A Table 6. Blueboy wheat: Labor and machinery budget, one acre, small farm, Census Subregion 17, North Carolina

Operation and date	Times over	Machinery				31 drawbar hp tractor use	Operator labor
		Size	Use	Annual ownership costs			
				Per hour	Per acre		
			(hours)	(dollars)		(hours)	(hours)
Break land (Sept.-Oct.)	1	3-14"	1.1	.46	.51	1.1	1.1
Disking (Oct.-Nov.)	1	7'[a]	.7	.30	.21	.7	.7
Drill and fertilizer (Oct.-Nov.)	1	8'[b]	.6	1.17	.70	.6	.8
Harvest (June)	1	Custom					
Haul (June)	1	Custom					
Total			2.4		1.42	2.4	2.6

[a]Tandem disk.

[b]Grain drill.

Appendix A Table 7. Soybeans: Budget for one acre, small farm, Census Subregion 17, North Carolina

Item	Description	Price per unit	Amount
		(dollars)	
Soybeans	25 bu.	2.57	64.25
Variable costs			
Seed	.5 bu.	4.15	2.08
Seed treatment	1 oz. 75 percent Thiram	.30	.30
Inoculation			.22
Fertilizer	4 cwt., 0-10-20	2.30	9.20
Lime[a]	.2 ton	7.75	1.55
Insecticide	1 lb. Seven 50 percent wp	.54	.54
Tractor[b]	4.5 hrs., 31 drawbar hp	.50	2.25
Combining	Custom, one acre	8.75	8.75
Hauling	Custom, per bu.	.05	1.25
Total			26.14
Annual ownership costs of other machinery			1.43
Total costs (except labor)			27.56
Returns			36.69

[a]1 ton every 5 years.

[b]For the average farm a 42-drawbar hp tractor is used with variable costs of $.71 per hour or $3.20 per acre. Returns are lowered to $35.74 per acre.

Appendix A Table 8. Soybeans: Labor and machinery budget, one acre, small farm, Census Subregion 17, North Carolina

Operation and date	Times over	Machinery				31 draw-bar hp tractor use	Operator labor
		Size	Use	Annual ownership costs			
				Per hour	Per acre		
			(hours)	(dollars)		(hours)	(hours)
Break land (March)	1	3-14"	1.1	.46	.51	1.1	1.1
Disking (April)	1	7'[a]	.7	.30	.21	.7	.7
Harrowing (May)	1	9'[b]	.4	.09	.04	.4	.4
Plant and fertilize (May)	1	2 row	.6	.58	.35	.6	1.0
Cultivate (May)	1	2 row	.7	.19	.13	.7	.7
Cultivate (June)	1	2 row	.7	.19	.13	.7	.7
Spraying (August)	1	4 row	.3	.21	.06	.3	.4
Combining (Oct.)	1	Custom					
Hauling (Oct.)	1	Custom					
Total			4.5		1.43	4.5	5.0

[a]Tandem disk.

[b]Section harrow.

Appendix A Table 9. Changes in soybean and grain budgets for medium and large farms eliminating custom harvesting

Item	Soybeans	Corn	Blueboy wheat
	(dollars per acre)		
Returns for 1 acre with 42 drawbar hp tractor omitting custom harvesting	45.74	67.24	47.88
Variable costs of harvesting[a]	3.34	4.41	3.86
Annual ownership costs of harvesting machinery[a]	5.87	9.64	7.36
Returns for 1 acre to be entered on tableau	36.53	53.19	36.66

[a]Source: Appendix A table 10.

Appendix A Table 10. Labor and machinery budget for harvesting soybeans, corn and Blueboy wheat, medium and large farms

Crop and operation	Machinery						Labor	
	Size	Use	Annual ownership costs		Variable costs			
			Per hour	Per acre	Per hour	Per acre	Operator	Hired
		(hours)	(dollars)				(hours)	
Soybeans								
Combining (Oct.)	10' SP	.50	5.98	2.99	2.08	1.04	.5	
Hauling (Oct).	1 1/2 ton truck	1.50	1.92	2.88	1.53	2.30	1.0	1.5
Total				5.87		3.34	1.5	1.5
Preharvest labor							5.0	
Total labor							6.5	1.5
Corn								
Harvest (Oct.)	2-row picker sheller	.80	7.72	6.18	2.08	1.66	.8	
Hauling (Oct.)	1 1/2 ton truck	1.80	1.92	3.46	1.53	2.75	1.0	1.8
Total				9.64		4.41	1.8	1.8
Preharvest labor							5.2	
Total labor							7.0	1.8
Blueboy wheat								
Combining (June)	10' SP	.75	5.98	4.48	2.08	1.56	.75	
Hauling (June)	1 1/2 ton truck	1.50	1.92	2.88	1.53	2.30	1.00	1.5
Total				7.36		3.86	1.75	1.5
Preharvest labor							2.60	
Total labor							4.35	1.5

Appendix B

Linear Programming Models

Four linear programming models were constructed--one for each size of farm analyzed. The programming matrices were very similar for each size of farm, although there were minor differences between the models for the two smallest and the two largest farms. The restriction columns differed among farm sizes only in the first two elements, acres of cropland and tobacco poundage quota, and in the number of row entries with zero restrictions. The basic model contained activities for producing corn, soybeans, wheat, and tobacco; eight activities for harvesting, curing, and marketing tobacco; a tractor activity; and nine labor hiring activities--one each for tobacco production labor and for the eight tobacco harvesting, curing, and marketing systems (table 1).

The model for the average farm contained the following changes from the small farm model. One row and one column were added to allow for a larger 42 DHP tractor in addition to the tractor on the small farm. The 42 DHP tractor was used exclusively in all crops except tobacco and was used to prepare the tobacco land for planting and as a second tractor during tobacco harvest. Therefore, the 31 DHP tractor row had less entries than in the small farm model. The 42 DHP tractor column was identical to that for the smaller tractor except that costs were $610.24 per year. Also the cropland acres and tobacco poundage quota elements were raised to 69.6 and 18,641, respectively, in the restriction column. The objective functions for the average farm differed slightly from those for the small farm because the coefficients for those activities that used the large tractor were changed by the amount of the increased operating cost of the large tractor.

For medium farms all the operator and hence hired labor coefficients were changed except for tobacco production. The harvesting operations for corn, soybeans, and wheat were assumed to be done by the operator with his own equipment rather than custom hired. Thus, one man was hired to help the operator during harvest which required the addition of three rows and three columns to the model. For the eight tobacco harvesting,

Appendix B Table 1. Linear programming model for small tobacco farm, Census Subregion 17, North Carolina

Row name	Restrictions	Corn	Soybeans	Wheat	Tobacco production	Tobacco harvesting systems using conventional barns: Hand harvesting	Tying machine	Priming aide	Priming aide and tying machine	Self-propelled priming aide	Bulk tobacco harvesting systems: Hand harvesting	Priming aide	Mechanical harvester	Fixed costs 31 DHP tractor	Hired labor for tobacco production	Hired labor for harvesting systems using conventional barns: Hand harvesting	Tying machine	Priming aide	Priming aide and tying machine	Self-propelled priming aide	Hired labor for bulk harvesting systems: Hand harvesting	Priming aide	Mechanical harvester
Cropland	30.1≥	1.0	1.0	1.0	1.25																		
Tobacco poundage quota	10614.0≥				2010.0																		
Total operator labor	2818.0≥	5.2	5.0	2.6	38.5	26.4	26.4	27.4	27.0	26.3	26.3	27.1	25.6		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
January-March operator labor	608.0≥		1.1		14.0										0.00524								
April-May operator labor	468.0≥	4.5	2.8												0.02543								
June operator labor	260.0≥		0.7		14.9										0.00970								
July operator labor	260.0≥				6.0	13.2	13.2	13.9	13.6	13.1	13.1	13.7	12.7		0.00963	0.027475	0.026260	0.025435	0.026525	0.024875	0.029185	0.029015	0.02001
August operator labor	260.0≥		0.4			7.1	7.1	7.4	7.3	7.1	7.1	7.3	6.8			0.01813	0.018435	0.01864	0.018365	0.01878	0.0177	0.017745	0.019995
September operator labor	260.0≥			1.1	1.8	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3			0.004395	0.005305	0.005925	0.00511	0.00634	0.003115	0.00324	0.009995
October operator labor	260.0≥			1.5	1.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8										
November-December operator labor	442.0≥	0.7																					
Total hired labor	0≤				76.3	228.8	156.5	169.6	162.5	158.5	105.2	101.2	69.8										
Hired labor for tobacco production	0≥				76.3										-1.0								
Hired labor for hand harvesting, conventional curing	0≥					228.8										-1.0							
Hired labor for tying machine conventional curing	0≥						156.5										-1.0						
Hired labor for priming aide, conventional curing	0≥							169.6										-1.0					
Hired labor for priming aide and tying machine conventional curing	0≥								162.5										-1.0				
Hired labor for self-propelled priming aide, conventional curing	0≥									158.5										-1.0			
Hired labor for hand harvesting, bulk curing	0≥										105.2										-1.0		
Hired labor for priming aide, bulk curing	0≥											101.2										-1.0	
Hired labor for mechanical harvester bulk curing	0≥												69.8										-1.0
Tobacco production transfer row	0≥				-1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0										
31DHP tractor	0≥	4.5	4.5	2.4	22.6	23.1	23.1	25.2	24.4	13.8	23.0	24.7	13.1	800.0									
Short-run objective function		-49.32	-36.69	-37.88	146.01	-1146.17	-1080.75	-1119.39	-1057.27	-1045.94	-949.42	-870.87	-401.54	497.16	0.90	0.94	0.99	0.98	0.99	0.93	1.06	1.07	1.04
Long-run objective function		-49.32	-36.69	-37.88	146.01	-1097.22	-1031.80	-1070.44	-1008.32	- 996.99	-949.42	-870.87	-401.54	497.16	0.90	0.94	0.99	0.98	0.99	0.93	1.06	1.07	1.04

curing, and marketing activities, the amount of operator labor was lowered to 13.3 hours per acre for each system. The 13.3 hours were divided as follows: July, 4.5 hours; August, 2.7 hours; September, 3.3 hours, and October, 2.8 hours. Therefore, the total labor hours hired per acre was raised by an amount corresponding to the reduction in operator labor for each activity. In addition, the operator supervisory coefficients for hired labor had to be recomputed for the various monthly time periods. Because more labor was hired, the weighted wage rates in the objective functions were altered slightly. The acres of cropland and tobacco poundage quotas in the restrictions were raised to 143.2 and 31,872, respectively. No other changes were made in the average farm model.

For the large farm, the operator labor in the tobacco production activity was lowered to 18.1 hours per acre with a corresponding increase in the hours of labor hired. New coefficients were thus computed for the labor hiring activity for tobacco production to reflect changes in operator supervisory time per month and the weighted wage. The restrictions column was modified to include 369.6 acres of cropland and 64,726 pounds of tobacco quota. Also a curing labor activity was included to allow the operator to hire someone to cure tobacco if his time became too restricted with 32.20 acres of tobacco and 320 acres of corn. No other changes were made in the medium farm model.

Appendix C

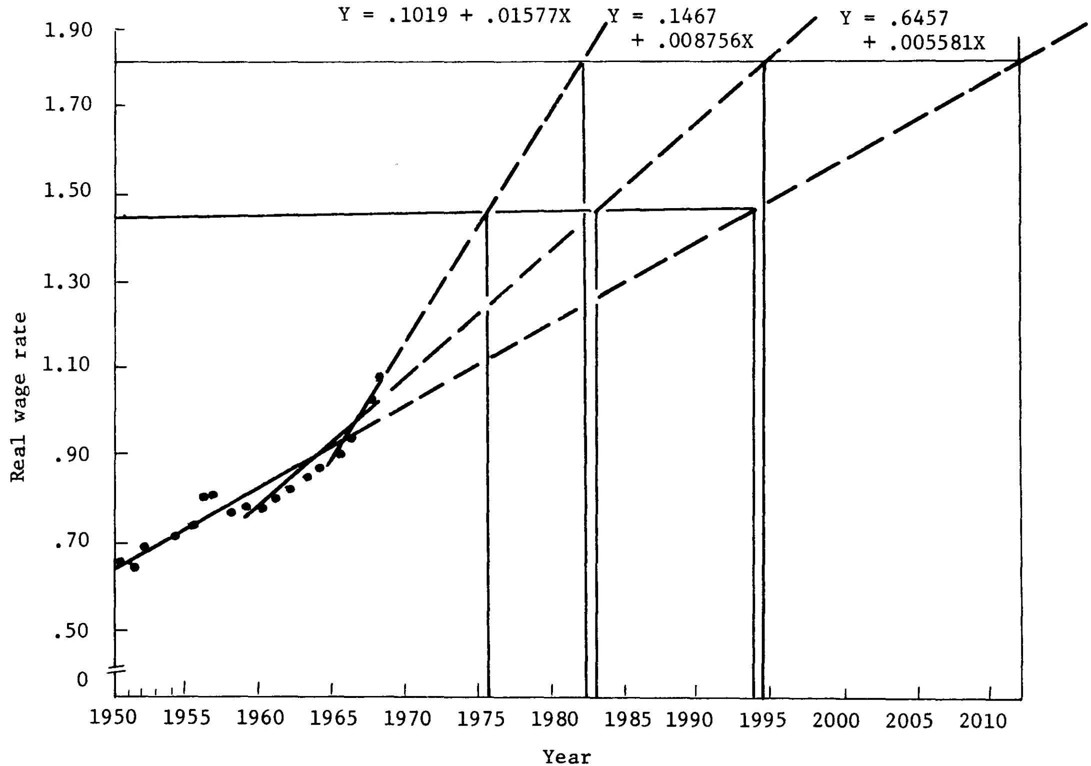
Wage Rate Projections

This section contains the wage rate projections made for farm labor. In making the projections, data on money wages paid North Carolina farm laborers without room and board were collected for the period 1950-1968 and deflated by the index of prices paid by farmers for all inputs, *i.e.*, the Parity Index, to change the wages to real terms based on two sets of data: 1910-14 dollars and 1967 dollars (Appendix C, table 1). The real wage data in 1967 dollars were plotted against time and three sets of projections were made (Appendix C, figure 1). The regression for the entire series of data shows a rise in the real wage rate of .56 cents per hour per year. The slope of the line fitted to the last 10 observations is .88 cents per hour per year, while that for the last 5 years is 1.58 cents per hour per year. All three b coefficients were significant (Appendix C, table 2). Obviously projections based on the regression for the last 5 years are the most optimistic and hence the most favorable to the adoption of the mechanical harvester. For if wages rise at a slower rate, it will take longer for the harvester to become profitable.

Appendix C Table 1. Wages paid farm labor in North Carolina without room and board from 1950-1968[a]

Year	Money wage rate	Parity index	Real wage rate	
			1910-14	1967
	(dols. per hour)	(1910-14 = 100)	(dols. per hour)	
1950	.49	256	.1914	.6546
1951	.54	282	.1914	.6546
1952	.58	287	.2021	.6912
1953	.59	277	.2130	.7285
1954	.59	278	.2122	.7257
1955	.60	276	.2174	.7435
1956	.66	278	.2374	.8119
1957	.68	287	.2369	.8102
1958	.67	294	.2279	.7794
1959	.70	298	.2349	.8034
1960	.70	300	.2333	.7979
1961	.72	302	.2384	.8153
1962	.75	307	.2443	.8355
1963	.78	312	.2500	.8550
1964	.80	313	.2556	.8741
1965	.85	321	.2648	.9056
1966	.92	334	.2754	.9419
1967	1.01	342	.2953	1.0100
1968	1.13	354	.3192	1.0917

[a]Source: U. S. Department of Agriculture (1954, 1962, 1967c, 1969).



Appendix C Figure 1. Real wages in 1967 dollars paid for North Carolina farm labor 1950-68 and projections to specified real wage rates

Appendix C Table 2. Regressions fitted to three sets of real wage data for North Carolina farm labor

Data set	Regression coefficient and computed T-value (change in real wage, cents per year)	Intercept value	R^2
1950-1968	.005581 (11.743)**	.6457	.89
1959-1968	.008756 (7.725)**	.1467	.88
1964-1968	.01577 (8.231)**	.1019	.96

**Significant at .01 level.

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