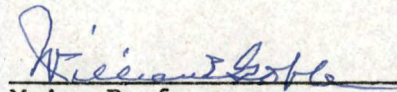


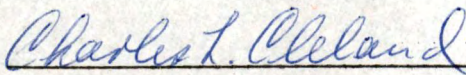
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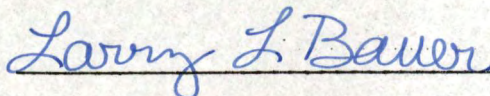
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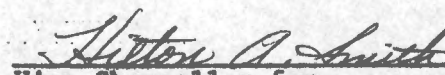

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recommend its acceptance:





Accepted for the Council:


Vice Chancellor for
Graduate Studies and Research

MECHANICAL VERSUS MANUAL HARVESTING COSTS
OF SOUTHERN PEAS IN WEST TENNESSEE

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Carlton Joe McKenzie

March 1969

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ABSTRACT

The sharp increase in acreage of Southern peas and increasing shortage of farm labor have increased the need for a shift from manual to mechanical harvesting. Mechanical combines and complementary equipment require large capital investments. The producer and processor need information to compare manual and mechanical harvesting costs at different levels of output in Tennessee. The specific objectives of this study were:

1. To determine the input-output coefficients for harvesting Southern peas manually and mechanically.
2. To estimate the fixed, variable, and total unit costs of harvesting Southern peas manually and mechanically, and to determine the acreage and volume necessary for mechanical harvesting to be profitable.
3. To determine harvesting costs when mechanical harvesters were used at maximum and less than maximum capacity.
4. To ascertain harvesting costs with 10, 20, and 30 percent losses with the mechanical harvester.

Time and production studies were made with 282 manual harvesters, nine combines, and three swathers. Farms studied for manual harvesting were randomly selected from planting schedules provided by the local processing plant. Total costs per acre to harvest Southern peas mechanically were related to yield per acre, output per hour, length of

the harvest season, the depreciation period, and annual acreage harvested. Average output per man-hour for hand-picked peas was 28.18 pounds (unshelled) or 16.9 pounds (shelled) at a 60 percent shell-out. The mobile viner averaged 387.54 pounds (shelled) per hour (based on total field hours). The mobile viner's output per man-hour was 23 times more than a person harvesting manually.

For manual harvesting fixed costs were \$8.12 per acre. Variable costs were \$71.64 (assuming 2,000 pounds of unshelled peas per acre), and total costs were \$79.76 per acre. Annual fixed costs for one combine with 5- and 10-year depreciation schedules were \$6,207.01 and \$5,346.43, respectively, and variable costs were \$11.44 per hour.

Assuming an output rate of 387.54 pounds (shelled) per hour for the combine, a 500-hour season, and a 5- and 10-year depreciation period, mechanical harvesting was more expensive than the manual method (\$79.76 per ton) for both the 5- and 10-year depreciation period for one to 11 combines. When the season length was 750 hours, mechanical harvesting costs were equivalent to the manual method when 345 tons were harvested annually. When 400 and 500 tons were harvested annually, costs per ton declined to \$72.38 and \$70.35, respectively. With a depreciation period of 10 years, hand and machine harvesting costs were the same when 300 tons were harvested annually. When 400 and 500 tons were harvested annually, there were savings of \$12.20 and \$14.34 per ton, respectively, by harvesting mechanically.

Hand and machine harvesting costs for only one combine with a 5- and 10-year depreciation period, and 400 pounds output per hour, were the same when 134 and 118 tons, respectively, were harvested.

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CHAPTER I

INTRODUCTION

I. THE PROBLEM AND IMPORTANCE OF THE STUDY

Southern peas have consistently increased as an agricultural enterprise in West Tennessee since 1940. Although Southern peas are not considered a major agricultural crop in Tennessee, there has been a sharp increase in acreage during the last 25 years. From 1954 to 1964, the acreage of Southern peas grown for processing in Tennessee increased from 1,604 to 11,865 acres, respectively, an increase of 739.7 percent. The value of the average annual production for the period 1964-68 was approximately \$1,210,000. The 1964 crop was grown on 1,552 farms with an average of 7.64 acres per farm.¹

All Southern peas grown for processing in West Tennessee in 1967-68 were grown by written contract with the processor. Of the total farms producing Southern peas in 1964, 38.7 percent of them grew the crop under contract or agreement.²

Tennessee ranked third nationally in 1964 from the standpoint of the acreage of Southern peas. Texas led the nation in acreage and Georgia was second (Table I). Only 12 states produced Southern peas in 1964.

¹United States Bureau of the Census, United States Census of Agriculture: 1964. Tennessee (Washington: Government Printing Office, 1967), p. 17.

²Ibid., p. 35.

TABLE I
ACREAGES OF SOUTHERN PEAS, BY STATE,
FOR THE 1954 AND 1964 CENSUS

State	Acreage Produced		Change 1954-64 (acres)	Percent Change 1954-64
	1954	1964		
Texas	30,380	27,606	- 2,774	- 9.1
Georgia	28,570	22,194	- 6,376	- 22.3
Tennessee	1,604	11,865	10,261	739.7
Alabama	11,145	8,059	- 3,086	- 27.6
Florida	10,149	6,010	- 4,139	- 40.7
Mississippi	6,131	2,685	- 3,446	- 56.2
Arkansas	1,598	2,070	472	29.5
South Carolina	1,757	1,822	65	3.6
Louisiana	2,694	1,744	- 950	- 35.2
Oklahoma	1,413	1,616	203	14.3
North Carolina	541	1,282	741	136.9
Virginia	1,234	386	- 848	- 68.7

Source: United States Bureau of the Census. United States Census of Agriculture: 1964. Tennessee, (Washington: Government Printing Office, 1967).

In 1964, 97.5 percent of the Southern peas in Tennessee was grown in the Western part of the state and 98.0 percent of the state's total production was grown in counties that grew at least 25 acres.³ Tennessee's ten major producing counties include: Fayette, Haywood, Madison, Hardeman, Shelby, Crockett, Gibson, Tipton, Weakley, and Lauderdale. These counties produced 96.4 percent of the state's total crop of Southern peas in 1964. Figure 1 shows the location of the major counties producing Southern peas in Tennessee and the acreage produced in these counties.

Southern peas grown on the family farm were usually harvested manually. Sufficient labor exists in the production area to allow farmers to produce only small acreages of Southern peas. If large acreages are produced, the only alternative would be to harvest the crop mechanically. The existing problem is to determine at what acreage it would be economical to change from manual harvest of Southern peas to mechanical harvest.

Among the variables affecting the decision of a producer to purchase a Southern pea combine, farm size in the commercial area was very important to determine whether potential production would be profitable. Table II reveals that 70.8 percent of the total number of farms growing Southern peas in the top ten counties in 1964 contained less than 100 acres per farm. Over 50 percent of the farms had less than 50 acres. Only 4.79 percent of the farms in the Southern pea producing area of West Tennessee had acreages greater than 500.

³Ibid., pp. 404-13.

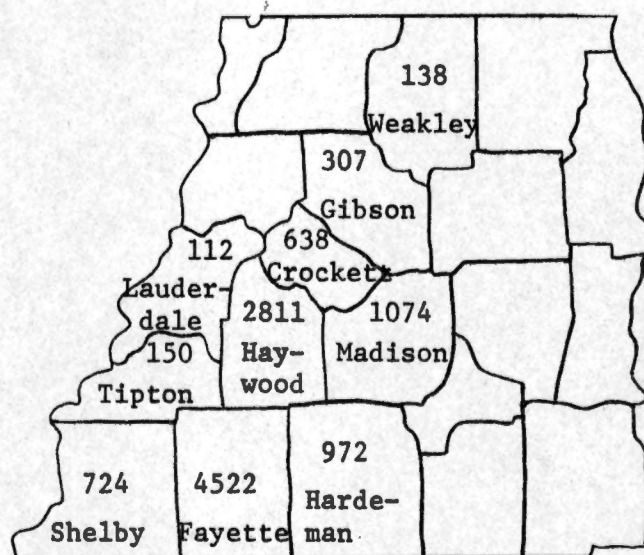


Figure 1. Commercial acreage of Southern peas produced in ten major counties in Tennessee.

Source: United States Bureau of the Census, United States Census of Agriculture: 1964. Tennessee (Washington: Government Printing Office, 1967), pp. 404-13.

TABLE II
 SIZE OF FARM DISTRIBUTION AND ACRES OF CROPLAND FOR THE
 TOP TEN SOUTHERN PEA PRODUCING COUNTIES,
 WEST TENNESSEE, 1964^a

Size and Distri- bution (acres)	Number of Farms ^b	Percent of Total Farms	Acres of Crop- land	Percent of Total Area Crop- land	Average Number of Crop- land Acres Per Farm
0 - 49	11,298	53.36	136,680	12.73	12.70
50 - 99	3,687	17.42	111,795	10.41	27.53
100 - 179	2,640	12.47	153,035	14.25	50.56
180 - 259	1,179	5.57	109,272	10.17	86.52
260 - 499	1,354	6.39	211,307	19.68	153.24
500 - 999	690	3.26	187,697	17.47	296.79
Over 1,000	323	1.53	164,282	15.29	579.97
Area Total	21,171	100.00	1,074,068	100.00	50.73

^aGiven by counties in Appendix Table XX.

^bThe word "farm" is to be interpreted as all land on which agricultural operations were conducted in 1964 under the control or supervision of one person or partnership. Less than 10 acres were counted as farms if agricultural sales were greater than \$250. Greater than 10 acres were counted as farms if agricultural sales amounted to at least \$50.

Source: United States Bureau of the Census. United States Census of Agriculture: 1964. Tennessee, (Washington: Government Printing Office, 1967), pp. 275-83.

It was found that a minimum of 100 acres of Southern peas was required to be under contract on a farm before the processor would agree to harvest the crop mechanically. However, in a custom harvesting operation, it is hypothesized that smaller acreages could be harvested mechanically. Table XX of the Appendix shows the size distribution of farms in the study area by counties with the number of farms and acres of cropland.

Another important variable related to the harvest of Southern peas manually or mechanically is the characteristics of available cropland in the surrounding area. Total cropland for the 21 West Tennessee counties in the study area contained 2,868,798 acres in 1964, a decrease of 4 percent from 1959.⁴ The top ten producing counties had 1,706,165 acres of total cropland in 1964 of which 0.6 percent was devoted to the production of Southern peas. From the standpoint of cropland harvested rather than total cropland, the acreage of Southern peas was 1.1 percent of the 1,027,068 acres in the top ten counties.⁵

In growing any agricultural commodity, irrespective of the harvesting method, a major consideration in the choice of a crop is whether the crop may be marketed easily and profitably. There were 15 vegetable processing plants located in Tennessee in 1968 (Figure 2). Seven of these plants processed by canning and eight processed by freezing. Seven

⁴Total cropland includes: cropland harvested, cropland used only for pasture, and cropland not harvested and not pastured.

⁵United States Census of Agriculture: 1964. Tennessee, pp. 275-83.

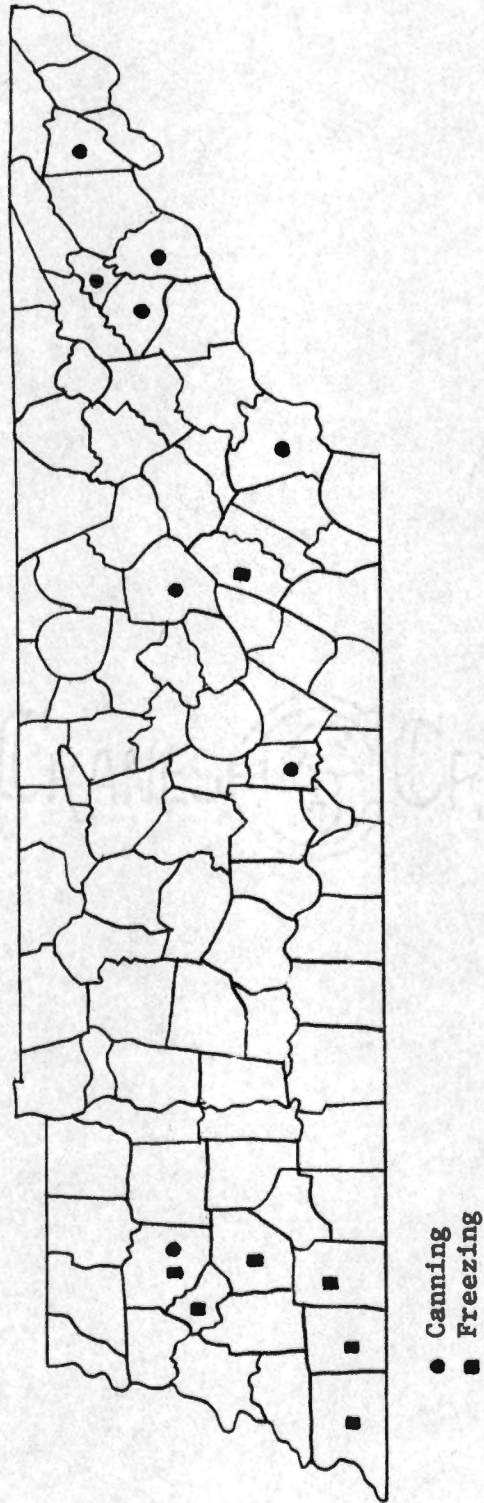


Figure 2. Vegetable processing plants in Tennessee, 1968.

of the freezing operations were located in the western part of the state. Outlets for the Southern pea acreage in the study area included processing plants at Bells, Bolivar, Memphis, and Rossville with assembly stations at Brownsville, Danceyville, and Humboldt.

Labor wage rates for persons to harvest peas have increased substantially in recent years (Figure 3). There has also been some difficulty in obtaining sufficient numbers of pickers at the time peas were ready to harvest and, in many instances, shortage of labor has become the limiting factor in the enlargement of Southern pea acreages on individual farms.

Introduction of the FMC (Food Machinery and Chemical Corporation) combines and similar types of mechanical harvesters have given the farmer an alternative method of harvesting Southern peas. Manpower requirements and the time required to harvest acreages of peas have been reduced considerably by mechanical harvesting. Harvesting mechanically may offer substantial savings compared with harvesting manually but the use of mechanical combines requires a large capital investment.

II. OBJECTIVES

The general objective of this study was to assist the grower and processor of Southern peas to choose the most economical harvesting method. The specific objectives of this study were:

1. To determine the input-output coefficients for harvesting Southern peas manually and mechanically.
2. To estimate the fixed, variable, and total unit costs of harvesting Southern peas manually and mechanically, and to

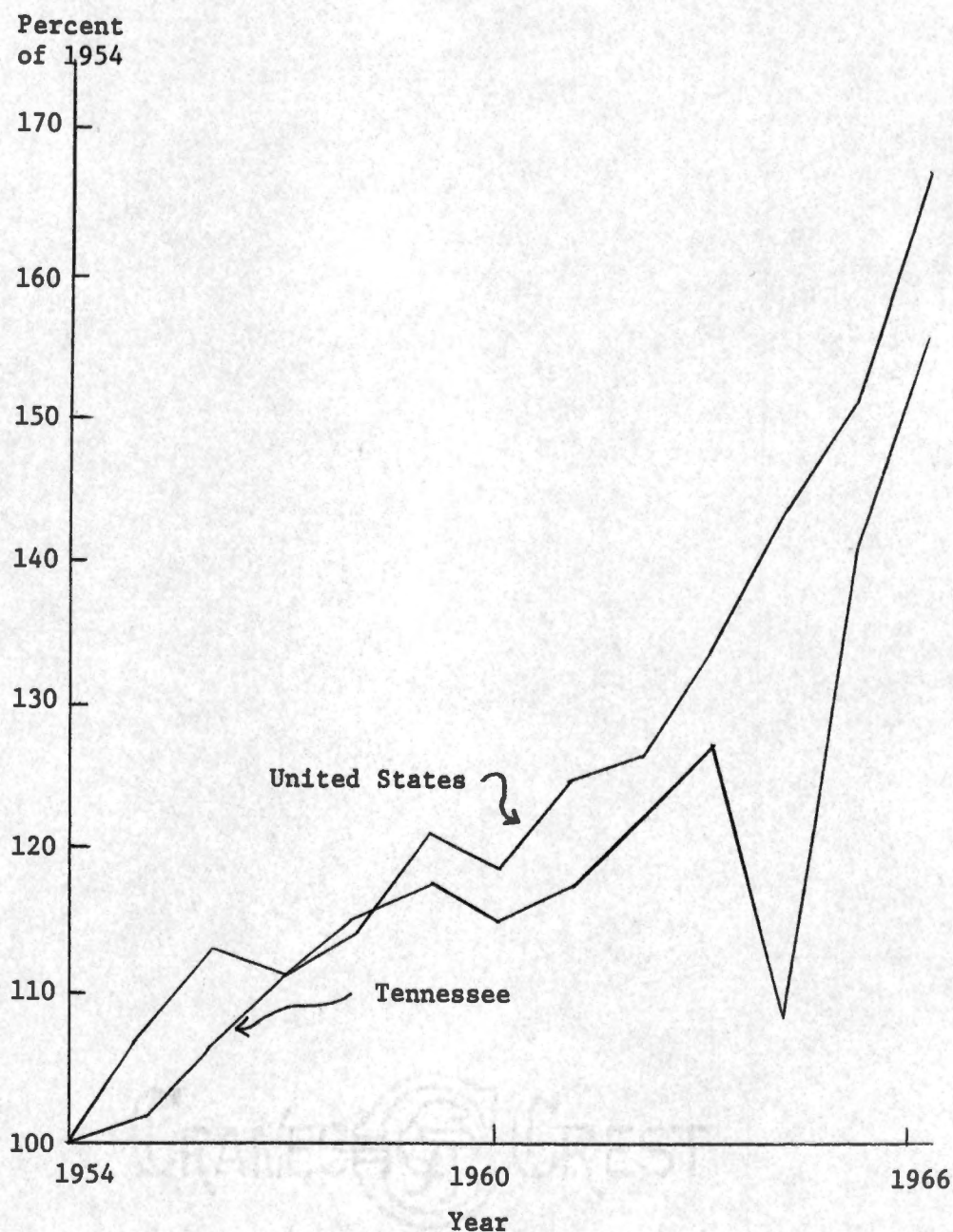


Figure 3. Farm wage rates, 1954-66, as a percent of 1954.

Source: United States Department of Agriculture, Handbook of Agricultural Charts, 1967, Agricultural Handbook No. 348 (Washington: Government Printing Office, 1967), p. 17.

determine the acreage and volume necessary for mechanical harvesting to be profitable.

3. To determine harvesting costs when mechanical harvesters were used at maximum and less than maximum capacity.
4. To ascertain harvesting costs with 10, 20, and 30 percent losses with the mechanical harvester.

III. OPERATIONS IN HARVESTING

Figure 4 gives a flow chart of the operations in harvesting Southern peas manually and mechanically. In the manual harvesting operation, the field forman collected his workers from the surrounding area (provided they did not live on the farm) and delivered them to the field that was to be harvested. The field foreman (usually the farm owner) performed the weighing operations and paid each worker at each weigh period (on some family operations, weights were not kept). One person was usually designated to empty the sacks. Loading the peas in the field was done exclusively by hand and bulk-dumped into a vehicle in which they were to be transported to the receiving station. The farmer provided return transportation for the workers to their homes in most cases. Some instances were observed where the pickers provided their own means of transportation.

At the receiving station the peas and transportation vehicle were weighed as one unit. The seller then unloaded the peas onto an electrically operated conveyor that shifted the peas into a truck or trailer in which they were transported to the processing plant. One man

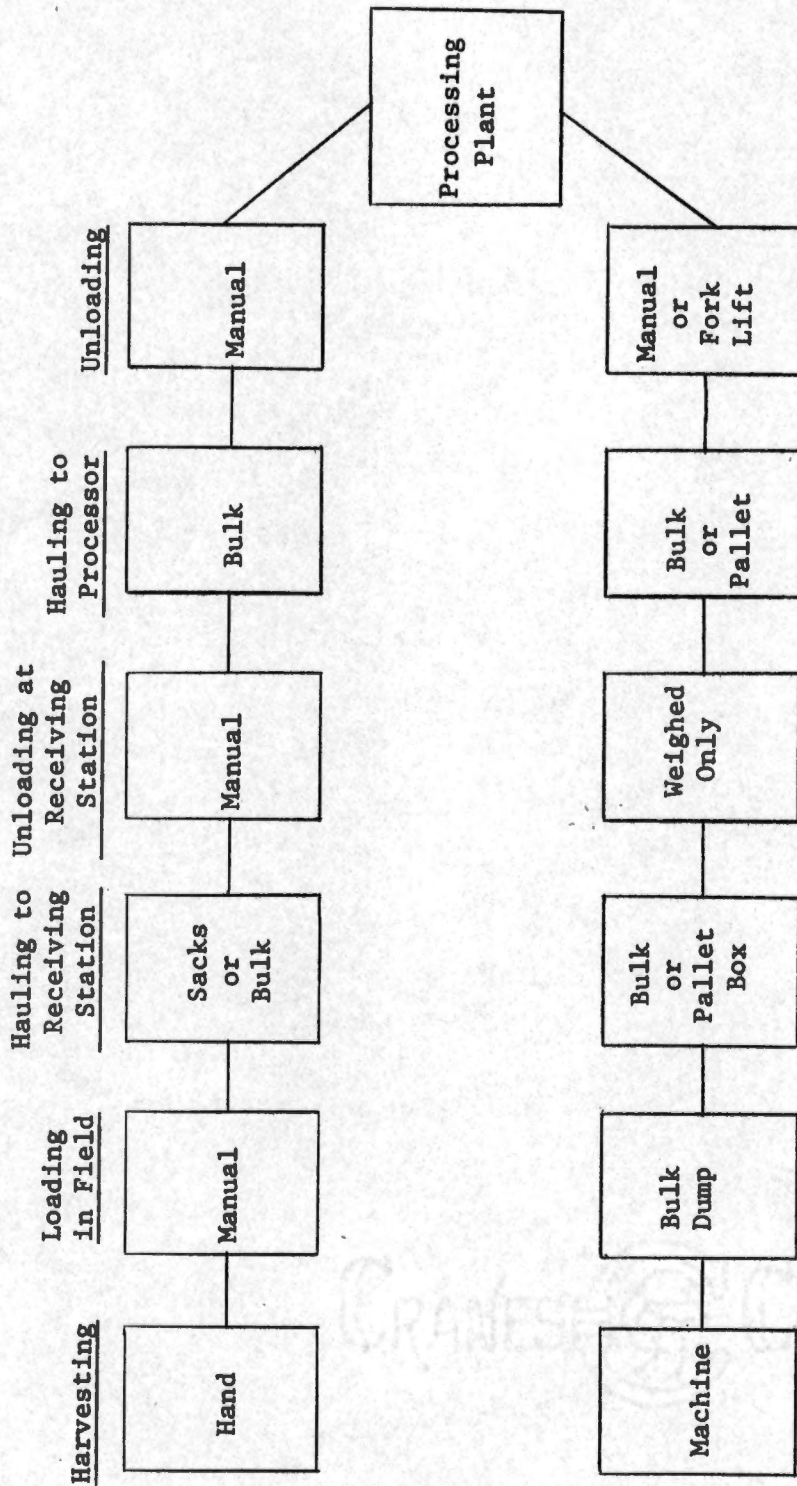


Figure 4. Alternative methods of harvesting, loading, transporting, and unloading Southern peas in West Tennessee, 1968.

usually unloaded the vehicle. Two additional men were required by the processor to operate the conveyor and keep it loaded and also keep empty vehicles in their proper places. At no time were hand-picked peas hauled directly to the processing plant. Any peas spilled on the ground by the grower were picked up before he left the conveyor. Upon leaving the conveyor, the empty vehicle was weighed and the seller was paid for his load of peas.

From the receiving station hand picked peas were transported to the processing plant by tractor and trailer or by truck, depending upon the distance of the receiving station from the processing plant. At the processing plant the peas were unloaded manually (usually four men per trailer). Manual harvesting costs for the farmer did not include any additional costs beyond those incurred at the receiving station.

Harvesting of Southern peas mechanically in West Tennessee was done with the FMC combine. To harvest peas with this machine, they first were cut with a swather which cut three or four rows simultaneously and placed the peas in a windrow. The combine then harvested the peas and hydraulically dumped them into bulk truck beds for transport to the receiving station. All commercial operations observed were bulk-dumped from the combine. At the receiving station the peas were weighed and hauled directly to the processing plant where they were unloaded manually.

IV. PROCEDURE

Time and production studies were done on the farms of 282 producers of Southern peas in Crockett, Fayette, Hardeman, Haywood and

Madison counties to obtain input-output data for the hand harvest operation. In the study of manual harvesting, names of all farmers harvesting peas manually under contract were obtained from each receiving station. From a list of growers under contract, growers were chosen at random according to planting date schedules. If a selected grower was not harvesting on the day he was contacted, the interviewer proceeded to the next farm on the list. Workers were observed for one day on each farm during which time the interviewer kept records of weights and timed by stop watch the various operations involved in manual harvest. At the receiving station, the unloading time was determined for hand-picked peas.

Information was obtained on nine mechanical harvesters by time and production studies of machines in operation. Combines were observed for 72.23 hours. Cost information was obtained from records at the plant, and from the foremen, drivers, and mechanics. Where more combines were operating simultaneously than the interviewer could accurately observe, combines were numbered and selected at random.

Only one swather, which cut the pea vines and placed them in a windrow, was required for each group of four machines. Time and motion studies were made on those swathers in operation during the study.

In calculating the pea-vine ratio (the ratio of shelled pea weight to the sum of pea + vine + hull weight), representative samples were measured off for each field studied. The rows in the field plot were numbered and equal intervals of each group of three rows were sampled at random. The vines with the peas were cut at a height

equivalent to the swather height of cut. Peas were picked off the vines and weighed separately. All vines were weighed 15 minutes after cutting to allow equivalent evaporation. The plot was harvested separately from the rest of the field in order to obtain an accurate yield per acre for the test plot. Samples from each test plot were shipped by air to The University of Tennessee where they were shelled and weighed.

V. REVIEW OF LITERATURE

In a period of about 15 years, the method of harvesting Southern peas has developed from an entirely manual operation to one with a large percentage of mechanical harvesting.

An intermediate step between manual harvesting and the green pea combine, involved the use of the stationary viner. The stationary viner, used by Gerber and others, involved the following procedure: (1) cutting the peas; (2) hauling peas and vines to the vining station (four to eight men required per viner); (3) disposal of vines; and (4) trucking shelled peas to the processing plant.⁶ The mobile viner, sometimes called the pea combine, began to replace the stationary viner in the early 1950's. The experimental models pulled the vines from the ground rather than have a swather cut and windrow the crop ahead of the shelling operation.

In 1957, the combine was manufactured by the following companies: (1) Food Machinery Company; (2) Scott; and (3) Frank Hamacheck Machine Company.⁷

⁶"Gerber's Experience with the Green Pea Combine," The Canning Trade, LXXIV (January 14, 1952), p. 76.

⁷"Experiments with Mobile Viners Point the Way to Lower Labor Costs and Faster Handling," Quick Frozen Foods, XIX (June, 1957), p. 52.

By 1961, the Georgia Experiment Station had designed, constructed, and tested four small and relatively inexpensive mechanical harvesters for Southern peas. However, none of them had a satisfactory cleaning mechanism.⁸ In the same year, Georgia Experiment Station found that the average Southern pea producer spent \$25 per acre for production expenses, \$16 per acre for picking, and received a net return to land and management of \$23 per acre.⁹

In a study conducted by the University of Delaware in 1962, it was concluded that the lowest cost method for harvesting peas (green) was the converted mobile viner followed by the commercially-built mobile viner.¹⁰ The study revealed that \$19 per ton of peas could be saved by using the commercial mobile viner at capacity (35 acres at 1.5 tons of green peas per acre) when compared with a double stationary viner with a hand feeder. Field losses from mobile viners were found to be relatively small (2 or 3 percent).

In 1963, a study conducted at the Florida Agricultural Experiment Station showed that manual pre-harvest labor requirements were 18.2 man-hours per acre plus 18 tractor-hours per acre. The harvesting operation

⁸Mechanical Harvesters for Southern Peas, Georgia Agricultural Experiment Station, Circular N. S. 36 (Georgia, 1963), p. 18.

⁹The Economies of Producing Southern Peas for Canning in Georgia, Georgia Agricultural Experiment Station, Mimeograph Series N. S. 129 (Georgia, 1961), p. 11.

¹⁰Harvesting Peas and Lima Beans, University of Delaware, Agricultural Experiment Station, Circular 32 (Delaware, 1962), p. 3.

required 81.8 man-hours per acre, no tractor-hours, and 2.9 man-hours per acre for transportation to the market.¹¹

Cascade Frozen Food Company reported in 1963, that by using the green pea combine instead of the stationary viner, its pea pack quality could be increased by at least 10 percent.¹² This increase in quality was largely the result of decreased time required between the harvest operation and actual processing at the plant. Cascade's report necessitates an explanatory comment. No mechanical shelling device has yet been developed which does not cause some bruising of the product. It therefore should be emphasized that for processing, blanching should follow mechanical shelling as quickly as feasible in order to arrest the post harvest deterioration which begins immediately as a result of the combined effects of injury, oxidation, enzymatic activity, and growth of micro-organisms.

Any Southern pea variety to be commercially successful for processing, must be capable of being machine harvested and shelled. By 1964, plant breeders had begun programs to try to develop a variety of Southern peas adapted to mechanical harvest. Field tests of the Arkansas Agricultural Experiment Station pointed out the need for a distinct bush-type pea¹³ which resulted in the incorporation of this characteristic

¹¹Labor and Material Requirements for Vegetable Crops, Florida Agricultural Experiment Station, Bulletin 660 (Florida, 1963), pp. 76-78.

¹²"Mobile Pea Viners Provide Cascade with Increased Speed, Efficiency," Quick Frozen Foods, XXVI (August, 1963), p. 322.

¹³F. L. Bailey and A. A. Kattan, "Factors Affecting Yield of Once-Over-Harvested Southern Peas," Arkansas Farm Research, XIII (January, 1964), p. 9.

into the Blackeye and Cream varieties with efforts being made toward the Crowder and Purple Hull groups. Whether peas were mechanically or manually harvested, they needed to have a concentrated maturity span, high positioning of the pods on the plant, and a high yield capacity. Floricream,¹⁴ developed by Lorz and Halsey of the Florida Agricultural Experiment Station, was perhaps, as determinate and had as short a maturity span as any standard cream variety available in 1964.

Maturity dates were extremely important to "once-over-harvested" crops. Bailey and Kattan, in 1964, found the critical factors of "once-over-harvested" peas to be: (1) planting date; (2) irrigation; and (3) use of the proper varieties. They hypothesized that because of the Southern pea's drought resistance, adaptation to large-scale farming operations, and low fertility needs, its production outlook was optimistic.¹⁵

A study conducted by William E. Goble and others, in 1967, revealed that the efficiency of the green pea combine was a function of its drum speed.¹⁶ Different screen combinations showed no significant difference in pounds of peas harvested. The highest amount of green peas harvested was obtained at a drum speed of 170 rpm. Trash content was found to be inversely proportional to the drum speed of the combine.

¹⁴John L. Bowers, "Breeding Southern Peas for Mechanized Harvest," Arkansas Farm Research, XIII (September-October, 1964), p. 11.

¹⁵Bailey and Kattan, loc. cit., p. 9.

¹⁶W. E. Goble and others, "Progress Report on Mechanical Harvesting of Southern Peas." Tennessee Farm and Home Science, Progress Report No. 68 (December, 1968), p. 11.

This study showed that the percentage of green peas harvested mechanically was approximately half the amount harvested manually (approximately 52 percent manually and 27 percent mechanically). When less than 50 percent of the peas were green, the grade automatically dropped to "B."

In Eastern Oregon and Washington, a study was conducted in 1967 comparing the efficiency of the green pea combine to the stationary viner. At levels of annual output above 1,800 tons, the green pea combine costs were found to be lower than the costs of the stationary viner operation. Increasing the hauling distance from the pea field to the vining station increased the cost of the stationary viner operation approximately 95 cents per ton of shelled peas for each mile beyond one mile. Decreasing the hourly output of the green pea combine reduced its comparative advantage. Labor requirements for the combine in the study area were estimated at 59 percent of those required for the stationary viner operation.¹⁷

¹⁷ Norman K. Whittlesey and Jack B. Duff, An Economic Analysis of Alternative Methods of Harvesting Green Peas in Eastern Washington and Oregon, Washington Agricultural Experiment Station, Bulletin 684 (Washington, 1967), pp. 1-2.

CHAPTER II

COSTS OF HARVESTING SOUTHERN PEAS MANUALLY

The total cost of manual harvesting of Southern peas consists of fixed costs and variable costs. Fixed costs are those costs that occur at zero levels of output and remain the same for all levels of output. Variable costs are those costs that vary with the different levels of productivity.

I. FIXED COSTS

The fixed costs for the manual harvest of Southern peas were found to be relatively small. Cost of containers was the major fixed cost. In all observations made on the manual harvest of Southern peas, sacks were used for picking containers. Due to its ease in handling, the nine foot sack was preferable. In most instances, the grower furnished the containers. In addition to container costs, fixed costs included interest, taxes, insurance, and scales.

The average price paid for a nine foot sack in 1968 was \$3.50 with an average of four sacks and four pickers being required per acre. Estimated life of the containers was two years. Multiple use of the sacks was not considered. Table III shows the annual fixed costs for containers per acre of Southern peas harvested in West Tennessee in 1968.

TABLE III
ESTIMATED ANNUAL FIXED COSTS PER ACRE FOR CONTAINERS
USED IN MANUAL HARVEST OF SOUTHERN PEAS
IN WEST TENNESSEE, 1968^a

Item	Container Cost Per Acre
Depreciation ^b	\$7.00
Interest ^c	0.84
Taxes ^d	0.14
Insurance ^e	<u>0.14</u>
Total	\$8.12

^aBased on an average cost of \$14.00 for harvesting containers with an expected life of two years (multiple use not considered).

^bBased on 50 percent of average purchase price per acre (straight line method with no salvage value).

^cBased on 6 percent of average purchase price per acre.

^dBased on 1 percent of average purchase price per acre.

^eBased on 1 percent of average purchase price per acre.

II. VARIABLE COSTS

Variable costs are a function of the volume of peas harvested, picker transportation costs, foreman (usually the farm owner or operator), and one or more persons to empty sacks and maintain records at the field.

The largest single variable cost incurred in the manual harvest operation was hired labor. Picking rates ranged from \$1.00 to \$1.50 per hundred-weight with an average rate of \$1.31 being paid on the farms observed. Average yield for hand-picked peas was approximately 1,800 pounds per acre (unshelled) in 1968.

Transportation cost for hauling workers to and from the field was an important factor in variable costs. It was a function of the distance travelled, truck size, elapsed time, and operator's wage rate. Workers usually assumed that transportation would be provided by the grower. The assumption was made that the grower would travel 10 miles to transport workers for each day of work. Most of the growers transported workers in half ton trucks at a computed cost of 13 cents per mile (includes grower's wage rate).¹⁸

The grower usually filled the position of field foreman. On most of the farms observed, he weighed the containers and paid the workers at each weigh interval. Either the foreman or one of the hired pickers emptied the sacks into the transport vehicle. In this study, the average

¹⁸ Glenn H. Glover, Cost of Farm Machinery Used for Cotton Production in Tennessee, Tennessee Agricultural Experiment Station, unpublished study (Tennessee, 1965), pp. 24-28.

farm wage rate for the area, which in 1966 was \$0.87, was charged to the foreman and the person emptying the sacks (lugger).¹⁹

The output for manual harvesting per man-hour was obtained from 266 observations. The yields ranged from 200 to 1,300 pounds of peas per acre, once over the field. An average production for all ages (ranged from 6 to 74 years with an average age of 22.65 years) was 28.18 pounds (unshelled) of peas per man-hour. Four workers per acre averaged 112.72 pounds of peas per hour of work or 908.76 pounds per eight-hour day. At a yield of 600 pounds per acre, the required harvest time was 5.32 hours (including time for breaks) or 2.66 hours per picking over the field (assuming two pickings over the field regardless of the field size or yield per acre).

Costs for transporting the peas to the receiving station were based on the assumptions that the farmer travelled at an average rate of 20 mph. and lived an average of eight miles from the receiving station. The peas were assumed to be hauled on a half ton truck. Table IV shows that the estimated total variable cost per acre (once over) to hand harvest Southern peas was \$20.77. The decreasing order of importance of the variables involved was: labor (\$7.80); transportation of workers and wages of field foreman (\$4.63 each); hauling peas to the receiving station and return home (\$2.08); transporting workers (\$1.30); and unloading peas at the receiving station (\$0.33).

¹⁹ United States Department of Agriculture, Handbook of Agricultural Charts, Agricultural Handbook No. 348 (Washington, 1967), p. 17.

TABLE IV
ESTIMATED VARIABLE COSTS PER ACRE (ONCE-OVER) FOR
SOUTHERN PEAS, WEST TENNESSEE, 1968^a

Item	Cost
Labor (pickers) ^b	\$ 7.80
Transportation (hauling pickers) ^c	1.30
Wages for field foreman ^d	4.63
Lugger ^e	4.63
Transportation to receiving station and return ^f	2.08
Unload at receiving station ^g	<u>0.33</u>
Total variable cost	<u>\$20.77</u>

^aAssumed yield of 600 pounds (unshelled) once over the field.

^bBased on \$1.30 per hundred-weight of unshelled peas.

^cBased on 10 miles travel for one day's pick-up and delivery of workers computed at 13 cents per mile.

^dCost calculated by determining the length of time required to harvest an acre with an assumed picking rate of 28.18 pounds (unshelled) per man-hour, four pickers per acre, and wage rate for the foreman set at \$0.87 per hour.

^eCalculated for one man (lugger) to empty sacks at \$0.87 per hour.

^fBased on one round trip using a half ton truck, 20 mph., and eight miles each way computed at 13 cents per mile.

^gAssumes a wage rate of \$0.87 per hour per worker, 0.135 hours to unload 600 pounds plus 0.250 hours in delay time for each trip = 0.385 hours. The unloading rate per man-hour was 4,439.35 pounds.

Time and motion studies at the receiving stations showed that an average farmer unloaded 4,439.35 pounds manually per man-hour with a hay fork. The majority of farmers used one man in the truck (half ton) to fork the peas to a conveyor belt. One man was adequate to unload half ton trucks. The unloading rate of 4,439.35 pounds per man-hour was based on the assumption that the farmer did not have to wait for other farmers to unload peas.

Table V indicates the variations in output per man-hour based upon age groups. Highest productivity was found in the age group of 30-39 years (40.6 unshelled pounds per man-hour). With the exception of the 50-59 year age group, output per man-hour changed consistently by age group. Output per man-hour decreased sharply below 10 years of age (12.3 unshelled pounds) and above 69 years of age (27.2 unshelled pounds). A 10 percent increase in yield per acre yielded a 5.24 percent increase in output per man-hour on the average of all field observations.

Appendix Table XXI shows the output per man-hour, hours per acre, and acres per hour for several combinations of yield per acre and number of pickers. Weights are expressed as pounds of unshelled peas.

A stepwise multiple regression analysis was run with output per man-hour as the dependent variable and number of hours worked, age of the worker, yield per acre, and amount of break time taken by each worker, as the independent variables. These independent variables were selected to determine if they significantly affected output per man-hour. The standard error of estimate was 13.4541. The F test showed all four variables significant at the 5 percent level. The variation of

TABLE V
 OUTPUT PER MAN-HOUR IN HARVESTING SOUTHERN PEAS,
 BY AGE GROUP, WEST TENNESSEE, 1968^a

Age group (Years)	Number of Observations	Percent of Total Observations	Average Output Per Man-Hour (Pounds) (Unshelled)
Less than 4	0	0.00	0.0
5 - 9	19	7.14	12.3
10 - 14	98	36.84	28.4
15 - 19	72	27.06	34.2
20 - 24	11	4.13	35.1
25 - 29	5	1.87	35.6
30 - 39	9	3.37	40.6
40 - 49	17	6.38	37.1
50 - 59	19	7.13	39.3
60 - 69	11	4.12	36.1
70 and over	5	1.87	27.2

^aBased on 266 field observations with varying field sizes and yields per acre.

the independent variables explained 22.63 percent of the variation in output per man-hour. The estimated equation for output per man-hour was of the form

$$Y = 32.51 + 4.42(X_1) - 3.54(X_2) + 0.28(X_3) + 0.004(X_4)$$

where:

Y = Output per man-hour

X_1 = Break time in hours

X_2 = Number of hours worked

X_3 = Age of worker in years

X_4 = Yield per acre in pounds (unshelled).

III. TOTAL COSTS

Total cost for hand-picking Southern peas is the sum of total fixed and total variable costs. The variation in harvesting costs per acre is primarily the result of changes in yield per acre.

In the models introduced in this study, an additional hired laborer is provided to weigh or empty sacks. However, in small family operations, the field foreman and lugger may be eliminated from the variable cost function since no weight records are kept. Transportation for hired labor may also be eliminated in cases where farm labor lives on the farm or is provided by the farm family. Total costs would also vary from the estimates in Table VI as the distance from the receiving station and truck size varied. Table VI indicates that total harvesting cost per acre increases as yield per acre increases but total

TABLE VI

TOTAL COST PER ACRE FOR MANUAL HARVEST OF SOUTHERN PEAS IN WEST TENNESSEE, 1968^a

Costs	Yield Per Acre ^b (Pounds-Unshelled)									
	600	1,200	1,500	1,800	2,000	2,100	2,400	2,700	3,000	
Fixed cost	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12	8.12
Variable cost: ^c										
Pickers	7.80	15.60	19.50	23.40	26.00	27.30	31.20	35.10	39.00	
Hauling pickers	2.60	2.60	2.60	2.60	5.20	5.20	5.20	5.20	5.20	
Field foreman	4.63	9.27	11.58	13.89	15.43	16.21	18.52	20.84	23.15	
Lugger	4.63	9.27	11.58	13.89	15.43	16.21	18.52	20.84	23.15	
Transport to receiving station and return	4.16	4.16	4.16	4.16	8.32	8.32	8.32	8.32	8.32	
Unloading at receiving station	0.55	0.67	0.73	0.79	1.26	1.28	1.34	1.40	1.46	
Total cost per acre	32.49	49.69	58.27	66.85	79.76	82.64	91.22	99.82	108.40	
Cost per pound	0.054	0.041	0.039	0.037	0.039	0.039	0.038	0.037	0.036	

^aBased on Tables III and IV, pages 20 and 23.^bBased on two pickings during the harvest season.^cBased on an average work day of eight hours per worker, farm wage rates at \$0.87 per hour with one foreman and one lugger, one trip to the receiving station for each day required to harvest peas, and unloading based on all trips to receiving station for each yield.

harvesting cost per pound of peas picked, decreases at first, increases, and then decreases. The rise and fall in harvesting costs per pound is explained by the fact that transportation cost for pickers and delivery of the product to the receiving station changes discretely as the number of days required to harvest the specified yield per acre changes.

Harvesting costs per acre ranged from \$32.49 to \$108.40 for total yields per acre of 600 and 3,000 pounds (unshelled), respectively. At a yield of 2,000 pounds per acre (unshelled), the cost to harvest an acre manually was \$79.76.

CHAPTER III

COST OF MECHANICALLY HARVESTING SOUTHERN PEAS

Two basic types of machines are now available to the Southern pea grower to harvest peas mechanically: (1) the self-propelled green pea combine; and (2) the tractor-drawn green pea combine.²⁰ The tractor-drawn green pea combine has an automatic levelling device that keeps the machine level on most slopes. The tractor that pulls that combine lacks such a device; consequently, harvesting operation is restrained to relatively level terrain. The tractor-drawn combine is used in the cost models developed in this study.

I. PERFORMANCE OF THE HARVESTERS

To determine the harvester performance, time and production studies were made on nine mechanical harvesters in the study area. Table VII shows that 3.16 acres could be picked per 10-hour day with an average output per combine per hour of 387.54 pounds (shelled). The maximum number of acres harvested per day would be 5.2 acres at an output per hour per combine of 638.00 pounds (shelled). Table VII reveals that actual working time was 67.39 percent of total field hours of which 6.65 percent was unloading time. The remainder of the total field hours was

²⁰By changing screen size, the green pea combine may be adapted to harvest green peas, Southern peas, and lima beans.

TABLE VII

SOUTHERN PEA HARVESTER PERFORMANCE BASED ON NINE
MACHINES, WEST TENNESSEE, 1967^a

Acres harvested per day per machine: ^b		
Breaks excluded		<u>Acres</u> 5.20
Breaks included		3.39
Breaks and service time included		3.16
Pounds of peas harvested per hour per machine		
Breaks excluded		<u>Pounds</u> 638.00
Breaks included		416.05
Breaks and service time included ^c		387.54
Time distribution per day: ^d	Percent of total <u>field hours</u>	<u>Number of hours</u>
Working time:		
Harvesting ^e	60.74	6.07
Unloading	<u>6.65</u>	<u>0.67</u>
Total	67.39	6.74
Moving time	1.78	0.18
Down time	19.76	1.98
Service time	6.85	0.68
Other time ^f	<u>4.21</u>	<u>0.42</u>
Total	32.59	3.26
Fuel and lubrication per hour:		
Gas (FMC combine)--gal. per hour		3.50
Diesel (tractor)--gal. per hour		1.00
Lubrication: Combine--20.0 percent of fuel cost per hour		
Swather--16.0 percent of fuel cost per hour		

^aBased on an average yield of 1,226.22 pounds of shelled peas per acre and an average ground speed of 76.74 fpm.

^bBased on a 10-hour day and an average yield of 1,226.22 pounds per acre.

^cService time should be included when computing output per hour even though it is usually done before harvesting can begin (due to vine dampness). Lunch time is included in this calculation.

TABLE VII (Continued)

^dComputed as a percentage of total field hours based on a 10-hour day.

^eIncludes turning time and signifies actual harvest time.

^fIncludes traffic congestion in the field, lunch breaks, and instructions from foreman.



consumed in moving time (1.78 percent), down time (19.76 percent), service time (6.85 percent), and time lost due to traffic congestion, lunch breaks, and instructions from field foreman (4.21 percent). In decreasing order of importance, Table VII shows time distribution per day as follows: (1) harvesting; (2) down time; (3) service time; (4) unloading time; (5) other time (see footnote "f" of Table VII, and (6) moving time.

Table VIII shows a breakdown of the performance of individual harvesters and groups of harvesters. Output per hour per machine ranged from 74.40 pounds to 544.51 pounds (based on total time). Picking time expressed as a percentage of total time ranged from 6.69 percent to 82.29 percent and averaged 61.06 percent for the study. Unloading time expressed as a percentage of total time ranged from 0.44 percent to 18.5 percent with an average of 6.37 percent. Other time similarly expressed ranged from 12.5 percent to 92.85 percent of total time and averaged 32.56 percent. Other time included moving time, down time, service time, traffic congestion, lunch breaks, and instructions from foreman.

Operator Competence

Information was difficult to obtain on combine efficiency as related to the driver's competence. It was the general feeling of the machine drivers, mechanics, and field supervisors that experience and competence contributed to lower repair and maintenance costs through better care and knowledge of the machine.

Pea-Vine Ratios

Combine output capacity is related to the pea-vine ratio. The pea-vine ratio as used in this study was the ratio of shelled pea weight

TABLE VIII

PERFORMANCE OF SOUTHERN PEA HARVESTERS BASED UPON OUTPUT
STUDIES FOR NINE MECHANICAL HARVESTERS,
WEST TENNESSEE, 1967

Group ^a	Output Per Machine Hour for Total Time ^b	Output Per Machine Hour for Picking Time	Picking Time as a Percent of Total Time ^c	Unloading Time as a Percent of Total Time	Other Time as a Percent of Total Time ^d
	(Pounds)	(Pounds)			
I	140.02	376.18	37.22	8.51	54.25
	348.39	775.86	44.90	18.50	36.38
	500.00	651.11	76.79	6.60	16.60
	466.92	595.53	78.40	4.57	17.02
Average	363.83	599.67	59.33	9.60	31.06
II	74.40	1,111.11	6.69	0.44	92.85
	479.17	582.28	82.29	5.20	12.50
	536.08	747.13	71.75	6.80	21.44
Average	363.22	813.51	53.58	4.15	42.26
III	544.51	704.66	77.27	2.08	20.64
	465.54	627.47	74.19	4.39	21.40
Average	505.03	666.07	75.73	3.24	21.02
Average for study	395.00	638.00	61.06	6.37	32.56

^aEach group includes mechanical harvesters studied on different farms.

^bTotal time includes: service time, actual harvest time, moving time, down time, unloading time, and other time (traffic congestion, instructions from foreman). Lunch time is not included in this calculation.

^cPicking time = actual harvest time. Breaks excluded. Includes turning time.

^dOther time includes: moving time; down time; service time; traffic congestion; lunch breaks; and instructions from foreman.

to the pea + vine + hull weight. A ratio of 1:5 would contain 20 percent peas and 80 percent vines and hulls. Low pea-vine ratios result in higher hourly output capacities for equivalent yields per acre. Total hourly material intake is affected by the ground speed and capacity of the machine but output capacity is dependent upon the pea-vine ratio as well as driver competence and machine limitations. Usually, a low pea-vine ratio is associated with a high yield and vice versa but it might be possible to have a low pea-vine ratio without a high yield. This situation would exist where both peas and vines were low.

An attempt was made to relate the pea-vine ratio to vine height. It was hypothesized that the higher the vines (assuming equivalent yields per acre) the lower the pea-vine ratio. Three test plots were studied. The average pea to vine ratio for these plots was 1:6.02 with an average vine height of 17.74 inches. Table IX gives a theoretical presentation of output per hour based on the intake quantity or pea-vine ratio. For example, if the pea to vine ratio was 1:6 and the total intake of peas, hulls, and vines per combine per hour was 3,000 pounds, the estimated output per hour of shelled peas per combine would be 500 pounds. For an equivalent total intake per hour, if the pea to vine ratio dropped to 1:4, the estimated output per combine per hour would be 750 pounds of shelled peas. In this model, no reference is made to vine height because no concrete relationship was found between vine heights and the ratio of peas to vines.

TABLE IX

SOUTHERN PEA COMBINE OUTPUT CAPACITY IN POUNDS OF SHELLED PEAS PER HOUR
AS AFFECTED BY PEA-VINE RATIO, WEST TENNESSEE, 1968^a

Pea-Vine Ratio ^b	Total intake per hour (peas + hulls + vines) in pounds					
	1,000	2,000	3,000	4,000	5,000	10,000
1:10.0	100	200	300	400	500	1,000
1: 9.0	111	222	333	444	555	1,111
1: 8.0	125	250	375	500	625	1,250
1: 7.5	134	267	400	533	667	1,066
1: 7.0	143	286	429	571	714	1,142
1: 6.5	154	308	462	615	769	1,230
1: 6.0	167	333	500	667	833	1,333
1: 5.5	182	364	545	727	909	1,454
1: 5.0	200	400	600	800	1,000	1,600
1: 4.5	222	444	667	889	1,111	1,778
1: 4.0	250	500	750	1,000	1,250	2,222
1: 3.5	286	571	857	1,143	1,429	2,500
1: 3.0	333	667	1,000	1,333	1,667	2,857
						3,300

^a Synthesized.

^b The pea-vine ratio as used in this analysis is the ratio of shelled peas to pea + vine + hull weight. A ratio of 1:5 would contain 20 percent peas and 80 percent vines and hulls by weight.

II. FIXED COSTS ASSOCIATED WITH MECHANICAL HARVESTING

Fixed costs are incurred even if no peas are harvested. However, once fixed costs have been incurred, they have no bearing upon decisions regarding an increase or decrease in production.

According to the 1968 prices given by the Food Machinery Corporation of Columbus, Ohio, the cost of a tractor-drawn Southern pea combine was \$17,000. Freight cost to the study area (Bells, Tennessee) from Columbus was \$450 for one combine, and \$200 for each combine in a multiple-unit shipment. Fixed cost consists of depreciation, interest on investment, taxes, insurance, and housing. An average purchase price for a tractor to pull the combine was \$6,927 plus \$200 freight to the study area. Table X shows the estimated annual fixed costs associated with the Southern pea combine were \$4,402.75 and \$3,868.21 for 5- and 10-year depreciation periods, respectively. Due to the possibility of obsolescence which could make it uneconomical to operate the combine, the annual fixed costs were based on a 5- and 10-year depreciation schedule. The straight line method of depreciation was used in order to show an average depreciation cost throughout the expected life of the machine.

Additional fixed costs for mechanical harvesting were computed for additional equipment as follows: (1) one swather for each group of four combines; (2) a half-ton truck for the mechanic; and (3) a half-ton truck for the supervisor.

TABLE X

ESTIMATED ANNUAL FIXED COST TO OPERATE THE MECHANICAL SOUTHERN
PEA HARVESTER, 5- AND 10-YEAR DEPRECIATION
SCHEDULES, WEST TENNESSEE, 1968^a

Item	5-Year Depreciation Schedule	10-Year Depreciation Schedule
Depreciation ^b	\$3,089.65	\$2,090.93
Interest ^c	926.90	1,254.56
Taxes ^d	154.48	209.09
Insurance ^e	154.48	209.09
Housing ^f	<u>77.24</u>	<u>104.54</u>
Total	\$4,402.75	\$3,868.21

^aBased on FMC combine purchase price of \$17,000 plus freight of \$450 (Columbus, Ohio, to study area); tractor purchase price of \$6,927 plus \$200 freight; combine salvage values of \$6,000 and \$2,000 for 5- and 10-years, respectively; and tractor salvage values of \$3,128.75 and \$1,667.72 for 5- and 10-years, respectively.

$$^b \text{Depreciation} = \frac{\text{Purchase Price} + \text{Freight} - \text{Salvage Value}}{\text{Depreciation Period}}$$

^cBased on 0.06 (Purchase Price + Freight - Salvage Value).

^dBased on 0.01 (Purchase Price + Freight - Salvage Value).

^eBased on 0.01 (Purchase Price + Freight - Salvage Value).

^fBased on 0.005 (Purchase Price + Freight - Salvage Value) due to the fact that a storage cost is incurred either by using a building for off-season housing or accepting higher costs incurred as a result of exposure to weather.

Table XI shows the estimated annual fixed costs associated with the swather were \$1,586.83 and \$1,303.11 for 5- and 10-year depreciation periods, respectively.

For complementary equipment required for mechanical harvesting, Table XII shows the annual fixed costs for the mechanic's truck and the supervisor's truck were \$217.43 and \$175.11 for 5- and 10-year depreciation periods, respectively. Trucks hired to haul peas from the field to the processing plant were paid on a mileage basis (25 cents per mile, one way). Therefore, no fixed cost was charged for these trucks. One-third of the annual fixed cost for the mechanic's truck was charged to Southern pea harvest because of his time spent on pea harvesting during the year. Since the supervisor spent only one-third of his time in supervising the harvest of Southern peas during the harvest season, only 0.1089 of the annual fixed cost for his truck was charged to the harvesting of this crop.

Table XIII shows the total annual fixed costs associated with the mechanical harvesting of Southern peas. It is emphasized that total harvesting costs were based on bulk dump loading in the field. Two 2-ton trucks were adequate for four combines where the distance from the processing plant was not over 20 miles. For a 5-year depreciation period, estimated total annual fixed costs ranged from \$6,207.01 for one combine, to \$53,575.12 for 11 combines. On a 10-year depreciation period, these values decreased to \$5,346.43 for one combine and \$46,769.06 for 11 combines, respectively.

TABLE XI

ESTIMATED ANNUAL FIXED COST TO OPERATE THE MECHANICAL
SOUTHERN PEA SWATHER, 5- AND 10-YEAR DEPRECIATION
SCHEDULES, WEST TENNESSEE, 1968^a

Item	5-Year Depreciation Schedule	10-Year Depreciation Schedule
Depreciation ^b	\$1,113.56	\$ 704.38
Interest ^c	334.07	422.63
Taxes ^d	55.68	70.44
Insurance ^e	55.68	70.44
Housing ^f	<u>27.84</u>	<u>35.22</u>
Total	\$1,586.83	\$1,303.11

^aBased on a purchase price of \$8,000; freight cost of \$200; salvage value of \$2,632.20 and \$1,156.20 after 5- and 10-years, respectively.

$$^b \text{Depreciation} = \frac{\text{Purchase Price} + \text{Freight} - \text{Salvage Value}}{\text{Depreciation Period}}$$

^cBased on 0.06 (Purchase Price + Freight - Salvage Value).

^dBased on 0.01 (Purchase Price + Freight - Salvage Value).

^eBased on 0.01 (Purchase Price + Freight - Salvage Value).

^fBased on 0.005 (Purchase Price + Freight - Salvage Value).

TABLE XII

ESTIMATED ANNUAL FIXED COSTS FOR COMPLEMENTARY EQUIPMENT
ASSOCIATED WITH MECHANICAL HARVESTING OF SOUTHERN
PEAS, 5- AND 10-YEAR DEPRECIATION SCHEDULES,
WEST TENNESSEE, 1968^a

Item	5-Year Depreciation Schedule	10-Year Depreciation Schedule
Mechanic's truck		
Depreciation ^b	\$117.15	\$ 72.60
Interest ^c	35.15	43.56
Taxes ^d	5.86	7.26
Insurance ^e	5.86	7.26
Housing ^f	2.93	3.63
Sub-total	<u>\$166.95</u>	<u>\$134.31</u>
Supervisor's truck ^g		
Depreciation	\$ 35.39	\$ 22.05
Interest	10.62	13.23
Taxes	1.79	2.21
Insurance	1.79	2.21
Housing	0.89	1.10
Sub-total	<u>\$ 50.48</u>	<u>\$ 40.80</u>
Total (both trucks)	\$217.43	\$175.11

^aPurchase price for half-ton trucks was estimated at \$2,325 with 5- and 10-year salvage values of \$700 and \$300, respectively. Costs associated with the mechanic's truck included an additional \$200 for tools and tool boxes with 5- and 10-year salvage values of \$50 and \$25, respectively.

$$^b \text{Depreciation} = \frac{\text{Average Purchase Price} - \text{Salvage Value}}{\text{Depreciation Period}} \times 0.33.$$

$$^c \text{Based on } 0.06 (\text{Average Purchase Price} - \text{Salvage Value}) \times 0.33.$$

$$^d \text{Based on } 0.01 (\text{Average Purchase Price} - \text{Salvage Value}) \times 0.33.$$

$$^e \text{Based on } 0.01 (\text{Average Purchase Price} - \text{Salvage Value}) \times 0.33.$$

$$^f \text{Based on } 0.005 (\text{Average Purchase Price} - \text{Salvage Value}) \times 0.33.$$

^gCalculations based on same equations as the mechanic's truck except the constant 0.33 became 0.1089.

TABLE XIII
ESTIMATED TOTAL ANNUAL FIXED COST TO MECHANICALLY
HARVEST SOUTHERN PEAS BY NUMBER OF MACHINES
AND DEPRECIATION PERIOD, WEST TENNESSEE,
1968^a

Number of Machines	Depreciation Period	
	5-Years	10-Years
1	\$ 6,207.01	\$ 5,346.43
2	10,609.76	9,214.64
3	15,012.51	13,082.85
4	19,415.26	16,951.06
5	25,404.84	22,122.38
6	29,807.59	25,990.59
7	34,210.34	29,858.80
8	38,613.09	33,727.01
9	44,602.67	38,898.33
10	49,005.42	42,766.54
11	53,575.12	46,769.06

^aBased on Tables X, XI, and XII, pages 37, 39, and 40.



Fixed costs were charged to Southern pea harvesting alone, for the combines and swathers since the harvesting of English peas and lima beans was not considered in this study. However, the Southern pea combine could be used to harvest lima beans and green peas (English peas). The availability of these crops would aid in determining whether to invest in a combine. Annual use of the machinery could be increased with the availability of these crops and thereby lower annual fixed cost per unit of the crops harvested.

III. VARIABLE COSTS

Variable costs are incurred while the combine, vine cutter and trucks are in operation. Variable costs for mechanical harvesting of Southern peas include: (1) labor; (2) fuel; (3) lubrication; (4) repairs; and (5) costs involved in hauling the harvested crop to the processing plant. Labor cost included one driver per operating machine (\$1.25 per hour), a driver for each swather (\$1.25 per hour), a field mechanic (\$2.00 per hour), and a supervisor (\$2.50 per hour).

Table XIV presents an estimate of the variable cost per hour to operate the Southern pea combine. Total variable cost per hour for labor, fuel, lubrication, and repairs was \$4.192. Fuel requirements were 3.5 gallos of gasoline per hour for the combine at 29.1 cents per gallon and 1.0 gallon of diesel fuel per hour for the tractor at 26.9 cents per gallon. Lubrication was based on 20 percent of fuel cost.

TABLE XIV

ESTIMATED VARIABLE COST PER HOUR TO OPERATE THE MECHANICAL SOUTHERN PEA HARVESTER, BY NUMBER OF MACHINES IN OPERATION, WEST TENNESSEE, 1968^a

Number of Machines	Labor ^b	Fuel ^c	Lubrication ^d	Repairs	Total Variable Cost
	Dollars Per Hour				
1	1.25	1.288	0.258	1.396	4.192
2	2.50	2.576	0.516	2.752	8.344
3	3.75	3.864	0.774	4.128	12.516
4	5.00	5.152	1.032	5.504	16.668
5	6.25	6.440	1.290	6.880	20.860
6	7.50	7.728	1.548	8.256	25.032
7	8.75	9.016	1.806	9.632	29.204
8	10.00	10.304	2.064	11.008	33.376
9	11.25	11.592	2.322	12.384	37.548
10	12.50	12.880	2.580	13.760	41.720
11	13.75	14.168	2.838	15.136	45.892

^a Includes operational cost for the tractor which pulls the combine.

^b Based on \$1.25 per hour for the tractor driver.

^c Based on 3.5 gallons of gasoline per hour at 29.1 cents per gallon (area prices) for the combine and one gallon of diesel fuel per hour for the tractor at 26.9 cents per gallon.

^d Based on interviews with drivers, other studies, company records, and agricultural engineering estimators (20 percent of fuel costs).

^e Based on company records and agricultural engineering estimators: 2 percent of initial investment cost (\$17,450 for a single purchase and \$17,200 for multiple unit purchases) for a 250-hour season; 4 percent for a 500-hour season; and 6 percent for a 750-hour season.

Repairs were based on a 500-hour season and estimated at 4 percent of initial cost for combines and crawler tractors.²¹

Table XV shows the variable cost per hour to operate each swather was \$3.092. The swather required 4.0 gallons of gasoline per hour at 29.1 cents per gallon. Lubrication costs were estimated at 16 percent of fuel cost (based on interviews with drivers, other studies, company records, and agricultural engineering estimators). Repair costs were based on a 500-hour season at 3.0 percent of initial swather cost.

In determining variable cost per hour for complementary equipment and personnel (Table XVI), one-third of the supervisor's wage rate of \$2.50 per hour was charged to Southern pea harvesting. Additional labor included the mechanic at a wage rate of \$2.00 per hour. Fuel costs per 10-hour day for the mechanic's truck and the supervisor's truck were estimated at 5 gallons each at 29.1 cents per gallon (tax cannot be refunded). Lubrication costs were computed at 16 percent of fuel cost and repair cost was based on a 500-hour season at 5 percent of the initial cost for the mechanic's truck and the supervisor's truck. Total variable cost per hour to operate complementary equipment ranged from \$4.156 for 1-2 combines, to \$8.078 for 11-12 combines. When adding the eleventh combine, an additional mechanic and half-ton truck were required. Table XVII is a summary of the three preceding tables and reveals that the order of importance of variable costs included in Southern pea harvesting is: (1) labor; (2) fuel; (3) repairs; (4) transportation of the commodity to the processing plant; and (5) lubrication. Values suggested for fuel costs may be reduced by the grower

²¹Whittlesey and Duff, op. cit., p. 28.

TABLE XV

ESTIMATED VARIABLE COSTS PER HOUR TO OPERATE THE MECHANICAL SOUTHERN PEA
SWATHER, BY NUMBER OF SWATHERS IN OPERATION, WEST TENNESSEE, 1968

Number of Swathers	Labor ^a	Fuel ^b	Lubrication ^c	Repairs ^d	Total Variable Cost
	Dollars Per Hour				
1	1.25	1.164	0.186	0.492	3.092
2	2.50	2.328	0.372	0.984	6.184
3	3.75	3.492	0.558	1.476	9.276
4	5.00	4.656	0.744	1.968	12.368
5	6.25	5.820	0.930	2.460	15.460

^aBased on one driver at \$1.25 per hour.

^bBased on 4.0 gallons of gasoline per hour at 29.1 cents per gallon.

^cBased on 16 percent of fuel cost as a result of interviews with drivers, other studies, company records, and agricultural engineering estimators.

^dBased on company records, other studies, and agricultural engineering estimators as follows: 1.5 percent of initial investment for a 250-hour season; 3.0 percent for a 500-hour season; and 4.5 percent for a 750-hour season.

TABLE XVI

ESTIMATED VARIABLE COSTS PER HOUR FOR COMPLEMENTARY EQUIPMENT AND PERSONNEL
ASSOCIATED WITH MECHANICAL HARVESTING OF SOUTHERN PEAS, BY NUMBER
OF MACHINES IN OPERATION, WEST TENNESSEE, 1968

Number of Machines	Labor ^a	Fuel ^b	Lubrication ^c	Repairs ^d	Trans. To Market ^e	Total Variable Cost
	Dollars Per Hour					
1 - 2	2.833	0.291	0.047	0.485	0.500	4.156
3 - 6	2.833	0.291	0.047	0.485	1.000	4.656
7 - 9	2.833	0.291	0.047	0.485	1.500	5.156
10	2.833	0.291	0.047	0.485	2.000	5.656
11 - 12	4.833	0.437	0.070	0.738	2.000	8.078

^aBased on a wage rate of \$2.50 per hour for the supervisor with 1/3 of his time being spent relative to pea harvesting, and a mechanic's wage rate of \$2.00 per hour; one mechanic per 10 machines and one supervisor for each group of 20 machines.

^bBased on five gallons of gasoline per 10-hour day at 29.1 cents per gallon for both the mechanic and supervisor's truck (tax cannot be refunded).

^cBased on 16 percent of fuel cost as a result of other studies and agricultural engineering research.

^dBased on an initial investment of \$2,325 for the supervisor's truck and \$2,525 for the mechanic's truck and tools. Annual repair cost was based on 5 percent of the initial investment cost (from Glenn Glover, Cost of Farm Machinery Used for Cotton Production in Tennessee, unpublished study, University of Tennessee, p. 24), estimated annual repair cost of 2.5 percent of initial investment cost for a 250-hour season, 5.0 percent for a 500-hour season, and 7.5 percent for a 750-hour season.

^eBased on an average distance of 20 miles from the processing plant, 10-hour day, 25 cents per mile (paid one way) for 2-ton trucks, and two trips per day maximum for each truck.

TABLE XVII

ESTIMATED TOTAL VARIABLE COST PER HOUR TO MECHANICALLY HARVEST SOUTHERN
PEAS, BY NUMBER OF MACHINES IN OPERATION, WEST TENNESSEE, 1968^a

Number of Machines	Labor	Fuel	Lubrication	Repairs	Trans. To Market	Total Variable Cost
	Dollars Per Hour					
1	5.333	2.743	0.491	2.373	0.500	11.440
2	6.583	4.031	0.749	3.729	0.500	15.592
3	7.833	5.319	1.007	5.105	1.000	20.264
4	9.083	6.607	1.265	6.481	1.000	24.436
5	11.583	9.059	1.709	7.857	1.000	31.208
6	12.833	10.347	1.967	9.725	1.000	35.872
7	14.083	11.635	2.225	11.101	1.500	40.544
8	15.333	12.923	2.483	11.978	1.500	44.217
9	17.833	15.375	2.927	14.345	1.500	51.980
10	19.083	16.663	3.185	15.721	2.000	56.652
11	22.333	18.097	3.466	17.350	2.000	63.246

^aBased on Tables XIV, XV, and XVI, pages 43, 45, and 46.

applying for a tax refund.²² Total variable cost per hour to mechanically harvest Southern peas ranged from \$11.440 for one combine to \$63.246 for 11 combines.

Unloading time at the processing plant was not considered in variable costs since the growers hired trucks and drivers and paid them on a mileage basis.

Table XVIII shows how the associated requirements change in relation to the number of combines in operation. As the number of combines increase, some of the associated requirements (maintenance, supervision, and number of swathers) increase less than proportionately thereby reducing cost per unit of output. For example, one swather is required for each group of four combines in operation. One mechanic is sufficient for each group of 10 combines and one supervisor can oversee 20 combines.

IV. TOTAL COST

Appendix Table XXII shows that total harvesting cost per acre by annual acreage harvested, length of season, machine output rate per hour, and depreciation period. Numerical values obtained for total harvesting costs per acre were identical with harvesting costs per ton.

Subsequent models were based on 5- and 10-year depreciation periods, machine output rates of 387.54 and 638.00 pounds (shelled) per

²²A credit of four cents per gallon is allowed for federal tax (from Farmers Gas Tax Credit, United States Treasury Department, Internal Revenue Service, Publication No. 308, p. 10). A state tax of seven cents per gallon is deductible.

TABLE XVIII

COMPLEMENTARY MACHINE AND PERSONNEL REQUIREMENTS ASSOCIATED WITH MECHANICAL
HARVESTING OF SOUTHERN PEAS, WEST TENNESSEE, 1968^a

Number of Machines	Number Required						Hired Trans. Cost Per Hour ^b
	Swathers	Swather Operators	Mechanics	Field Supervisors	Pick-Up Trucks	2-Ton Trucks	
1	1	1	1	1	2	1	\$0.50
2	1	1	1	1	2	1	0.50
3	1	1	1	1	2	2	1.00
4	1	1	1	1	2	2	1.00
5	2	2	1	1	2	2	1.00
6	2	2	1	1	2	2	1.00
7	2	2	1	1	2	2	1.50
8	2	2	1	1	2	2	1.50
9	3	3	1	1	2	2	1.50
10	3	3	1	1	2	2	2.00
11	3	3	2	1	3	2	2.00

^aBased on information received in survey.

^bBased on an average output of shelled peas per machine of 387.54 pounds, 10-hour day, 12,000 pound maximum load for 2-ton trucks, average distance from processing plant of 20 miles, and 25 cents per mile (paid one way) to hire peas hauled.

hour, three lengths of season (250, 500, and 750 hours), and an annual acreage harvested ranging from 15 to 500 acres. In the study area, average output per hour per combine was 387.54 pounds (shelled). Maximum output was 638.00 pounds (shelled). The length of the season in the study area was approximately 500 hours. By operating the combines on lima beans locally or on peas and lima beans in adjoining states, a maximum season length of 750 hours might be attained.

For a 5-year depreciation period and 387.54 pound (shelled) output per combine per hour, total harvesting costs per acre (when 500 acres were harvested) were \$136.88, \$90.47, and \$70.35 for season lengths of 250, 500, and 750 hours, respectively. If only 15 acres were harvested annually and the other variables remained unchanged, total harvesting costs per acre would increase to \$472.83 for each season length.

The combination of inputs that approximates the seasonal conditions of the study area is a 10-year depreciation period, 500-hour season, and 387.54 pounds (shelled) output per combine per hour (Appendix Table XXII). With these seasonal conditions, total harvesting costs per acre ranged from \$415.46 for 15 acres harvested, to \$82.83 for an annual acreage harvested of 500 acres. By increasing the length of the season to 750 hours and holding the other variables constant, total harvesting costs per acre (when 500 acres were harvested) declined to \$65.42.

To attain the most economical harvesting conditions, a grower might assume a 10-year depreciation period, attain an output per hour per combine of 638.00 pounds (shelled) per hour, and increase the length of season to 750 hours. Given these seasonal conditions, total harvesting

costs per acre dropped to \$47.24 when 500 acres were harvested (Appendix Table XXII).

The processor in the study area did all the mechanical harvesting at no explicit cost. The grower merely contracted his crop to the processor to be harvested mechanically.

CHAPTER IV

COMPARATIVE COSTS PER ACRE FOR MANUAL AND MECHANICAL HARVESTING

Total costs per acre for harvesting Southern peas are compared for manual and mechanical harvesting in this chapter. Harvesting costs per acre or per ton (assuming 2,000 pounds of unshelled peas per acre) were compared by using average total cost curves constructed from Appendix Table XXII.

Average total cost, ATC, per ton was computed by adding average fixed cost, AFC, per ton and average variable cost, AVC, per ton. Generally, ATC decreases as output increases from zero, attains a minimum, and increases thereafter. ATC is often referred to as the "unit cost" of production (cost of harvesting in this study). The initial decrease in ATC was caused by the spreading of fixed costs among an increasing number of tons of peas harvested annually and the increasing efficiency with which the variable inputs were used. Theoretically, as the number of tons of peas harvested increased further, AVC would attain a minimum and begin to increase; when these increases in AVC could no longer be offset by decreases in AFC, ATC per ton would begin to rise. For example, if increasing the number of combines from 10 to 11 required an additional mechanic and half-ton truck, the increase in variable cost per acre harvested could outweigh the decrease

in fixed cost arising from the increased annual volume. Under such conditions, the ATC curve would show decreasing returns to size of operation. At 500 acres harvested annually, this effect had not begun. The regions in Figures 5-8 where the ATC curve fell, were in an area of increasing returns to size. The ATC curves depict the minimum average cost for each output level and by so doing would determine the optimum number of acres to harvest.

The number of combines required to harvest a specified tonnage varied by the annual tonnage harvested, length of the harvest season, and output per hour per combine. For example, at an output per hour per combine of 387.54 pounds and a 250-hour season, the number of combines required to harvest 15 and 500 tons varied from one to eleven, respectively. By increasing the season length to 500 hours, the number of combines required to harvest 15 and 500 tons was one and six, respectively (Appendix Table XXIII).

I. HARVESTING COST FOR A 250-HOUR SEASON

Figures 5-8 show ATC per ton for harvesting Southern peas by depreciation period, season length, and output per hour per combine. Yield per acre was held constant at 2,000 pounds (unshelled).

For a 250-hour season and a 5-year depreciation period, ATC per ton of peas harvested was greater for the mechanical method than the manual method where output per hour per combine was 387.54 pounds (shelled). For example, Figure 5 shows that where 15 tons were harvested annually, mechanical harvesting costs were \$472.83 per ton as opposed to

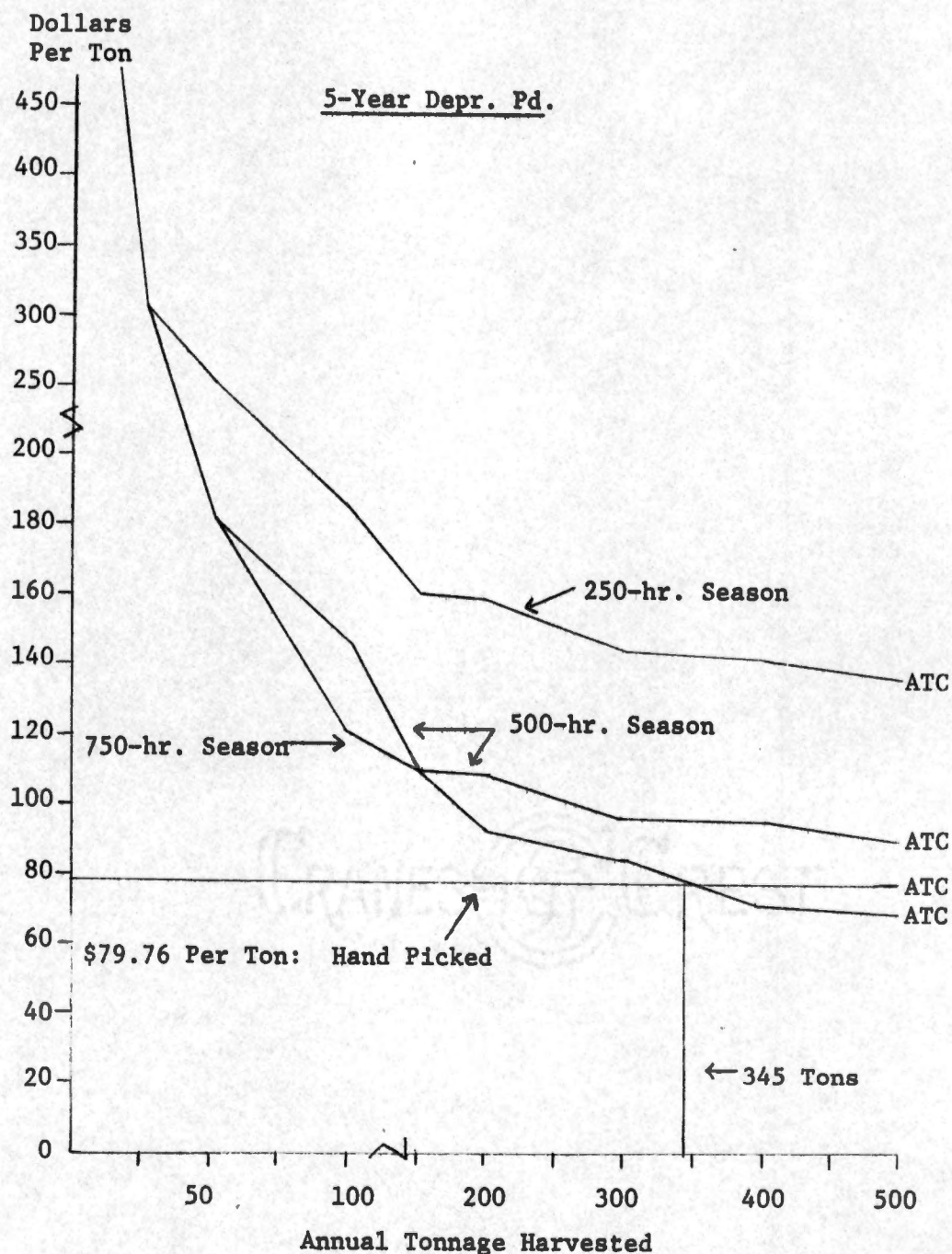


Figure 5. Average total cost per ton for harvesting Southern peas manually and mechanically, assuming 250, 500, and 750-hour seasons, 387.5 pounds output per hour per combine, and a 5-year depreciation period.

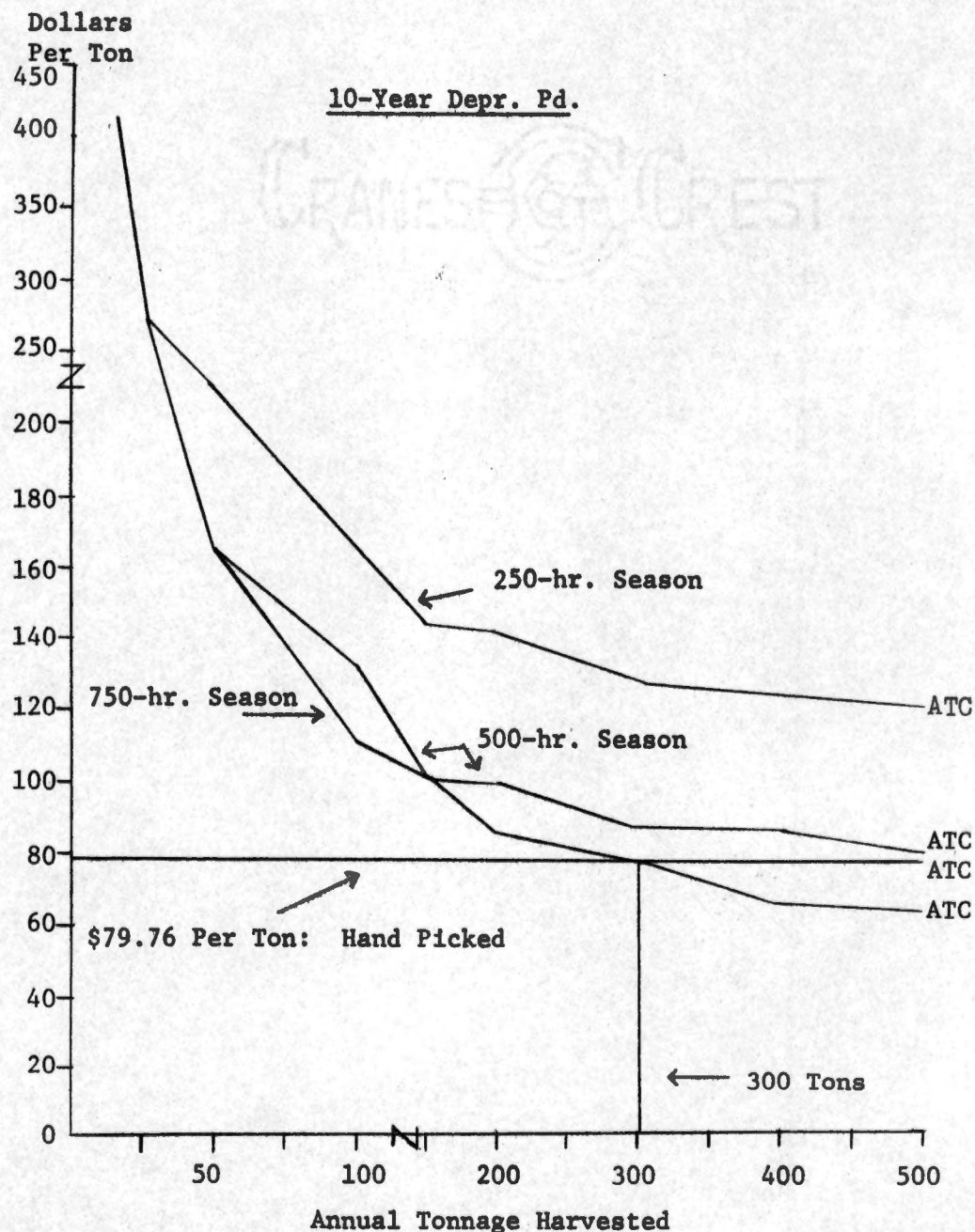


Figure 6. Average total cost per ton for harvesting Southern peas manually and mechanically, assuming 250, 500, and 750-hour seasons, 387.5 pounds output per hour per combine, and a 10-year depreciation period.

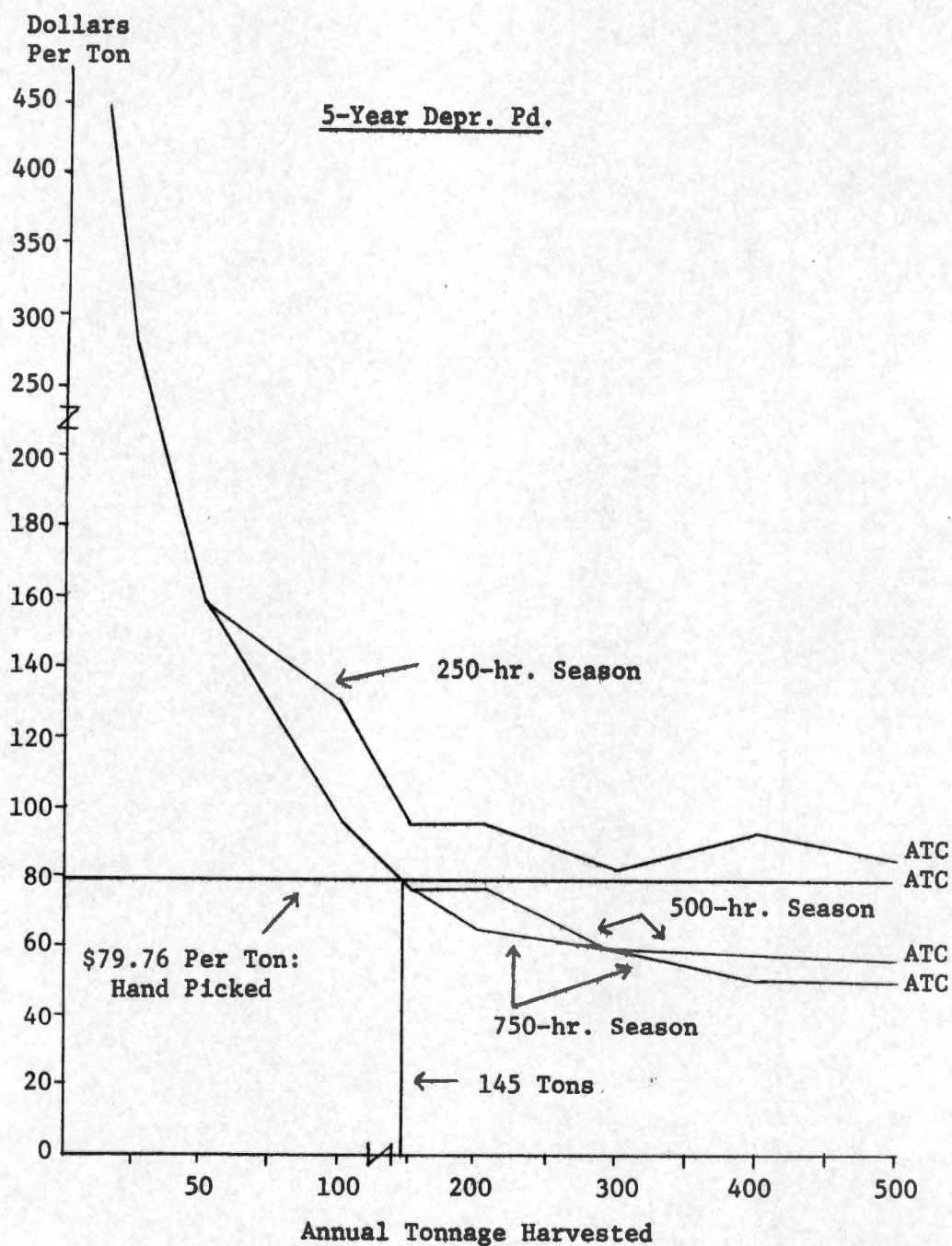


Figure 7. Average total cost per ton for harvesting Southern peas manually and mechanically, assuming 250, 500, and 750-hour seasons, 638 pounds output per hour per combine, and a 5-year depreciation period.

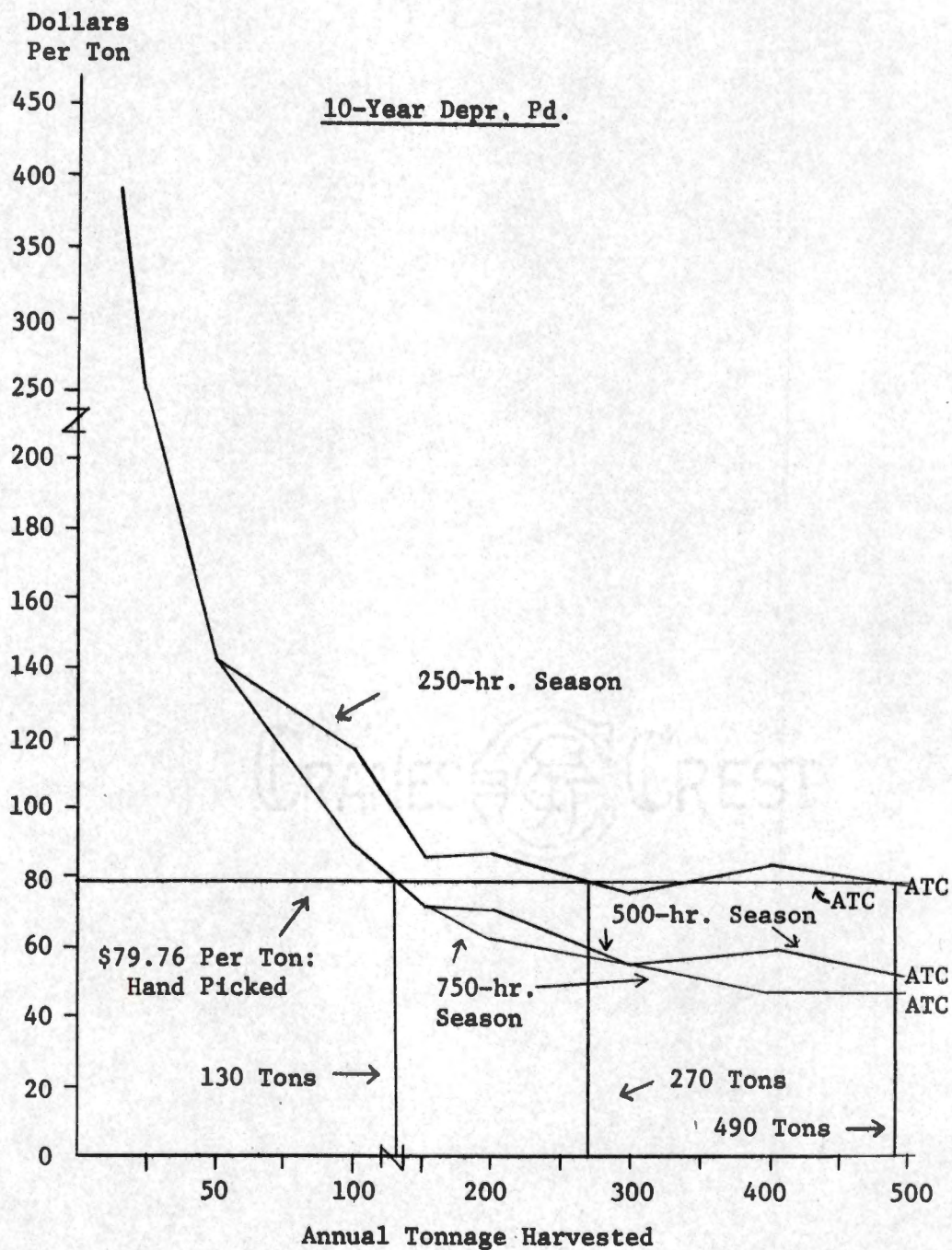


Figure 8. Average total cost per ton for harvesting Southern peas manually and mechanically, assuming 250, 500, and 750-hour seasons, 638 pounds output per hour per combine, and a 10-year depreciation period.

\$79.76 per ton for manually harvested peas. Where the annual tonnage harvested increased to 500 tons, mechanical harvesting was still more expensive than manual harvesting (\$136.88 per ton). By increasing the depreciation period to 10 years, the mechanical harvesting method cost \$472.83 and \$123.27 for 15 and 500 tons, respectively (Figure 6). For a 250-hour season, mechanical harvesting costs per ton were less than the manual method only, when the output per hour per combine increased to 638 pounds (shelled) and the depreciation period was 10 years (Figure 8). Equivalent harvesting costs per ton for the two methods (\$79.76) occurred where annual tonnage harvested was 270 tons. Mechanical harvesting costs per ton decreased to \$75.56 where 300 tons were harvested annually. However, if the annual volume harvested increased to 400 and 500 tons, harvesting costs per ton were \$83.63 and \$77.96, respectively. This effect resulted from increased AFC required to harvest the additional volume.

II. HARVESTING COST FOR A 500-HOUR SEASON

Peas were harvested in the study area from July 15 to September 15, or approximately 500 harvesting hours. With output per hour per combine at 387.54 pounds (shelled), a season length of 500 hours, and fixed costs depreciated over a 5-year period, Figure 5 shows that ATC per ton of peas harvested were greater for the mechanical method than the manual method between 15 and 500 tons. For example, to harvest 15 tons per year mechanically, cost \$472.83 per ton; 50 tons, \$183.17 per ton; 100 tons, \$146.33 per ton; 200 tons, \$109.91 per ton; 400 tons,

\$95.65 per ton; and 500 tons, \$90.47 per ton. Manual harvesting costs were constant at \$79.76 per ton. By increasing the depreciation period to 10 years, Figure 6, page 55, shows mechanical harvesting costs per ton decreased to \$82.83 where 500 tons were harvested annually. The above combination of inputs would be an applicable model for a grower in the study area to use in determining mechanical harvesting costs per ton. If the grower planned to harvest in adjoining states, he would choose a model with a longer season length.

By increasing output per hour per combine to 638 pounds (shelled) and maintaining a 500-hour season, Figures 7 and 8, pages 56 and 57, respectively, show ATC per ton to harvest peas mechanically was equivalent to manual harvesting costs (79.76 per ton) at 145 and 130 tons harvested annually for 5- and 10-year depreciation periods, respectively. By harvesting 500 tons annually, mechanical costs per ton were \$57.89 and \$52.96 for 5- and 10-year depreciation periods, respectively. It must be emphasized that attaining a 638-pound output per hour per combine would require continuous harvesting (no time allowance for breaks, service time, or breakdown) and is illustrated only to show maximum output conditions.

III. HARVESTING COST FOR A 750-HOUR SEASON

By harvesting English peas, Southern peas, and lima beans locally or in adjoining states, a grower might attain a 750-hour season. Where average output per hour per combine was 387.54 pounds (shelled) and fixed costs were depreciated over a 5-year period, Figure 5, page 54,

shows equivalent harvesting costs for manual and mechanical harvesting methods (\$79.76 per ton) where 345 tons were harvested annually. For annual tonnages harvested of 400 and 500 tons, mechanical harvesting costs per ton were \$72.38 and \$70.35, respectively. By increasing the depreciation to a 10-year period, equivalent harvesting costs per ton (\$79.76) occurred where 300 tons were harvested annually. If 400 or 500 tons were harvested annually, costs per ton dropped to \$67.56 and \$65.42, respectively, for the mechanical harvester.

Figure 7, page 56, depicts harvesting costs per ton for a 5-year depreciation period, an output per hour per combine of 638 pounds (shelled), and a 750-hour season length. These inputs required maximum use of the combine and harvesting additional crops locally or in adjoining states. With these conditions given, equivalent harvesting costs per ton of peas harvested occurred at 145 tons (annual harvest).

For a 10-year depreciation period, equivalent harvesting costs per ton of peas harvested occurred where 130 tons were harvested annually (Figure 8, page 57). This input combination shows maximum output per combine per hour (638 pounds) and maximum season length attainable (750 hours).

IV. HARVESTING COSTS FOR 10, 20, AND 30 PERCENT LOSSES

Figures 9 and 10 show harvesting costs per ton for 5- and 10-year depreciation periods, respectively, where 10, 20, and 30 percent losses were incurred. Output per hour per combine was 387.54 pounds (shelled) and the season length was 500 hours. Based on the harvesting

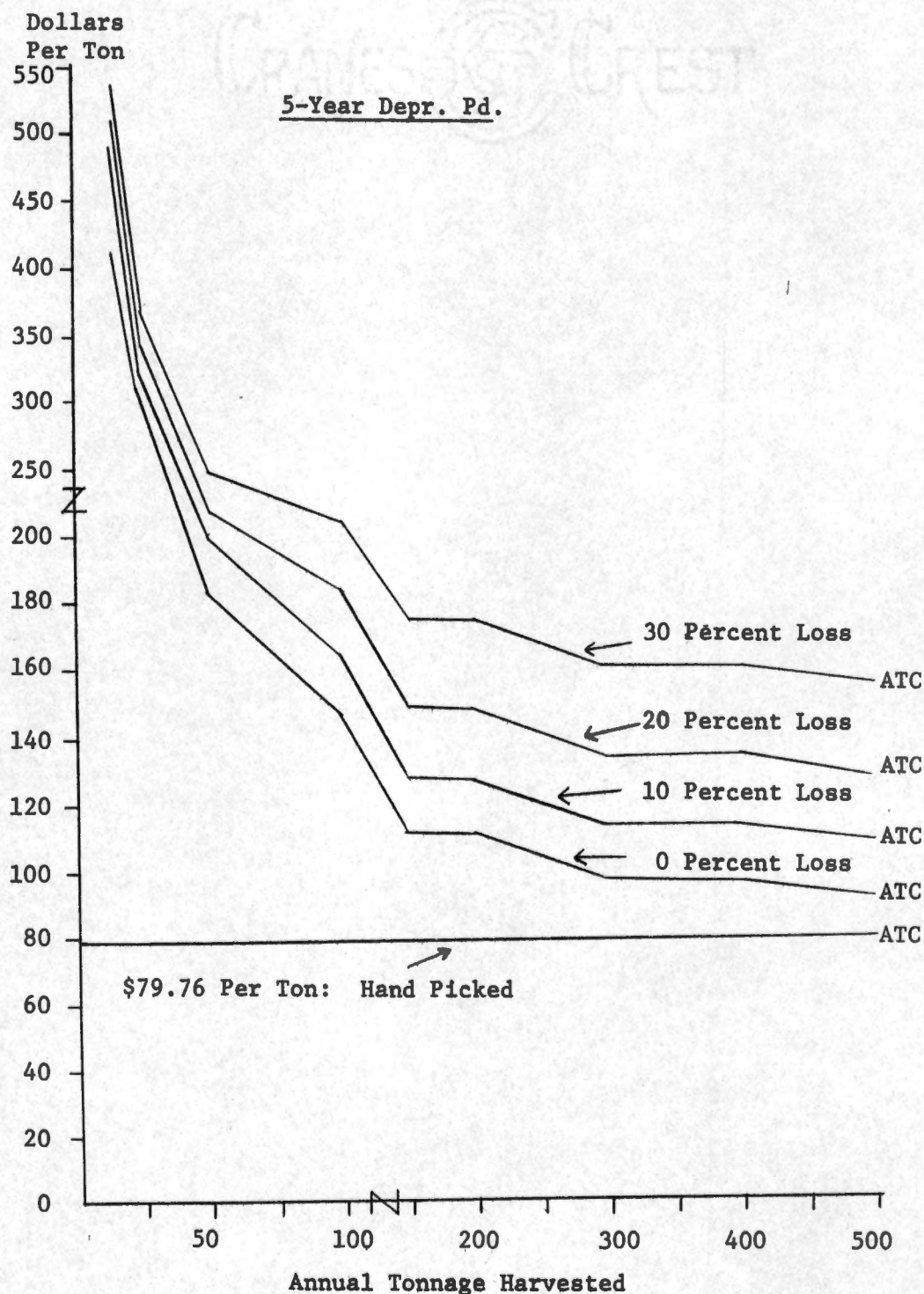


Figure 9. Average total cost per ton for harvesting Southern peas manually and mechanically, assuming a 10, 20, and 30 percent loss of peas in the field, 387.5 pounds output per hour per combine, 5-year depreciation period, and a 500-hour season.

cost per ton for a 2,000-pound (unshelled) recovered yield per acre, harvesting cost per ton increased \$16.67, \$37.50, and \$64.29 for 10, 20, and 30 percent losses, respectively. For example, a 10 percent loss increased harvesting costs per ton at a constant rate of \$16.67. A 20 and 30 percent loss increased harvesting costs per ton by a constant \$37.50 and \$64.29, respectively. Where 500 tons were harvested annually and the depreciation period was 5 years, harvesting costs per ton for 10, 20, and 30 percent losses were \$107.14, \$127.97, and \$154.76, respectively. Where the depreciation period was 10 years and 10, 20, and 30 percent losses were incurred, harvesting costs per ton were \$99.50, \$120.33, and \$147.12, respectively. These costs were comparable to a constant cost per ton of \$79.76 for hand-picked peas.

V. SAVINGS PER ACRE (DOLLARS)

Table XIX projects the estimated amount of savings per acre (dollars) for mechanical harvesting by the number of acres harvested (15-500), 5- and 10-year depreciation periods, 387.54 and 638 pounds (shelled) output per hour per combine, and season lengths of 250, 500, and 750 hours. Negative numbers indicate the estimated dollar values that the mechanical harvesting method increases harvesting costs per acre as opposed to the hand harvest method. Positive numbers show estimated amounts of savings in harvesting costs per acre by converting to the mechanical method. Numerical values were based on a recovered yield per acre of 2,000 pounds (unshelled) and losses in the field were not considered.

TABLE XIX

ESTIMATED SAVINGS PER ACRE (DOLLARS) FOR MECHANICAL HARVEST OF SOUTHERN PEAS, BY
ACRES HARVESTED, DEPRECIATION PERIOD, OUTPUT PER HOUR PER MACHINE, AND
LENGTH OF SEASON (HOURS), WEST TENNESSEE, 1968^a

Number of Acres Harvested	Savings Per Acre (Dollars) ^b			
	Depreciation Period		Depreciation Period	
	5-Year	10-Year	5-Year	10-Year
	387.54-lb. output, 250-hr. season		387.54-lb. output, 500-hr. season	
15	-393.07	-335.70	-393.07	-335.70
25	-227.55	-193.13	-227.55	-193.13
50	-172.67	-144.76	-103.41	-86.20
100	-105.22	-85.92	-66.57	-52.62
150	-81.20	-64.77	-31.20	-21.90
200	-79.40	-62.99	-30.15	-20.50
300	-64.27	-49.77	-16.48	-8.26
400	-61.38	-47.12	-15.89	-7.69
500	-57.12	-43.51	-10.71	-3.07
	387.54-lb. output, 750-hr. season		638.00-lb. output, 250-hr. season	
15	-393.07	-335.70	-369.85	-312.48
25	-227.55	-193.13	-204.33	-169.91
50	-103.41	-86.20	-80.19	-62.98
100	-41.34	-32.73	-50.82	-36.87
150	-31.20	-21.90	-15.45	-6.15
200	-13.52	-6.54	-16.37	-6.72
300	-5.13	1.30	-4.02	4.20
400	7.38	12.20	-13.41	-3.87
500	9.41	14.34	-6.90	1.80

TABLE XIX (Continued)

Number of Acres Harvested	Savings Per Acre (Dollars) ^b			
	Depreciation Period		Depreciation Period	
	5-Year	10-Year	5-Year	10-Year
	638.00-lb. output, 500-hr. season		638.00-lb. output, 750-hr. season	
15	-369.85	-312.48	-369.85	-312.48
25	-204.33	-169.91	-204.03	-169.91
50	-80.19	-62.98	-80.19	-62.98
100	-18.12	-9.51	-18.12	-9.51
150	2.57	8.31	2.57	8.31
200	2.23	9.21	12.92	17.22
300	19.91	24.56	19.91	24.56
400	21.16	20.98	28.76	32.24
500	21.87	26.80	28.66	32.52

^aBased on Appendix Table XXII and a cost per ton for hand harvested peas of \$79.76.

^bMinus figures show that machine harvesting is more expensive than the hand harvest method by the numerical value given. Positive figures indicate the added returns per acre (ton) of peas harvested in excess of those returns attainable by the hand harvest method. Emphasis must be placed on the fact that savings per acre is synonymous to savings per ton of peas harvested.

Where the combine output rate per hour was 387.54 pounds (shelled) and the depreciation period was 5 years, the mechanical method of harvesting peas was more expensive per acre than the manual method (\$79.76) until the season length was extended to 750 hours and the annual tonnage harvested was 345 tons (Figure 5, page 54). For example, when 300 tons were harvested annually, the mechanical method cost \$84.89 per acre; \$5.13 per acre more than the manual method. By increasing the annual tonnage harvested to 400 tons, the mechanical method cost \$72.38 per acre, an increase in returns per acre of \$7.38 in excess of the manual harvesting method. By increasing the depreciation period to 10 years and harvesting 400 acres annually, mechanical harvesting cost \$67.56 per acre and yielded an increase in returns per acre of \$12.20 in excess of those returns received by manual harvesting.

For a 10-year depreciation period, an output rate per hour per combine of 638 pounds (shelled), and a 250-hour season, mechanical harvesting cost \$75.56 per acre when 300 tons were harvested annually, \$4.20 per acre less than the manual harvesting method. For a 500-hour season and a 10-year depreciation period, mechanical harvesting returned \$8.31 per acre more than the manual harvesting method when 150 acres were harvested annually. If annual acreage harvested increased to 500 acres, mechanical harvesting saved \$26.80 per acre as opposed to the manual method.

To illustrate maximum conditions (638 pounds output per hour per combine, 750-hour season, and a 10-year depreciation period), mechanical harvesting showed a theoretical savings per acre of \$32.52 as opposed to the manual harvesting method when 500 acres were harvested annually.

CHAPTER V

SUMMARY

From 1954 to 1964, the acreage of Southern peas grown for processing increased sharply from 1,604 to 11,865. Shortage of labor has emphasized the need to shift from manual to mechanical harvesting. Mechanical combines and complementary equipment require large investments. The producer and processor need information to compare manual and mechanical harvesting costs at different levels of output in Tennessee. The specific objectives of this study were:

1. To determine the input-output coefficients for harvesting Southern peas manually and mechanically.
2. To estimate the fixed, variable, and total unit costs of harvesting Southern peas manually and mechanically, and to determine the acreage and volume necessary for mechanical harvesting to be profitable.
3. To determine harvesting costs when mechanical harvesters were used at maximum and less than maximum capacity.
4. To ascertain harvesting costs with 10, 20, and 30 percent losses with the mechanical harvester.

Input-output coefficients for manual harvesting were developed from field data obtained on 282 pickers of Southern peas in West Tennessee during the summers of 1967-68. An average of four workers

were used per acre with an average output per man-hour of 28.18 pounds (unshelled) or 16.9 pounds (shelled) at a 60 percent shell-out. Average yields per acre ranged from 1,800 pounds to 2,000 pounds (unshelled). Harvesting rates per man-hour were highest (40.6 pounds per man-hour--unshelled) between the ages of 30-39 years.

For all hand harvest observations, sacks were used as picking containers and were the major part of fixed costs. When fixed costs were \$8.12 per acre, variable costs were \$71.64 for a 2,000 pound (unshelled) yield per acre. Labor was the major variable cost (\$26.00 per acre). Total cost per acre for hand picked peas was \$79.76 for a 2,000 pound (unshelled) yield.

Coefficients for mechanical harvesting obtained from time and production studies of nine combines and three swathers revealed the average output per hour per combine for actual harvest time was 638 pounds of shelled peas. Output per hour per combine averaged 387.54 pounds of shelled peas per hour for total harvest time. On a total time basis, the machines were 23 times as efficient as the hand harvesting method. On an actual harvest time basis, the machines were 36.8 times as efficient. Actual working time was 67.39 percent of total field hours. Down time was the next most important variable in total time (19.76 percent). In decreasing order of importance, the remainder of the total field hours was divided into 6.85 percent for service time, 4.21 percent for other time (traffic congestion, lunch breaks, and instructions from foreman), and 1.78 percent for moving time.

Due to the relative newness of the mobile viner and the possibility of obsolescence, because of technological improvements, making the operation of the machine not economical, fixed costs were based on 5- and 10-year depreciation periods. The major fixed cost was the combine and tractor combination, followed in decreasing order of importance by the swather and trucks for the mechanic and supervisor. Multiple use of the combines was not considered in this study, but the machines were capable of harvesting lima beans and green peas. For a 5- and 10-year depreciation period and bulk dump loading in the field, estimated total annual fixed costs for a combine and tractor were \$4,402.75 and \$3,868.21, respectively. Other fixed costs for mechanical harvesting based on 5- and 10-year depreciation periods included: \$1,586.83 and \$1,303.11, respectively, for the swather; and \$217.43 and \$175.11, respectively, for the combined costs of the mechanic's and supervisor's trucks.

For mechanical harvesting, variable costs per hour in decreasing order of importance included: labor (\$5.333); fuel (\$2.743); repairs (\$2.373); transportation of the harvested crop to the processing plant (\$0.500); and lubrication (\$0.491). To operate one combine, variable costs totaled \$11.44 per hour (Table XVII, page 47).

Total costs per acre to harvest Southern peas mechanically were related to yield per acre, output rate per combine, length of the harvest period, length of the depreciation period, and annual acreage harvested.

Four of the 12 estimates of harvesting cost developed in this study closely approximated harvesting conditions in the area studied.

The models were based on the following variables: one to 11 combines, a combine output rate per hour of 387.54 pounds (shelled); season length of 500 hours; and a 5-year depreciation period. A second model extended the depreciation period to 10 years. When 15 acres were harvested annually, mechanical costs were \$472.83 and \$415.46 per ton for Models 1 and 2, respectively. By increasing the annual acreage harvested to 500 acres, these costs were reduced to \$90.47 and \$82.83 per ton for the same models. Mechanical harvesting was more expensive than the manual method (\$79.76 per ton) regardless of which depreciation period was chosen.

Model 3 had a 5-year depreciation period, 387.54 pounds (shelled) output per hour per combine, and a 750-hour season. Model 4 was based on a 10-year depreciation period. In Model 3, hand and machine harvesting costs were the same (\$79.76 per ton) when 345 tons were harvested annually. When 400 and 500 tons were harvested annually, costs per ton dropped to \$72.38 and \$70.35, respectively. When the same tonnages were harvested, there were savings per ton of \$7.38 and \$9.41, respectively, by using the FMC combine. With a depreciation period of 10 years, hand and machine harvesting costs were the same when 300 tons were harvested annually. When 400 and 500 tons were harvested annually, there were savings of \$12.20 and \$14.34 per ton, respectively, over the manual method.

Hand and machine harvesting costs for only one combine with a 5- and 10-year depreciation period, and 400 pounds output per hour, were the same when 134 and 118 tons, respectively, were harvested.

Combines were operating at maximum capacity in this study when the season length was 750 hours and the output per hour per combine was 638 pounds (shelled). For a 5-year depreciation period, mechanical harvesting costs per ton were equal to the manual method (\$79.76 per ton) when 145 tons were harvested annually. For a 10-year depreciation period, mechanical harvesting costs per ton were equal when 130 tons were harvested annually.

For comparative costs in harvesting, recovered yield per acre was estimated at 2,000 pounds (unshelled). Estimates were made to determine the amount of increased cost per acre when 10, 20, and 30 percent of the total yield was left in the field by the combines. For a 500-hour season and 387.54 pounds (shelled) output per hour per combine, harvesting costs per acre increased according to the following constants: \$16.67 for a 10 percent loss; \$37.50 for a 20 percent loss; and \$64.29 for a 30 percent loss. When 500 acres were harvested annually and the depreciation period was 5 years, harvesting costs per acre for 10, 20, and 30 percent losses were \$107.14, \$127.97, and \$154.76, respectively. For a 10-year depreciation period and 10, 20, and 30 percent losses, harvesting costs per acre were \$99.50, \$120.33, and \$147.12, respectively.

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APPENDIX

TABLE XX

FARM CHARACTERISTICS FOR THE TOP TEN COUNTIES IN THE SOUTHERN PEA
PRODUCING AREA, WEST TENNESSEE, 1968

County	Acreage Groups						Over 1,000
	0-49	50-99	100-179	180-259	260-499	500-999	
	<u>Size Distribution: Number of Farms</u>						
Crockett	711	360	226	82	96	31	11
Fayette	1,409	343	286	123	166	101	67
Gibson	1,292	769	525	186	181	69	15
Hardeman	653	255	272	133	143	88	37
Haywood	1,483	374	235	95	148	71	26
Lauderdale	1,084	264	228	101	102	66	27
Madison	1,258	289	185	92	117	64	47
Shelby	945	394	325	150	137	74	22
Tipton	1,258	289	185	92	117	64	47
Weakley	1,205	350	233	125	147	62	24
Total	11,298	3,687	2,640	1,179	1,354	690	323
	<u>Acreage of Cropland</u>						
Crockett	10,095	12,621	15,416	10,002	19,014	11,147	6,034
Fayette	19,025	7,789	10,465	7,504	15,867	22,203	36,568
Gibson	15,226	23,031	33,819	20,109	37,373	23,198	11,026
Hardeman	9,786	4,878	7,378	5,710	10,028	10,658	8,768
Haywood	22,094	12,348	13,090	9,163	25,865	23,367	14,034
Lauderdale	15,817	8,454	13,384	10,721	18,879	22,387	23,875
Madison	12,843	9,779	13,264	9,584	14,168	15,155	6,647
Shelby	11,668	7,412	9,222	6,968	17,812	24,509	37,022
Tipton	15,172	10,690	12,958	13,269	31,243	23,569	17,950
Weakley	4,954	14,793	24,039	16,242	21,058	11,504	2,358
Total	136,680	111,795	153,035	109,272	211,307	187,697	164,282

TABLE XX (Continued)

County	Acreage Groups					
	0-49	50-99	100-179	180-259	260-499	500-999
	Average Cropland Acres Per Farm					
Crockett	14.19	35.05	68.21	121.97	198.06	359.58
Fayette	13.50	22.70	36.59	61.00	95.58	219.83
Gibson	11.78	29.94	64.41	108.11	206.48	336.20
Hardeman	14.98	19.12	27.12	42.93	70.12	121.11
Haywood	14.89	33.01	55.70	96.45	174.76	329.11
Lauderdale	14.59	32.02	58.70	106.14	185.08	339.19
Madison	13.59	24.81	40.81	63.89	103.41	204.79
Shelby	9.27	25.64	49.84	75.73	152.33	382.95
Tipton	2.59	30.54	55.61	106.15	212.53	380.14
Weakley	7.64	22.44	48.56	82.86	134.12	294.97
Total	12.70	27.53	50.56	86.52	153.24	296.79
(Avg.)						
						548.54
						545.79
						735.06
						236.97
						539.76
						884.25
						302.13
						787.70
						747.91
						471.60
						579.97

Source: United States Bureau of the Census, United States Census of Agriculture: 1964, Tennessee (Washington: Government Printing Office, 1967), pp. 275-83.

TABLE XXI
PERFORMANCE OF MANUAL HARVESTERS^a

Number of Workers	Yield Per Acre (Pounds) ^b					
	600	900	1200	1500	1800	2100
1	20.25	24.49	28.18	31.87	35.22	38.28
5	101.25	122.45	140.90	159.35	176.10	191.40
10	202.50	244.90	281.80	318.70	352.20	382.80
15	303.75	367.35	422.70	478.05	528.30	574.20
20	405.00	489.80	563.60	637.40	704.40	765.60
25	506.25	612.25	704.50	796.75	880.50	957.00
30	607.50	734.70	845.40	956.10	1056.60	1148.40
40	810.00	979.60	1127.20	1274.80	1408.80	1531.20
50	1012.50	1224.50	1409.00	1593.50	1761.00	1914.00
60	1215.00	1469.40	1690.80	1912.20	2113.20	2296.80
70	1417.50	1714.30	1972.60	2230.90	2465.40	2679.60
80	1620.00	1959.20	2254.40	2549.60	2817.60	3062.40
90	1822.50	2204.10	2536.20	2868.30	3169.80	3445.20
100	2025.00	2449.00	2818.00	3187.00	3522.00	3828.00
Output Per Man-Hour (Pounds)						
1	46.41	43.87	41.15	38.28	35.22	31.87
5	232.05	219.35	205.75	191.40	176.10	159.35
10	464.10	438.70	411.50	382.80	352.20	318.70
15	696.15	658.05	617.25	574.20	528.30	478.05
20	928.20	877.40	823.00	765.60	704.40	637.40
25	1160.25	1096.75	1028.75	957.00	880.50	796.75
30	1392.30	1316.10	1234.50	1148.40	1056.60	956.10
40	1856.40	1754.80	1646.00	1531.20	1408.80	1274.80
50	2320.50	2193.50	2057.50	1914.00	1761.00	1593.50
60	2784.60	2632.20	2469.00	2296.80	2113.20	1912.20
70	3248.70	3070.90	2880.50	2679.60	2465.40	2230.90
80	3712.80	3509.60	3292.00	3062.40	2817.60	2549.60
90	4176.90	3948.30	3703.50	3445.20	3169.80	2868.30
100	4641.00	4387.00	4115.00	3828.00	3522.00	3187.00
Hours Per Acre						
1	64.64	61.55	58.32	54.86	51.11	47.07
5	12.93	12.31	11.66	10.97	10.22	9.41
10	6.46	6.15	5.83	5.49	5.11	4.71
15	4.31	4.10	3.89	3.66	3.41	3.14
20	3.23	3.08	2.92	2.74	2.56	2.35
25	2.59	2.48	2.33	2.19	2.04	1.88
30	2.15	2.05	1.94	1.83	1.70	1.57
40	1.62	1.54	1.46	1.37	1.28	1.18
50	1.29	1.23	1.17	1.10	1.02	0.94
60	1.08	1.03	0.97	0.91	0.85	0.78

TABLE XXI (Continued)

Number of Workers	Yield Per Acre (Pounds) ^b								
	600	900	1200	1500	1800	2100	2400	2700	3000
	Hours Per Acre								
70	0.42	0.52	0.61	0.67	0.73	0.78	0.83	0.88	0.92
80	0.37	0.46	0.53	0.59	0.64	0.69	0.73	0.77	0.81
90	0.33	0.41	0.47	0.52	0.57	0.61	0.65	0.68	0.72
100	0.30	0.37	0.43	0.47	0.51	0.55	0.58	0.62	0.65
	Acres Per Hour								
1	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
5	0.17	0.14	0.12	0.11	0.10	0.09	0.09	0.08	0.08
10	0.34	0.27	0.23	0.21	0.20	0.18	0.17	0.16	0.15
15	0.51	0.41	0.35	0.32	0.29	0.27	0.26	0.24	0.23
20	0.68	0.54	0.47	0.42	0.39	0.36	0.34	0.32	0.31
25	0.84	0.68	0.59	0.53	0.49	0.46	0.43	0.41	0.39
30	1.01	0.82	0.70	0.64	0.59	0.55	0.51	0.49	0.46
40	1.35	1.09	0.94	0.85	0.78	0.73	0.69	0.65	0.62
50	1.69	1.36	1.18	1.06	0.98	0.91	0.86	0.81	0.77
60	2.03	1.63	1.41	1.27	1.17	1.09	1.03	0.97	0.93
70	2.36	1.90	1.64	1.49	1.37	1.28	1.20	1.14	1.08
80	2.70	2.18	1.88	1.70	1.57	1.46	1.37	1.30	1.24
90	3.04	2.45	2.11	1.91	1.76	1.64	1.54	1.46	1.39
100	3.38	2.72	2.35	2.12	1.96	1.82	1.71	1.62	1.55

^a Synthesized from field observations, West Tennessee, 1968.

^b All numbers representing "pounds" are recorded for unshelled peas.

TABLE XXII

ESTIMATED TOTAL COST PER ACRE FOR HARVESTING SOUTHERN PEAS BY NUMBER OF ACRES HARVESTED,^a DEPRECIATION PERIOD, OUTPUT PER HOUR PER MACHINE AND LENGTH OF SEASON (HOURS), WEST TENNESSEE, 1968^b

Type of Cost ^c	Annual Acreage Harvested ^d									
	15	25	50	100	150	200	300	400	500	
	Dollars Per Acre									
	5-year depreciation period, 387.54-lb. output, 250-hr. season									
AFC	413.80	248.28	212.20	150.13	129.44	127.02	114.03	111.51	107.15	
AVC	59.03	59.03	40.23	34.85	31.52	32.14	30.00	29.63	29.73	
ATC	472.83	307.31	252.43	184.98	160.96	159.16	144.03	141.14	136.88	
	10-year depreciation period, 387.54-lb. output, 250-hr. season									
AFC	356.43	213.86	184.29	130.83	113.01	110.61	99.53	97.25	93.54	
AVC	59.03	59.03	40.23	34.85	31.52	32.14	30.00	29.63	29.73	
ATC	415.46	272.89	224.52	165.68	144.53	142.75	129.53	126.88	123.27	
	5-year depreciation period, 387.54-lb. output, 500-hr. season									
AFC	413.80	248.28	124.14	106.10	70.73	75.06	64.72	63.51	59.62	
AVC	59.03	59.03	59.03	40.23	40.23	34.85	31.52	32.14	30.85	
ATC	472.83	307.31	183.17	146.33	110.96	109.91	96.24	95.65	90.47	
	10-year depreciation period, 387.54-lb. output, 500-hr. season									
AFC	356.43	213.86	106.93	92.15	61.43	65.41	56.50	55.31	51.98	
AVC	59.03	59.03	59.03	40.23	40.23	34.85	31.52	32.14	30.85	
ATC	415.46	272.89	165.96	132.38	101.66	100.26	88.02	87.45	82.83	

TABLE XXII (Continued)

Type of Cost ^c	Annual Acreage Harvested ^d									
	15	25	50	100	150	200	300	400	500	
	<u>Dollars per Acre</u>									
	<u>10-year depreciation period, 638-lb. output, 500-hr. season</u>									
AFC	356.43	213.86	106.93	53.46	35.64	46.07	30.73	32.71	33.90	
AVC	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>24.48</u>	<u>24.48</u>	<u>21.07</u>	<u>19.06</u>	
ATC	<u>392.24</u>	<u>249.67</u>	<u>142.74</u>	<u>89.27</u>	<u>71.45</u>	<u>70.55</u>	<u>55.20</u>	<u>58.78</u>	<u>52.96</u>	
	<u>5-year depreciation period, 638-lb. output, 750-hr. season</u>									
AFC	413.80	248.28	124.24	62.07	41.38	31.03	35.37	26.52	30.03	
AVC	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>24.48</u>	<u>24.48</u>	<u>21.07</u>	
ATC	<u>449.61</u>	<u>284.09</u>	<u>159.95</u>	<u>97.88</u>	<u>77.19</u>	<u>66.84</u>	<u>59.85</u>	<u>51.00</u>	<u>51.10</u>	
	<u>10-year depreciation period, 638-lb. output, 750-hr. season</u>									
AFC	356.43	213.86	106.93	53.46	35.64	26.73	30.72	23.04	26.17	
AVC	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>35.81</u>	<u>24.48</u>	<u>24.48</u>	<u>21.07</u>	
ATC	<u>392.24</u>	<u>249.67</u>	<u>142.74</u>	<u>89.27</u>	<u>71.45</u>	<u>62.54</u>	<u>55.20</u>	<u>47.52</u>	<u>47.24</u>	

^a Costs per ton and costs per acre may be used interchangeably since yield per acre was specified to be 2,000 pounds (unshelled).

^b Based on a yield per acre of 2,000 pounds (unshelled), 60.0 percent shell-out, Tables XIII and XVII, pages 41 and 47, respectively, and bulk dump.

^c AFC = Average Fixed Cost; AVC = Average Variable Cost; and ATC = Average Total Cost.

^d Synonymous to annual tonnage harvested.

TABLE XXIII

NUMBER OF COMBINES REQUIRED TO HARVEST SOUTHERN PEAS BY LENGTH
OF SEASON, OUTPUT PER HOUR PER COMBINE, AND ANNUAL
TONNAGE HARVESTED, 1968

Annual Tonnage	Length of Season (Hours)		
	250	500	750
Number of Combines Required at 387.54 Pounds Output Per Hour			
15	1	1	1
25	1	1	1
50	2	1	1
100	3	2	1
150	4	2	2
200	5	3	2
300	7	4	3
400	9	5	3
500	11	6	4
At 638 Pounds Output Per Hour			
15	1	1	1
25	1	1	1
50	1	1	1
100	2	1	1
150	2	1	1
200	3	2	1
300	4	2	2
400	6	3	2
500	7	4	3

CRANES ST. REST

VITA

Carlton Joe McKenzie was born in Big Sandy, Tennessee, on August 7, 1942. He was educated in the elementary schools of that city and was graduated from Big Sandy High School in 1961. The following September he entered The University of Tennessee at Martin. Combined intervals of public work and education resulted in his receiving the Bachelor of Science degree in General Agriculture in March, 1967. He subsequently entered the Graduate School of The University of Tennessee at Knoxville. In March, 1969, he received his Master of Science degree in Agricultural Economics.

He is married to the former Martha Lee Fitchpatrick of Big Sandy, Tennessee.