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A Computer Model for Analysis of Alternative Burley Tobacco Harvesting Practice

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TOBACCO in KENTUCKY

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by T.C. Bridges, L.G. Wells, G.A. Duncan and L.D. Swetnam

Introduction

Agricultural operations and practices have been the subject of many computer models and simulations. Holtman et al. (1970) developed a corn harvesting simulator, and Morey et al. (1971) used simulation techniques to analyze net profit of a corn harvesting and handling system during a particular weather year. Further, Loewer et al. (1977) advanced a model that assessed alternative beef production strategies for the individual farm with land, energy and capital as constraints. Bridges et al., (1979) developed a design simulation oriented toward the individual producer that examines corn harvesting systems and compares them regarding investment and annual cost. The CATCH (**C**omputer **A**nalysis of **T**obacco **C**utting and **H**ousing) simulation model (Bridges et al., 1980) was written to apply similar principles to the analysis of burley tobacco systems.

When the original CATCH model was developed, most burley tobacco was harvested by conventional methods which required little machine input and a substantial amount of labor. With the development of several alternative practices that can be used for harvesting and housing burley tobacco, the burley producer is now faced with several management decisions. If labor is a constraint, which system alternatives are best suited to work within the producer's labor force? At what point does a harvester system become economically feasible if lack of available workers causes the value of labor to increase dramatically? Consideration should be given to the amount of investment capital the producer is willing to spend and the type of curing facility desired.

To incorporate these considerations and provide individual producers with management information for given production situations, a revised computer model named CATCH22 has been developed and includes the latest alternative systems. This report provides a description of the model's capabilities and the management information it provides.

Program Capabilities

CATCH22 performs the following functions:

1. Examines and designs 50 alternative burley tobacco cutting and housing systems to meet system requirements imposed by the individual producer.
2. Performs a selective cost ranking of the 50 alternative systems considered.
3. Presents equipment and labor resources required by each system.

System Description and Flow Network

Figure 1 shows the various methods for cutting, transporting and housing burley tobacco examined in the CATCH22 model. These are identified in Table 1, along with work rates, capacities, necessary crew sizes and field efficiencies used for system analysis. Capacities and work rates for the conventional methods are stated in sticks or sticks per hour; those for the plant-notching systems (Powell and UK automated prototype) are in plants and plants per hour. The conventional tobacco stick is assumed to contain six plants.

The first three harvesting practices shown in Table 1 require the use of the stick; whereas, the Powell system (Casada et al., 1987) and the automated prototype system (Wells et al., 1990) deal directly with the plant. The conventional transportation methods are: flatbed wagon with tractor, flatbed truck, two-wheel rail wagon and tractor, portable curing frames (Yoder and Henson, 1972), cantilever beams with carrier (Walton et al., 1993), and cable hoist beams with carrier. The automated systems require a tractor and front-end loader for both the Powell frames and the automated harvester frames. Capacities, work rates and crew sizes for each transportation method are shown in Table 1. There are 10 possible curing facility options (Table 1), and capacities, filling rates and crew sizes are stated per barn bent or unit of storage. Options requiring conventional stick handling include a conventional four- to six-tier barn, two-tier forced-air barn, pole-type barn for the portable curing frames, tiered field curing structure holding conventional sticks (Walton et al., 1993), field curing structure holding cantilever beams (Walton et al., 1993), post-row field curing structure (Duncan and Isaacs, 1993), retrofitted cable hoist barn and new cable hoist barn. Frames for the Powell and automated harvesters generally are not moved to a storage structure but do require a protective cover while the tobacco is cured. Coverage options are a six-mil polyester plastic for the Powell frames and three-layer typar cover for the automated prototype frames.

The beginning point for system analysis is the point when the tobacco is ready for harvest, and the finish point is the time at which the tobacco is placed in the curing facility or under a protective cover. The program calculates a design harvest rate from producer inputs, and this rate is used to determine the necessary equipment and labor requirements for each feasible system. Equipment is selected for each system such that the capacity of the component equals or exceeds the design harvest rate. Storage capacity for each type of curing facility is based on total crop production

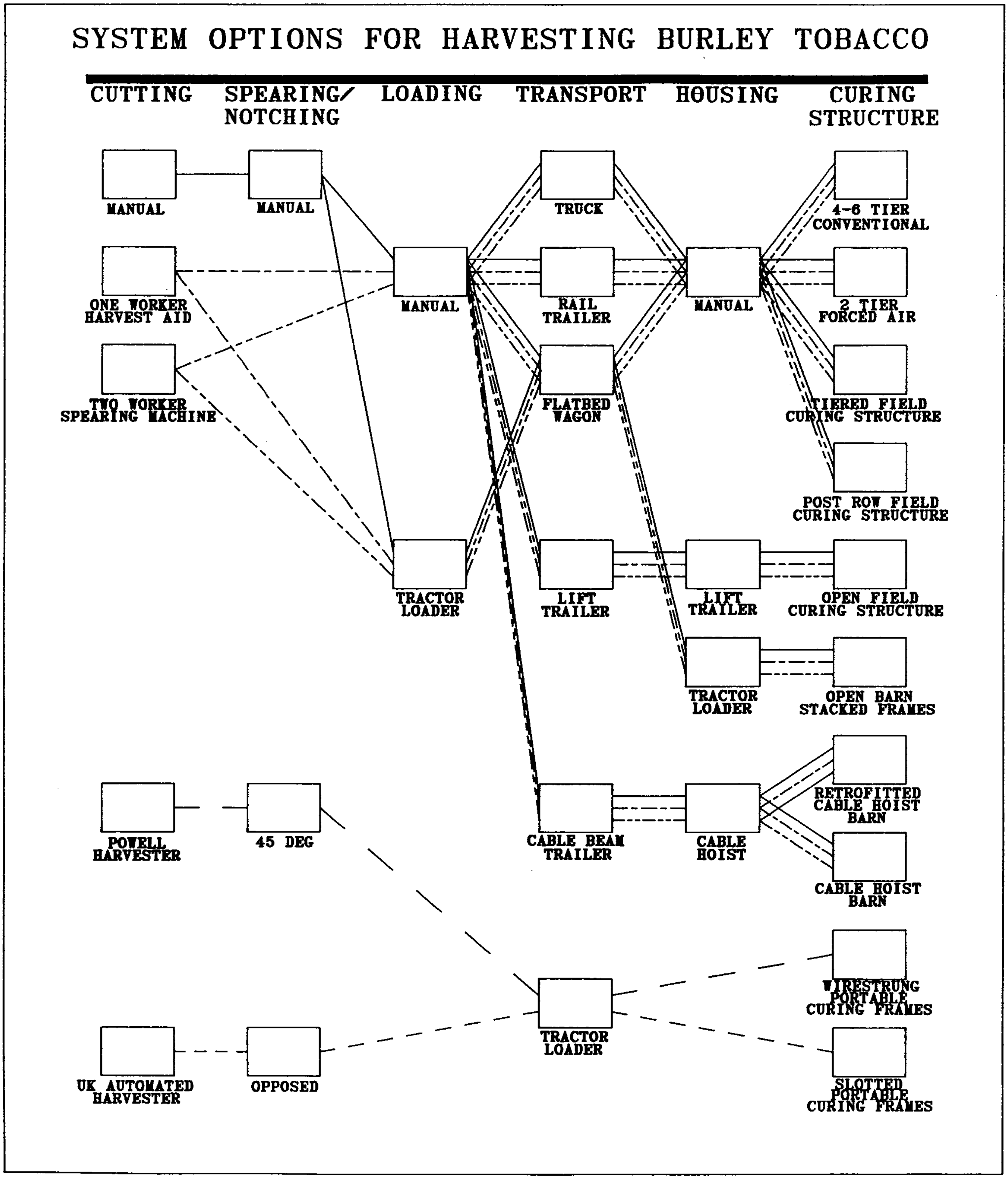

Figure 1. The flow network of the various harvesting options analyzed by CATCH22.

specified by the producer. Labor requirements for each alternative system are determined using the crew size necessary to complete each task at the design harvest rate. The work rates and capacities for the various tasks (Table 1) are average values and are based on observations reported by Wells and Miyake (1977) and Duncan, et al. (1991). When assigning labor to a system, CATCH22 assumes sufficient labor is available regardless of the specified harvest rate. The number of transportation units for each system is calculated using a procedure advanced by Hunt (1973) which determines sufficient vehicles to sustain the producer-imposed harvest rate. Each

Table 1. Alternative harvesting, transport and housing methods and associated work attributes[1] used in CATCH22

Harvesting Method	Harvest Rate		Crew Size wkrs	Field Eff., %
1. Manual cutting	100 stks/hr		1	75
2. One-worker harvest aid	120 stks/hr		1	85
3. Two-worker spearing machine	200 stks/hr		2	85
4. Powell harvester with tractor	1,485 plants/hr		5	85
5. UK automated prototype harvester	3,586 plants/hr		2	85
Transport Method	**Transport Capacity**	**Vehicle Loading Rate**	**Crew Size wkrs**	**Field Eff., %**
1. Flatbed wagon and tractor	120 stks	415 stks/hr	3	85
2. Flatbed truck	200 stks	415 stks/hr	3	85
3. Two-wheel rail wagon and tractor	130 stks	332 stks/hr	2	85
4. Portable curing frames and wagon[2]	34 stks	432 stks/hr	4	85
5. Cantilever beam and carrier	120 stks	327 stks/hr	2	85
6. Cable hoist beam and carrier	45 stks	327 stks/hr	2	85
7. Tractor and loader for Powell frames	--	--	1	85
8. Tractor and loader for automated frames	--	--	1	85
Housing Method[3]	**Unit Capacity**	**Filling Rate**	**Crew Size wkrs**	**Field Eff. %**
1. Four- to six-tier conventional barn bent	770 stks	480 stks/hr	4	75
2. Two-tier forced-air barn bent	504 stks	360 stks/hr	2	80
3. Open interior barn bent (portable curing frames)	462 stks	408 stks/hr	1	80
4. Tiered field curing structure section	160 stks	415 stks/hr	2	85
5. Field curing structure section (cantilever beams)	120 stks	1,320 stks/hr	2	90
6. Post-row field structure section	71 stks	327 stks/hr	2	90
7. Retrofitted cable hoist barn bent	700 stks	648 stks/hr	1	90
8. New cable hoist barn bent	1,020 stks	648 stks/hr	1	90
9. Wire strung frames for Powell system	264 plants	harvester rate	--	--
10. Slotted frames for automated harvester	450 plants	harvester rate	--	--

[1]Conventional system capacities and rates are stated in sticks (stks) or sticks per hour; plant-notching system capacities and rates are stated in plants or plants per hour.
[2] Capacity and fill rate refer to the pallet frames and not the wagon used for transport.
[3] Capacities, fill rates and crew sizes are per barn bent for conventional systems and per unit or frame for plant-notching systems.

system CATCH22 designs is a feasible alternative and an acceptable practice for harvesting burley tobacco.

Program Inputs

The CATCH22 model was designed to be a producer-oriented model and to provide management information for the individual tobacco farmer. To accomplish this objective, input information was restricted to that which the producer could readily supply. Input parameters that pertain to a particular farm include: conventional row and plant spacing in inches, estimate of the crop stand in percent, row and plant spacing for the automated harvesters in inches, total conventional acres of production, desired number of harvest days, length of the working day in hours, crop yield in pounds per acre, average wage rate in dollars per hour, average one-way transport distance from field to curing facility in miles and local cost of gasoline in dollars per gallon. Input parameters pertaining to program output include selection of a ranking variable and optional investment cost ranking. The ranking variable determines the basis for which the annual cost ranking of systems is shown on output. These choices are: 1 for cents per stick, 2 for cents per pound and 3 for dollars per acre.

Two distinct harvest rates are used in the model to design and select equipment and labor for each system. For conventional systems, the CATCH22 model uses conventional row and plant spacing and percent stand to determine the number of plants and conventional sticks for the total acreage and on a per acre basis. This allows the model to define the capacity and work rate for each conventional system component in Table 1 in terms of the producer's actual plant population. A design harvest rate (acres per day) is then determined from the total crop acres and the desired number of harvest days.

For the plant-notching systems (Powell and the automated prototype), the model determines the plant population from the harvester row and plant spacing inputs and the percent stand. The recommended row and plant spacing for plant-notching harvesters is 42 by 24 inches. Generally this plant spacing of 24 inches is greater than that specified for most conventional crops. This larger spacing means fewer plants per acre and a reduction in total crop poundage. If the conventional plant spacing is less than the harvester value of 24 inches, an equivalent acreage is determined by CATCH22 for the plant-notching systems to yield the same number of pounds as the conventional crop. The equivalent harvester acreage is determined by increasing the conventional acreage by a factor of 1.06, and the design harvest rate (acres per day) for the plant-notching systems is based on the increased acreage and desired number of harvest days. The percent crop stand is assumed to be the same for both conventional and harvester crop sizes.

Economic Considerations

Equipment for each alternative system in CATCH22 is selected based on the design harvest rate specified by the producer. Upon completion of analysis, the model compares each system with respect to investment, annual and labor costs. Investment costs determined by the model are considered for new equipment, and cost and economic life of the various equipment items used in CATCH22 are listed in Table 2. Representative manufacturer's list prices were used where available to determine the costs in Table 2, with the remainder being obtained from Duncan (1995), Swetnam (1995) and Nutt et al. (1990). The costs of curing facilities include construction costs. Tractors are assigned by size as follows: for transport to and from the curing facility, 50 horsepower (hp) unit; for use with the Powell loader, 70 hp; and for use with the automated prototype loader, 100 hp. Tractor investment costs were determined at $300 per horsepower.

The annual fixed cost of each equipment item is determined by summing the yearly depreciation based on the economic life of the item (Table 2), the interest cost of the investment and a charge for taxes, insurance and housing. The model uses a straight-line method of depreciation, a 10 percent interest rate and a value of 2 percent of the investment cost for taxes, insurance and housing to determine an item's annual cost. The salvage value of each item is assumed to be 10 percent of the investment cost unless the item has an initial value of $400 or less, at which time this value becomes zero (Nutt et al.,1990).

The total annual cost of a system includes the fixed cost of equipment as well as the operating cost and a labor charge associated with each practice. Operating costs are the sum of an energy charge plus a maintenance or repair charge for equipment based on the value of the item. The labor charge for each task is calculated based on the number of workers assigned to perform each task, average work rate to accomplish the task and hourly wage rate specified by the producer.

Program Aspects

The program begins analysis of the harvesting network (Figure 1) by determining the necessary number of harvesters to meet the design harvest rate specified by the producer. The required number of harvesters (including manual laborers) is based on the effective work rate and field efficiency of each harvester type (Table 1) and the design harvest rate. If the work rate of a particular harvester is not sufficient to meet the design rate for the daily harvest period, the number of harvesters is incremented by one until this requirement is satisfied. Labor requirements for harvesting are based on the required number of harvesters and their specified crew size.

After completion of the harvest section, the program determines the necessary capacity for each type of curing facility. For conventional systems, this curing capacity is stated in barn bents, with the total number determined by the capacity of these sections (Table 1) and total crop production. Once the required number of bents is known, the investment and annual costs of the curing facility (Table 2) are calculated along with worker-hours of labor necessary to house or fill this type of barn. The worker-hours of labor for a particular facility are dictated by the fill rate of the barn, number of workers per crew (Table 1) and specified harvest rate. If the rate of the barn crew doesn't meet the harvest rate for the specified harvest day, the crew size is incremented by one until this requirement is met. The model determines and keeps account of the daily worker-hours of labor and the required number of barn crews as well as the costs associated with each type of curing facility. For automated harvesting systems, the model determines the number of frames required to hold the entire crop and computes the amount of coverage and required hours of labor for covering.

After analysis of each curing facility, the program cycles through feasible alternative transportation methods between each harvester and curing option and determines the number of hauling units needed to sustain the harvest rate. The number of transport vehicles is a function of the time required to load the vehicle, the total time for field and road travel, any waste time that may be lost positioning wagons and opening gates, etc. and the unloading time at the curing facility. Vehicle loading time is based on the specified harvest rate and the work-rate (Table 1) for the particular type of transportation unit. Loading crews for each vehicle type are determined such that the design harvest rate is satisfied, and transport drivers are assigned based on the number of transport vehicles minus one. If only one hauling vehicle is required, no drivers are assigned, assuming the loading crew travels with the vehicle. Worker-hours for transport are based on an average on-farm travel speed of 5 mph, the average one-way transport distance input by the producer and the number of loads per day. A minimum number of transportation units is determined by CATCH22 for each conventional transport method excluding the pallet frames. For the plant-notching systems and conventional pallet frames, the program does not consider transport as a function of harvest rate. The assumption is that the frames (or pallets) need only be loaded at the harvest rate and can be transported to storage and/or covered at the producer's convenience. One consideration in use of the Powell harvesting system is that the frames cannot stand alone in the field and require stacking in a storage location preferably at the edge of the field. The CATCH22 program assigns one tractor and loader per Powell harvester for supplying empty frames and removing filled frames to the storage location. Based on the average harvest rate for the Powell machine (Table 1), it would require 10 to 11 minutes to fill a frame. If travel time to and from the producer's storage location becomes larger than this amount, an additional loader may be necessary for this system to sustain the harvest rate.

As each transportation method is analyzed, CATCH22 determines the investment and annual costs of each method. The investment costs of each method include cost of the hauling vehicles as

Table 2. Investment costs and economic life of various equipment items used in CATCH22		
Harvesters	**Investment Cost, $**	**Economic Life, Years**
1. Manual cutting	0.0	--
2. One-worker harvest aid	6,000	7
3. Two-worker spearing machine	15,000	7
4. Powell harvester	30,000	12
5. UK automated prototype harvester	100,000*	10
Transporters[1]	**Investment Cost, $**	**Economic Life, Years**
1. Flatbed wagon	1,000	12
2. Flatbed truck	18,000	12
3. Two-wheel rail wagon	400	10
4. Loader for portable curing frames	4,000	12
5. Cantilever beam carrier	3,500	12
6. Cable hoist beam carrier	350	10
7. Loader for Powell frames	5,000	12
8. Loader for automated harvester frames	6,000	12
Housing Types	**Investment Cost, $**	**Economic Life, Years**
1. Four- to six-tier conventional barn bent	2,800	40
2. Two-tier forced-air barn bent	3,100	40
3. Open interior barn bent (portable curing frames)	2,200	40
4. Tiered field curing structure section	161	20
5. Field curing structure section (cantilever beams)	161	20
6. Post-row field structure section	55	10
7. Retrofitted cable hoist barn bent	700	20
8. New cable hoist barn bent	3,700	20
Frame Types	**Investment Cost, $**	**Economic Life, Years**
1. Pallet frames	50	15
2. Cantilever beams	30	15
3. Cable hoist beams	38	15
4. Powell frames	75	7
5. Automated prototype frames	350*	15
Auxiliary Items	**Investment Cost, $**	**Economic Life, Years**
1. Hoist for cable hoist system	4,000	10
2. Conventional tobacco sticks	0.18	10
3. Hi-boy for stick dropping	5,000	12
4. Six-mil polyester plastic for Powell frames	0.02 $ per sq. ft.	1
5. Three-layer typar cover for automated frames	0.09 $ per sq. ft.	5

** Estimated costs when in production.*

[1] Tractors are assigned by size in CATCH22 as follows: for transport, 50 hp; for Powell loader, 70 hp; and for the automated loader, 100 hp. Investment costs for tractors are assigned at $300 per horsepower.

well as that of any needed tractors. The annual cost of each method includes operating costs and fixed cost of the equipment. However, only a portion of the fixed cost of tractors, trucks, and flatbed wagons is assigned to the annual cost for the tobacco operation. This portion is defined as twice the number of harvest days divided by 365, based on the assumption that one out of every two days will be a good harvest day and that these items will be used in other farm operations.

Once the analysis of all systems is complete, CATCH22 totals the costs and equipment for each. The program also determines the number of men required per day for each system based on the design harvest rate and the necessary crew(s) required to complete each task. The cost of labor for each system is calculated using the producer's wage rate and total worker-hours required to harvest the crop with that system. This cost, in addition to fixed and operating costs of the equipment, is included in the annual cost of a particular system.

Program Use and Considerations

An **example** producer's data set used to demonstrate the model is presented in Table 3, and the sample output from that run is shown in Appendices 1-3. Information presented in the sample output corresponds to these input parameters *only* and is not applicable to all burley harvesting situations. With the reduction of available labor in recent years and increased wages, CATCH22 allows the producer to consider the trade-offs between labor availability, labor costs and equipment costs. Listed in Appendices 1-3 is the necessary equipment, labor and cost information for each alternative system determined by the CATCH22 model and an economic ranking of all 50 systems.

Table 3. Sample input data set for CATCH22

T.C. BRIDGES	User Name
42	Conventional row spacing, inches
18	Conventional plant spacing, inches
97.5	Percent stand, %
42	Harvester row spacing, inches
24	Harvester plant spacing, inches
10.0	Conventional acreage
4.0	Days to harvest
10.0	Hours per workday
2,500.0	Yield, lb/ac
7.00	Average wage rate, $/hr
0.75	Average one-way travel distance, miles
1.00	Fuel cost, $/gal
1.0	Rank Variable, 1 for c/stk, 2 for c/lb, 3 for $/ac
N	Y for investment cost ranking, N for no ranking

The initial portion of Appendix 1 presents input harvest parameters used for the example producer's harvest situation (Table 3). The example shown is for a 10-acre crop to be harvested in four days which sets the harvest rate for the conventional systems to be 2.5 acres per day. The harvest rate for the plant-notching machines is determined to be 2.65 acres per day based on the increased crop size of 10.6 acres (as discussed earlier). Other pertinent parameters include an average wage rate of $7 per hour, an average one-way transport distance of 0.75 miles, a 10-hour workday and a local fuel cost of $1 per gallon. Listed with conventional crop parameters is the total number of plants and sticks for the specified acreage. The CATCH22 program also determines the total number of plants and an **equivalent** number of sticks for the harvester acreage. The equivalent number of sticks provides a comparison basis with conventional systems.

Following the harvest parameters in Appendix 1 is design and cost information for the conventional and plant-notching harvesters. Information shown with each harvester includes the required number, the investment and fixed cost, the crew size, the labor cost for harvest, an annual cost in cents per stick or stick equivalent and the harvester efficiency (%). The annual cost for each harvester includes the fixed cost of the machine(s), an estimate of the operating costs and the cost for labor. Below the conventional harvesting systems is a footnote indicating that a charge of $337 for stick dropping in this example is included in the labor cost for manual cutting. An additional item shown with the plant-notching harvesters is the number of frames required for the entire crop and their associated cost is included in the system investment and fixed cost. The efficiency listed with each harvester type (including manual) is indicative of how well the number of harvesters satisfies the design harvest rate. A higher efficiency (as with the two-worker spearing machine) indicates the capability of the harvester(s) is well matched to the design harvest rate. A lower efficiency, as shown with the automated harvester, indicates there is reserve capacity and the harvester(s) is working for only a portion of the day.

Appendix 2 presents the housing, frame or carrier information for the example producer situation in Table 3. Information for conventional housing design is shown initially and includes the number of barn bents of storage, the number of frames or carriers (if any), the investment and fixed cost for each structure, the crew size for filling at the design harvest rate, the cost for labor, an annual cost in cents per stick and a crew efficiency. The cost of conventional sticks is included in the investment and fixed cost of each structure. The annual cost for each housing option includes the fixed cost of the structure and frames or carriers plus the cost for labor and is compared on a per stick basis. Crew efficiency shows how well the required crew size satisfies or matches the design harvest rate, with a low efficiency indicating that the crew is not busy the entire harvest day. The example output in Appendix 2 shows that three of the conventional housing crews are above 90 percent in efficiency while the remainder are below 60 percent for the specified inputs. Below the conventional housing information (Appendix 2) is required number and cost information relative to conventional pallet frames, cantilever beams and cable hoist beams. This is followed by the amount, cost and labor requirements for covering the frames in the Powell and automated systems.

The economic ranking of the 50 systems determined by CATCH22 for the example production situation is shown in Appendix 3. Systems are ranked by annual cost from the least to the most expensive. Our example producer has selected cents per stick as the ranking variable (Table 3). The ranking information is as follows: system rank which identifies the position in the ranking, total investment, annual and labor cost, ranking variable (annual cost in cents per stick for this example), required number of workers and transport vehicles to sustain the harvest rate and overall efficiency for the entire work crew. Below each line showing the system cost and labor information is the system identification which describes the type of harvester, transport and housing component for the system at the current rank. The investment cost of the individual systems may seem expensive, but remember this value includes the "new" cost of all equipment including any tractors required by the system. The annual cost value includes an annual charge for all equipment, a charge for labor and the cost for operation and repair of the various equipment. The annual cost provides a better basis for economic comparison of systems than the investment value because it takes into account longevity of equipment and various labor and operating expenses associated with a given system.

The ranking shown in Appendix 3 exemplifies the set of input conditions in Table 3. For the example, the first six systems are within 5 cents per stick of one another in annual cost. This indicates that any of these would be suitable selections in terms of cost. These systems contain manual harvesting and lower cost housing facilities (post-row and tiered field curing structures); for most situations where labor is available, these systems will be favorable in cost comparisons. Available space is one consideration when selecting the post-row and tiered field curing structures. Using the recommendations in ID-116 (Duncan and Isaacs, 1993), seven sections of a post-row field structure require 96 feet of length. From the example in Appendix 3, 190 post-row sections are required to contain the 10-acre crop. If these sections were placed end to end, it would require a structure almost one-half mile in length. If these sections were placed in a four-row by seven-section configuration and allowing for nine feet on each side, 18 feet between the rows and 30 feet on either end for turning space, an area of approximately 0.25 acre would be required. This amount of space may not be feasible for many farm situations in Kentucky, and the producer may need to consider other housing options in larger crop situations.

Labor is always an important consideration with burley harvesting systems because these systems (especially the conventional options) tend to be labor intensive. Included in the annual cost ranking with each system (Appendix 3) are the required crew size, labor cost and overall crew efficiency. The total crew size includes workers for the various tasks of harvest, loading and transport and for filling the curing facility. Except for transport, most of these tasks require a work crew. These crews are assigned by the model to accomplish each task at the harvest rate specified by the producer. The total crew size for a given system in Appendix 3 then is the total of all crews assigned to complete each task in the system. Labor costs for each system are based on total worker-hours required to complete harvest and the hourly wage, not the actual number of harvest days. A percent utilization of the overall work crew is determined by dividing the total worker-hours for all tasks by the total worker-hours to complete harvest (i.e., the product of the number of harvest days and the number of hours per workday). This value gives some indication of the total worker efficiency with a higher percentage indicating better labor utilization by a particular system. For most systems analyzed by CATCH22, the overall efficiency value will never attain 100 percent because all crews do not work at the same rate. However, a lower utilization percentage, such as shown by system 6 (65 percent) in the example ranking (Appendix 3), indicates some reserve harvest capacity in this system and workers in tasks with less utilization may be allocated to other portions of the harvest operation. For example, system 6 (Appendix 3) uses the post-row field structure as the housing option. The housing crew efficiency is 57.3 percent (Appendix 2) for this option, indicating that some of the workers could be available for a portion of the workday for loading and transport.

The typical tobacco production situation in Kentucky is smaller than the example shown here. However, with increased leasing and the possibility that someday the burley allotment program may be removed by the government, the likelihood of larger crops and higher harvest rates is more conceivable than in the past. A concern as production capacities and harvest rates tend to increase is the large amount of workers needed for these labor intensive systems. The example production output shown (Appendices 1-3) is for a relatively high harvest rate of 2.5 acres per day, and, as the annual cost ranking shows, most of the systems require 10 or more laborers to complete harvest. The plant-notching harvesters (Powell and automated) were developed to provide higher harvesting capacity and to address the labor problem, but these systems were ranked 49th and 50th respectively in our cost example. A preliminary study (Bridges, et al., 1995) comparing the plant-notching systems with a conventional system containing manual cutting, flatbed wagons and a four- to six-tier conventional barn found that the Powell system became less expensive than the conventional system on an annual cost basis for a crop size of 20 acres and a harvest rate of two acres per day. As the harvest rate increased to five acres per day, the Powell system required a crop size of 50 acres to become less expensive. Crop sizes of 75 to 100 acres were required for the automated prototype to be cost competitive with the conventional system. However, this study also determined that a labor requirement of 25 workers was necessary for the conventional system to harvest 50 acres at five acres per day; whereas the Powell and automated systems required 15 and four workers respectively.

CATCH22 is a deterministic model that reflects the decisions of the individual producer. While the model is deterministic, the program has the added flexibility of multiple analyses of a particular burley operation. This flexibility allows a producer to vary certain input parameters (Table 3) and determine the effects of these variations on system costs in the economic rankings. One example of this is to vary harvest rate and/or length of the harvest day and examine the impact of the changes on the various equipment and labor for a given system. Another example is the variation of crop size or wage rate to ponder future situations and compare to the present. This added capability makes CATCH22 a powerful tool in aiding the producer in decision making.

Summary

The computer model CATCH22 was developed to provide the individual producer with comprehensive management information concerning burley tobacco harvesting systems. The program uses producer inputs to determine costs, equipment and labor for 50 alternative systems, and presents an economic ranking of all systems containing this information. This program allows the producer to concentrate on a system concept rather than the individual components that make up each system. The CATCH22 model is available from the Cooperative Extension Service, Biosystems and Agricultural Engineering Department, University of Kentucky.

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Appendix 1. Sample CATCH22 Output: Harvest Parameters and Harvester Design Information

Conventional Crop Parameters

Conv. Acreage = 10.0	Harvest Rate = 2.50 ac/day
Row Space = 42.0 in	Plant Space = 18.0 in
Plants per acre = 8089.7	Stks per acre = 1348.3
Per Cent Stand = 97.5	Total Sticks = 13483.

Harvester Crop Parameters

Harv. Acreage = 10.6	Harvest Rate = 2.65 ac/day
Row Space = 42.0 in	Plant Space = 24.0 in
Plants per acre = 6067.3	CHRAT Ratio = 1.06
Total Plants = 64313.2	Equivalent Sticks = 10719.

Harvest Parameters

Days To Harvest = 4.0	Hrs per workday = 10.0
Lbs Per Acre = 2500.0	Total Yield = 25000.0 lbs
Transport miles = .75	

Fuel and Labor Rates

Labor rate = 7.00 $/hr	Fuel = 1.00 $/gal

Conventional Harvesting Systems

	Harvesters (no)	Investment Cost ($)	Fixed Cost ($)	Crew Size (wkrs)	Labor Cost ($)	Annual Cost Cents per Stick	Harvester Eff. (%)
Manual Cutting	.0	.0	.0	5.	1595.5	11.9	89.9
One-Worker Harvest Aid	4.0	24000.0	4669.7	4.	925.3	42.6	82.6
Two-Worker Spearing Machine	2.0	30000.0	5837.1	4.	1110.4	52.2	99.1

NOTES: 1. The labor cost for manual cutting includes an additional charge of $ 337.07 for stick dropping.

Plant-Notching Systems

	Harvesters (no.)	Frames (no.)	Investment Cost ($)	Fixed Cost ($)	Crew Size (wkrs)	Labor Cost ($)	Annual Cost Cents per Stick Eq.	Harvester Eff. (%)
Powell Harvesting System	2.0	244.0	108300.0	12357.7	10.	1782.8	133.7	63.7
U.K. Automated System	1.0	143.0	150050.0	21939.7	2.	295.4	208.4	52.8

NOTES: 1. Powell System investment cost includes the cost of harvesters, pulling tractors and frames.
2. The Automated System investment cost includes the cost of harvesters and frames.
3. Tractor and loader costs for the plant-notching systems are included later in the transport analysis.
4. Annual cost per stick for the plant-notching systems is based on a total of 10719. equivalent conventional sticks.

Appendix 2. Sample CATCH22 Output:
Housing, Frame and Carrier Design Information

Conventional Housing Systems and Stick Carriers

Storage Bents (no)	Carriers (no)	Investment Cost ($)	Fixed Cost ($)	Crew Size (wkrs)	Labor Cost ($)	Annual Cost Cents per Stick	Crew Eff. (%)
Four- to Six-Tier Conv. Barn							
18.0	.0	52826.9	4848.7	4.	1048.7	43.7	93.6
Two-Tier Forced-Air Barn							
27.0	.0	86126.9	7795.8	4.	655.4	62.7	58.5
Open Interior Barn(Pallets)							
30.0	397.0	88276.9	8743.6	4.	1028.1	72.5	91.8
Tiered Field Curing Structure							
85.0	.0	16111.9	1893.7	2.	535.1	18.0	95.6
Field Structure(Cant. Beams)							
113.0	225.0	27369.9	3244.5	2.	158.9	25.2	28.4
Post-Row Field Structure							
190.0	.0	12876.9	2060.3	4.	641.4	20.0	57.3
Retrofitted Cable Hoist Barn							
20.0	300.0	31826.9	4010.3	1.	161.8	30.9	57.8
New Cable Hoist Barn							
14.0	300.0	69626.9	7040.6	1.	161.8	53.4	57.8

NOTES:1.The investment and fixed cost for conventional housing systems includes the cost for the bents of storage, sticks and carriers or frames.
2. The annual cost per stick is based on a total of 13483. sticks.

Conventional Frames or Carriers

	Storage Frames (no)	Investment Cost ($)	Fixed Cost ($)	Ann. Cost Cents per Stick
Pallet Frames	397.0	19850.0	2514.3	18.6
Cantilever Beams	225.0	6750.0	855.0	6.3
Cable Hoist Beams	300.0	11400.0	1444.0	10.7

Coverage for Plant-Notching Systems

	Coverage Amount (sq.ft.)	Investment Cost ($)	Fixed Cost ($)	Crew Size (wkrs)	Labor Cost ($)	Annual Cost Cents per Stick Eq.
Six-Mil Poly. Powell Frames	30500.0	610.0	646.6	3.	384.3	9.6
Typar for Automated Frames	40040.0	3803.8	989.0	3.	337.8	12.4

NOTES:1.Annual cost per stick for coverage of the plant notching frames is based on a total of 10719. equivalent conventional sticks.

Appendix 3. Sample CATCH22 Output:
Annual Cost Ranking of Alternative Systems
Systems are ranked from least cost to most expensive.

```
System Investment  Annual     Labor    Annual   Crew     Transport    Crew
 Rank     Cost      Cost      Cost      Cost    Size     Vehicles  Efficiency
          ($)       ($)        ($)     (c/stk) (wkrs)      (no.)       (%)

   1   75111.9    5275.7    3155.5     39.13    12.         3.      83.88
  System  1 I.D. is Manual Cutting
                    Flatbed Truck
                    Tiered Field Curing Structure

   2   71876.9    5548.7    3261.8     41.15    14.         3.      74.61
  System  2 I.D. is Manual Cutting
                    Flatbed Truck
                    Post-Row Field Structure

   3   85111.9    5657.2    3312.5     41.96    13.         4.      81.74
  System  3 I.D. is Manual Cutting
                    Flatbed Wagon
                    Tiered Field Curing Structure

   4   82711.9    5675.8    3139.4     42.10    14.         4.      71.49
  System  4 I.D. is Manual Cutting
                    Two-Wheel Rail Wagon
                    Tiered Field Curing Structure

   5   81876.9    5930.1    3418.7     43.98    15.         4.      73.37
  System  5 I.D. is Manual Cutting
                    Flatbed Wagon
                    Post-Row Field Structure

   6   79476.9    5948.7    3245.7     44.12    16.         4.      64.93
  System  6 I.D. is Manual Cutting
                    Two-Wheel Rail Wagon
                    Post-Row Field Structure

   7   68926.9    7406.8    2763.3     54.94    12.         6.      72.21
  System  7 I.D. is Manual Cutting
                    Cable Hoist Beam Carrier
                    Retrofitted Cable Hoist Barn

   8   87869.9    7993.4    2812.7     59.29    13.         3.      68.01
  System  8 I.D. is Manual Cutting
                    Cantilever Beam Carrier
                    Field Structure(Cant.Beams)

   9  111826.9    8744.3    3669.1     64.86    14.         3.      85.00
  System  9 I.D. is Manual Cutting
                    Flatbed Truck
                    Four- to Six-Tier Conv. Barn

  10  121826.9    9125.8    3826.0     67.68    15.         4.      83.07
  System 10 I.D. is Manual Cutting
                    Flatbed Wagon
                    Four- to Six-Tier Conv. Barn
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Appendix 3 Continued. Sample CATCH22 Output:
Annual Cost Ranking of Alternative Systems
Systems are ranked from least cost to most expensive.

System Rank	Investment Cost ($)	Annual Cost ($)	Labor Cost ($)	Annual Cost (c/stk)	Crew Size (wkrs)	Transport Vehicles (no.)	Crew Efficiency (%)
11	119426.9	9144.4	3653.0	67.82	16.	4.	74.02
System 11 I.D. is Manual Cutting Two-Wheel Rail Wagon Four- to Six-Tier Conv. Barn							
12	94111.9	9411.8	2485.4	69.81	11.	3.	80.69
System 12 I.D. is One-Worker Harvest Aid Flatbed Truck Tiered Field Curing Structure							
13	90876.9	9684.8	2591.6	71.83	13.	3.	71.20
System 13 I.D. is One-Worker Harvest Aid Flatbed Truck Post-Row Field Structure							
14	104111.9	9793.3	2642.3	72.63	12.	4.	78.64
System 14 I.D. is One-Worker Harvest Aid Flatbed Wagon Tiered Field Curing Structure							
15	101711.9	9811.9	2469.3	72.77	13.	4.	67.84
System 15 I.D. is One-Worker Harvest Aid Two-Wheel Rail Wagon Tiered Field Curing Structure							
16	100876.9	10066.2	2748.5	74.66	14.	4.	70.12
System 16 I.D. is One-Worker Harvest Aid Flatbed Wagon Post-Row Field Structure							
17	98476.9	10084.8	2575.5	74.80	15.	4.	61.32
System 17 I.D. is One-Worker Harvest Aid Two-Wheel Rail Wagon Post-Row Field Structure							
18	106726.9	10437.1	2763.3	77.41	12.	6.	72.21
System 18 I.D. is Manual Cutting Cable Hoist Beam Carrier New Cable Hoist Barn							
19	100111.9	10703.5	2670.4	79.39	11.	3.	86.70
System 19 I.D. is Two-Worker Spearing Machine Flatbed Truck Tiered Field Curing Structure							
20	96876.9	10976.4	2776.7	81.41	13.	3.	76.28
System 20 I.D. is Two-Worker Spearing Machine Flatbed Truck Post-Row Field Structure							

Appendix 3 continued. Sample CATCH22 Output:
Annual Cost Ranking of Alternative Systems
Systems are ranked from least cost to most expensive.

System Rank	Investment Cost ($)	Annual Cost ($)	Labor Cost ($)	Annual Cost (c/stk)	Crew Size (wkrs)	Transport Vehicles (no.)	Crew Efficiency (%)
21	110111.9	11084.9	2827.3	82.22	12.	4.	84.15
System 21 I.D. is Two-Worker Spearing Machine Flatbed Wagon Tiered Field Curing Structure							
22	107711.9	11103.6	2654.3	82.35	13.	4.	72.92
System 22 I.D. is Two-Worker Spearing Machine Two-Wheel Rail Wagon Tiered Field Curing Structure							
23	145126.9	11298.1	3275.8	83.80	14.	3.	74.97
System 23 I.D. is Manual Cutting Flatbed Truck Two-Tier Forced-Air Barn							
24	106876.9	11357.9	2933.6	84.24	14.	4.	74.84
System 24 I.D. is Two-Worker Spearing Machine Flatbed Wagon Post-Row Field Structure							
25	104476.9	11376.5	2760.6	84.38	15.	4.	65.73
System 25 I.D. is Two-Worker Spearing Machine Two-Wheel Rail Wagon Post-Row Field Structure							
26	87926.9	11542.9	2093.1	85.61	11.	6.	67.96
System 26 I.D. is One-Worker Harvest Aid Cable Hoist Beam Carrier Retrofitted Cable Hoist Barn							
27	155126.9	11679.6	3432.8	86.63	15.	4.	73.71
System 27 I.D. is Manual Cutting Flatbed Wagon Two-Tier Forced-Air Barn							
28	152726.9	11698.2	3259.8	86.76	16.	4.	65.24
System 28 I.D. is Manual Cutting Two-Wheel Rail Wagon Two-Tier Forced-Air Barn							
29	106869.9	12129.5	2142.5	89.96	12.	3.	63.76
System 29 I.D. is One-Worker Harvest Aid Cantilever Beam Carrier Field Structure(Cant.Beams)							
30	93926.9	12834.6	2278.2	95.19	11.	6.	73.97
System 30 I.D. is Two-Worker Spearing Machine Cable Hoist Beam Carrier Retrofitted Cable Hoist Barn							

Appendix 3 continued. Sample CATCH22 Output:
Annual Cost Ranking of Alternative Systems
Systems are ranked from least cost to most expensive.

System Rank	Investment Cost ($)	Annual Cost ($)	Labor Cost ($)	Annual Cost (c/stk)	Crew Size (wkrs)	Transport Vehicles (no.)	Crew Efficiency (%)
31	130826.9	12880.4	2998.9	95.53	13.	3.	82.39
System 31 I.D. is One-Worker Harvest Aid Flatbed Truck Four- to Six-Tier Conv. Barn							
32	114276.9	13041.9	3159.3	96.73	9.	2.	90.73
System 32 I.D. is Manual Cutting Pallet Frame Loader Open Interior Barn(Pallets)							
33	140826.9	13261.9	3155.8	98.36	14.	4.	80.51
System 33 I.D. is One-Worker Harvest Aid Flatbed Wagon Four- to Six-Tier Conv. Barn							
34	138426.9	13280.5	2982.8	98.50	15.	4.	71.02
System 34 I.D. is One-Worker Harvest Aid Two-Wheel Rail Wagon Four- to Six-Tier Conv. Barn							
35	112869.9	13421.2	2327.6	99.54	12.	3.	69.27
System 35 I.D. is Two-Worker Spearing Machine Cantilever Beam Carrier Field Structure(Cant.Beams)							
36	136826.9	14172.1	3184.0	105.11	13.	3.	87.47
System 36 I.D. is Two-Worker Spearing Machine Flatbed Truck Four- to Six-Tier Conv. Barn							
37	146826.9	14553.5	3340.9	107.94	14.	4.	85.23
System 37 I.D. is Two-Worker Spearing Machine Flatbed Wagon Four- to Six-Tier Conv. Barn							
38	144426.9	14572.2	3167.9	108.08	15.	4.	75.43
System 38 I.D. is Two-Worker Spearing Machine Two-Wheel Rail Wagon Four- to Six-Tier Conv. Barn							
39	125726.9	14573.2	2093.1	108.09	11.	6.	67.96
System 39 I.D. is One-Worker Harvest Aid Cable Hoist Beam Carrier New Cable Hoist Barn							
40	164126.9	15434.2	2605.7	114.47	13.	3.	71.58
System 40 I.D. is One-Worker Harvest Aid Flatbed Truck Two-Tier Forced-Air Barn							

Appendix 3 continued. Sample CATCH22 Output:
Annual Cost Ranking of Alternative Systems
Systems are ranked from least cost to most expensive.

```
System Investment  Annual     Labor     Annual   Crew    Transport    Crew
 Rank     Cost      Cost       Cost      Cost    Size    Vehicles  Efficiency
          ($)       ($)        ($)     (c/stk)  (wkrs)     (no.)       (%)

  41  174126.9   15815.7    2762.6    117.30    14.         4.      70.47
  System 41 I.D. is One-Worker Harvest Aid
                    Flatbed Wagon
                    Two-Tier Forced-Air Barn

  42  171726.9   15834.3    2589.6    117.44    15.         4.      61.66
  System 42 I.D. is One-Worker Harvest Aid
                    Two-Wheel Rail Wagon
                    Two-Tier Forced-Air Barn

  43  131726.9   15864.9    2278.2    117.67    11.         6.      73.97
  System 43 I.D. is Two-Worker Spearing Machine
                    Cable Hoist Beam Carrier
                    New Cable Hoist Barn

  44  170126.9   16725.9    2790.7    124.05    13.         3.      76.67
  System 44 I.D. is Two-Worker Spearing Machine
                    Flatbed Truck
                    Two-Tier Forced-Air Barn

  45  180126.9   17107.3    2947.6    126.88    14.         4.      75.19
  System 45 I.D. is Two-Worker Spearing Machine
                    Flatbed Wagon
                    Two-Tier Forced-Air Barn

  46  177726.9   17126.0    2774.6    127.02    15.         4.      66.06
  System 46 I.D. is Two-Worker Spearing Machine
                    Two-Wheel Rail Wagon
                    Two-Tier Forced-Air Barn

  47  133276.9   17178.0    2489.1    127.41     8.         2.      87.21
  System 47 I.D. is One-Worker Harvest Aid
                    Pallet Frame Loader
                    Open Interior Barn(Pallets)

  48  139276.9   18469.7    2674.2    136.99     8.         2.      95.47
  System 48 I.D. is Two-Worker Spearing Machine
                    Pallet Frame Loader
                    Open Interior Barn(Pallets)

  49  160910.0   17621.4    2480.9    164.40    10.         0.      63.67
  System 49 I.D. is Powell Harvesting System
                    Powell Front-End Loader
                    Six-Mil Poly. Powell Frames

  50  189853.8   25474.4     817.5    237.66     2.         0.      52.75
  System 50 I.D. is U.K. Automated System
                    Automated Front-End Loader
                    Typar for Automated Frames
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