COST ESTIMATES OF ALTERNATIVE WHEAT PRODUCTION SYSTEMS FOR GARFIELD COUNTY

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A number of factors have been instrumental in generating producer interest in reducing the number of tillage operations required for wheat production in Oklahoma. The price of fuel has risen relative to other factor prices, especially agricultural chemicals (Figure 1). Effective herbicides have recently been cleared for use in the state. If tillage operations are reduced, herbicides are essential for weed control during the summer fallow period. A third factor which has added to the interest in tillage reduction has been the introduction of grain drills capable of seeding wheat directly into untilled soil, or soil tilled to a lesser extent than necessary for conventional seeding equipment.

In response to the changing economic and technical environment, an interdisciplinary research team composed of agronomists, plant pathologists, entomologists, agricultural engineers, and agricultural economists was established at Oklahoma State University to define and evaluate alternative wheat production systems. One of the overall objectives of the ongoing research project is to determine the economic impacts of alternative systems. This report includes preliminary production cost estimates for 22 systems. The

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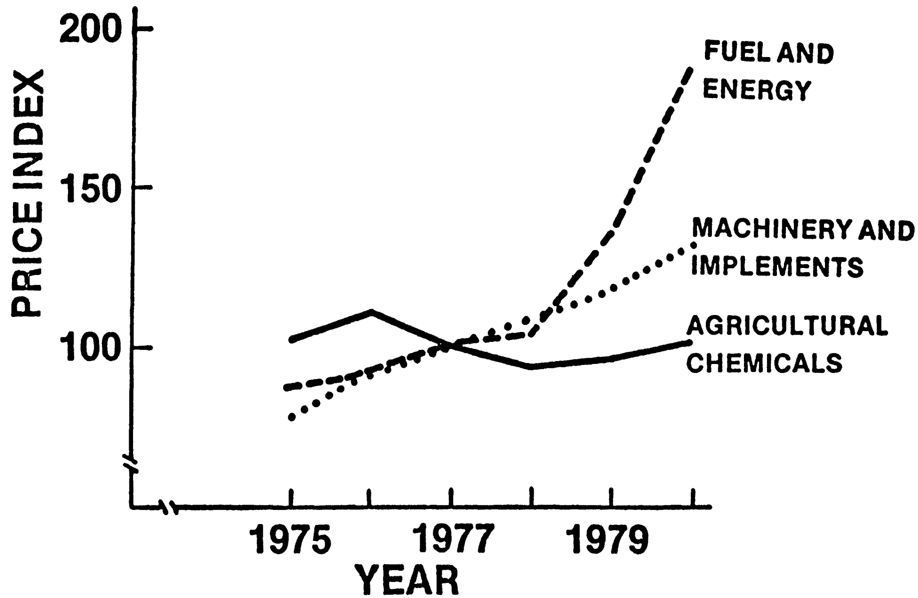


Figure 1. Indexes of prices paid for fuels, machinery, and chemicals (Source: USDA, Annual Price Summary, June 1981)

systems were defined by team members. Cost estimates are based upon the best information currently available. Quantities and types of production factors, including herbicides, were estimated from limited field tests. Information generated from ongoing field trials will be used to estimate forage and grain yield and yield variability, identify effective systems, and estimate net returns across systems.

STUDY AREA

Soil types and precipitation patterns vary greatly across Oklahoma. To help bound these variables, Garfield County in north central Oklahoma was chosen as the area of study. Farm size also varies greatly and affects the machinery requirements. For the purpose of this study, farm size was fixed at 1,240 acres seeded entirely to continuous winter wheat.

Garfield County is in the heart of the Oklahoma wheat belt. In 1980, Garfield County was the leading wheat producing county in the state, producing 13.89 million bushels (Oklahoma Crop and Livestock Reporting Service, 1981). Typically, 95 percent of the cropland in the county is planted to wheat.

Garfield County has a continental, temperate, subhumid climate. This climate is dominated by warm moist air flowing from the Gulf of Mexico, which frequently causes dramatic weather changes as it meets drier and colder air from the north. Rainfall data collected between 1931-1960 show an average annual precipitation rate of 29.15 inches. The annual precipitation has ranged from a low in 1956 of 13.42 inches to a high in 1957 of 51.46 inches. Over this period of years, the annual rainfall was distributed about 12 percent in winter, 30 percent in spring, 35 percent in summer, and 23 percent in fall (U.S. Department of Agriculture, 1967). With 58 percent of the annual precipitation falling during summer and fall, tilled wheat fields are very vulnerable to soil erosion losses.

Soil type is an important variable in machinery selection problems. The machinery sizes used in this study were selected for use on clay-loam soils, such as the Renfrom-Vernon-Kirkland Association. These soils cover about 23 percent of Garfield County. They have a heavy clay subsoil, absorb moisture slowly and require good soil conservation practices. About nine-tenths of this association is cultivated.

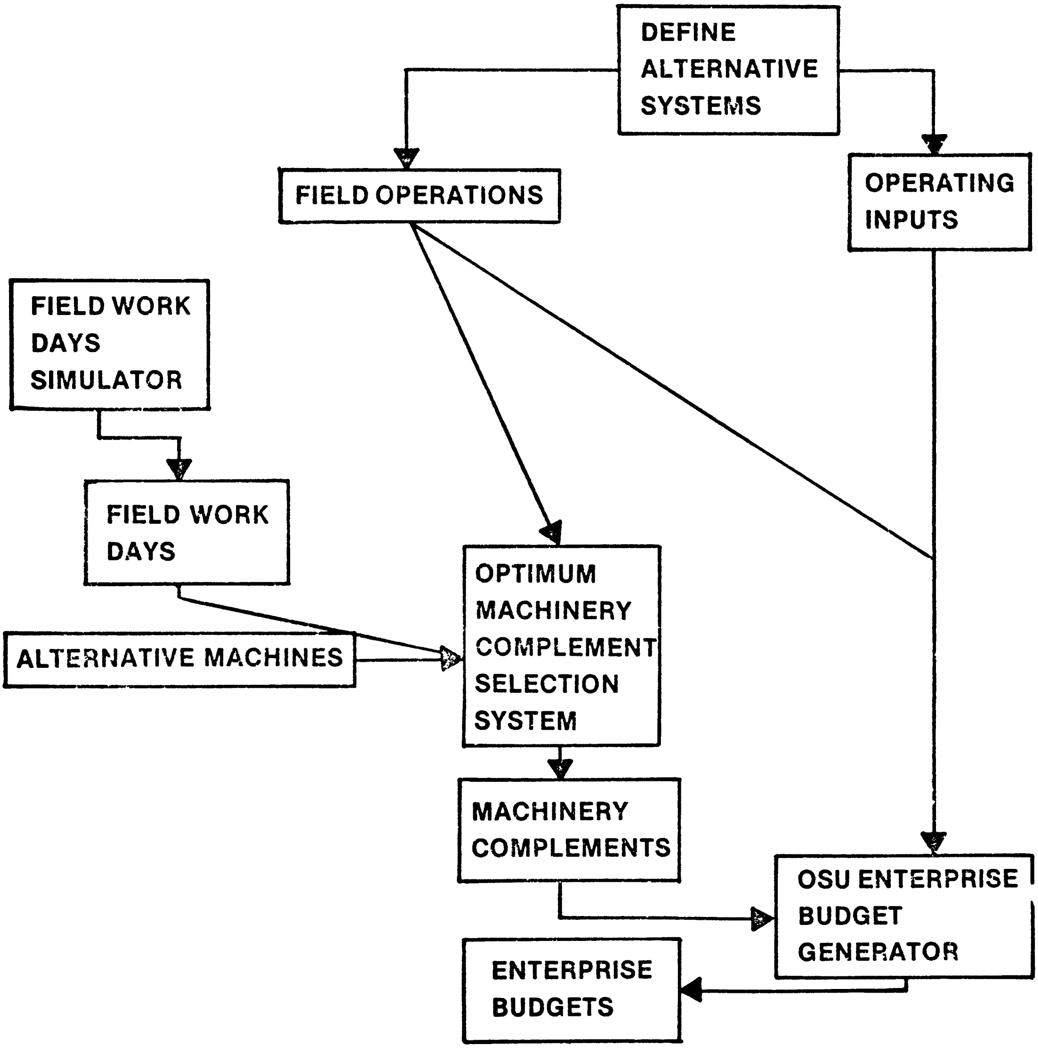
PROCEDURE

Consistent estimates of tractor and implement requirements, use levels and available field workdays are essential for a cost evaluation of alternative tillage systems. Since the size of the farm (1,240 tillable acres), the location (Garfield County), and the cropping pattern (continuous winter wheat) are fixed, an enterprise budgeting approach can be used to provide consistent estimates of fixed and operating costs across alternative production systems. Figure 2 presents a diagrammatic sketch of the steps taken to arrive at cost estimates using an enterprise budgeting approach.

ALTERNATIVE SYSTEMS

In the following discussion, 22 wheat production systems are defined in terms of tillage requirements. Fourteen combination systems are developed from eight base systems. Thus, only the tillage requirements of the first eight base systems are discussed in detail. After these eight systems are defined in terms of tillage requirements, the 14 combination systems are identified with respect to their component systems. Given these tillage requirements, the systems are further defined in terms of operating inputs. In the following discussion, each system is named and given an acronym. These acronyms are used to address the systems in the remainder of the report.

<u>Conventional Tillage (PLW)</u> The plow (PLW) system is one of three conventional systems identified. This system uses a moldboard plow as the major tillage tool. Plowing is preceded by an offset disk operation. By tilling the soil as quickly as possible with an offset disk, later deep tillage operations can be performed over a longer period of time. After the plow, the off-disk is used a second time to level and firm the soil. Dry starter fertilizer is applied with a fertilizer spreader and incorporated with a field cultivator. The starter fertilizer, 18-46-0, is used to satisfy the phosphate requirement and some of the nitrogen requirement. The remainder of the nitrogen requirement is filled by anhydrous ammonia, which must be knifed into the soil. The field cultivator is used to perform the final seedbed



gure 2. Steps for analysis

preparation. The wheat is seeded with a conventional drill. The timing of these field operations is given in Table 1.

Conventional Tillage (CHS) The chisel (CHS) system is the second of the three conventional systems identified. A chisel plow is the major tillage tool. As in the PLW system, an offset disk is the first tillage tool used after harvest. Unlike the plow, the chisel is used twice during June and July. After the second chisel operation, starter fertilizer is spread using a dry fertilizer spreader. The fertilizer is then incorporated into the soil with a field cultivator. Next, anhydrous ammonia is applied with a knife applicator. Final seedbed preparation is accomplished with a field cultivator. The field cultivator is followed by a conventional drill to sow the wheat.

Two Tillage (2TL) This system uses two tillage operations with a stubble mulch or sweep plow (v-blade).[1] The sweep (v-blade) is the major tillage tool and is used for tillage, spray application, and anhydrous ammonia application. The first sweep operation is performed immediately after harvest. This operation controls existing weeds by severing the roots below the soil surface. During this operation, a residual herbicide, Bladex, is applied. Bladex should control weeds, and in particular grasses through the summer months. The second sweep operation occurs in late August or early September. Anhydrous ammonia is applied simultaneously. This tillage should be performed late enough to control volunteer wheat as well as other weeds. This system also uses spot treatments of 2,4-D over one-half of the acreage to help control broadleaf weed problems.

A "stubble" drill is required by the reduced tillage systems. This drill is much heavier than a conventional drill. Since the soil has not been extensively tilled, colters on the stubble drill penetrate through the wheat straw and till a small band of soil for seed placement. The stubble drill is equipped with fertilizer boxes so that fertilizer, 18-46-0, can be applied through the drill.

One Tillage (1TLA) This system is identical to the 2TL system except that the first sweep (v-blade) operation is replaced with a herbicide application. Paraquat is used in a tank mix with Bladex and applied with a ground spray rig.

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[1] The stubble mulch or sweep plow discussed herein is a v-blade with "large" five to eight feet wide sweeps.

Paraquat is a contact herbicide and controls existing vegetation and thus substitutes for the the sweep in the 2TL system. Bladex should control weeds through the summer months.

One Tillage (1TLB) The fifth system (1TLB) uses a residual herbicide, Surflan, in early April to control weeds throughout the summer. This herbicide is available under an experimental use permit. Surflan is applied over the standing wheat crop as a pre-emergent herbicide. The first 2,4-D application in late February or early March is substituted in this system by a MCPA application. MCPA is similar to 2,4-D except that wheat plants are more tolerant of MCPA. This tolerance allows application of MCPA later in the growing season with less danger of plant injury. It also allows the MCPA to be applied in a tank mix with Surflan for aerial application. This eliminates one spray operation that the systems without Surflan require. In late summer, anhydrous ammonia is applied with the sweep(v-blade), which should control existing weeds. As with the other reduced tillage systems, 2,4-D is applied over one-half the acreage. The 18-46-0 fertilizer is applied with the stubble drill.

One Tillage (1TLC or 1TC) This system uses only one tillage operation. A specially equipped sweep (v-blade) is used to apply both Bladex and anhydrous ammonia simultaneously in late June. The sweep will control any existing weeds and the Bladex should control weeds through the summer. In August and September a one-half acreage application of 2,4-D is used to control broadleaf weeds. Paraquat is used to control all the vegetation in the field before the stubble drill operation.

Zero Tillage (OTLA) This system is similar to the 2TL and 1TLA systems. The sweep is totally replaced by herbicide applications. In late June, after harvest, a tank mix of Bladex and Paraquat is applied to control existing and emerging weeds. Liquid nitrogen is used as the second source of nitrogen since anhydrous ammonia cannot be applied without some type of soil disturbing operation. Broadleaf weeds are spot controlled with 2,4-D over one-half the acreage. Paraquat is used to control weeds ahead of the stubble drill.

Zero Tillage (OTLB) The second zero tillage system is very similar to the 1TLB system. The sweep used in the 1TLB is replaced by herbicide applications. Surflan is applied over the standing wheat crop. Liquid nitrogen is used as the second source of nitrogen. Broadleaf weeds are spot controlled with 2,4-D over one-half the acreage. Paraquat is used prior to drilling.

Combinations Fourteen combinations are formulated using the eight base systems. In each combination, two base systems are used. Each of these two systems is used on 50 percent of the total acreage and alternated between fields each year. Thus, one field never has the same system two years in a row. Combinations may be helpful to control weeds which present problems in one system, but are easily controlled by another system. They also offer the possibility of spreading the work load more evenly throughout the year. If two systems have different critical time periods, savings may by realized due to smaller labor and machinery requirements.

Most of the combinations in this study were designed to reduce the total number of acres covered in the later part of June. The PLW, CHS, 2TL, and 1TLC systems require a great deal of field work in the second half of June. Because of this time constraint, machinery must be selected for these systems which is large enough to perform the field operations in a short period of time. The 1TLA, 1TLB, 0TLA, and 0TLB systems are not machinery intensive in June. Most of the combinations were designed to include a system that is machinery intensive and a system that is not machinery intensive in June. The combinations designed are as follows: PLW/1TLA, PLW/1TLB, PLW/0TLA, PLW/0TLB, CHS/1TLA, CHS/1TLB, CHS/0TLA, CHS/0TLB, 2TL/1TLA, 2TL/1TLB, 1TLA/1TC, 1TLB/1TC, PLW/2TL, and PLW/CHS.

Operating Inputs

Quantities and prices of the operating inputs applied in each of the 22 systems are shown in Table 2. The operating inputs in Table 2 comprise the majority of the total variable costs for each system. The remaining variable cost components include annual operating capital, labor charges, fuel, lubrication, and machinery repairs. These variable costs are estimated in the budgeting process and are therefore not required as input data. Quantity requirements were based on estimates of the research team. July 1981 prices were used.

Several of the operating inputs (Table 2) were held constant across the systems. Ten ounces of parathion were aerially applied per acre to all systems. The parathion application is used to protect the wheat in each of the systems from potentially damaging greenbug infestations. An attempt was also made to maintain equal fertilization rates across the systems. Approximately 40 pounds per acre of phosphate was supplied to each of the systems via the 18-46-0 fertilizer. Since this fertilizer contains only 46 percent phosphate by weight, 88 pounds were required.

The mode of application for the 18-46-0 fertilizer varied among systems depending upon the type of tillage practices. For the PLW and CHS systems 18-46-0 was broadcast with a rented dry fertilizer spreader. The fertilizer was then incorporated using a field cultivator or an offset disk. The advantage of this application mode is speed. The dry fertilizer spreader can apply fertilizer to 25 acres per hour. The other mode of application was through the stubble drill. This mode was used in the reduced tillage systems. Application through a grain drill decreases field efficiency in a critical time period.

Each system was supplied 100 pounds per acre of actual nitrogen, 15.8 pounds of which was supplied by the 18-46-0. The remainder of the nitrogen was supplied by applying 103 pounds of anhydrous ammonia (NH_3) or 301 pounds of liquid nitrogen. Since liquid nitrogen is a more expensive source than NH_3, it was used only in the zero tillage systems. Potassium fertilizer was not applied to any of the systems.

All of the wheat production systems were seeded at a rate of one bushel per acre. Seed treatment was used on the reduced tillage systems to offer protection from fungi.

The herbicide rates found in Table 2 correspond to label recommendations. Surflan was applied at a rate of 1.25 pounds per acre. This herbicide was applied by air in a tank mix with 0.75 pints per acre of MCPA. Aerial application charges for either herbicide or pesticide application totaled $3.00 per acre. When MCPA was not applied, 0.75 pints per acre of 2,4-D were used in early spring to control winter annual broadleaf weeds. An application of 2,4-D over 50 percent of the reduced tillage acreage in late summer is used to control problem areas of broadleaf weeds. In the systems requiring Bladex, a 2.5 pound per acre application rate was used. Each application of paraquat for any of the systems contained 1.0 pint of paraquat per acre.

MACHINERY REQUIREMENTS

One major problem associated with using enterprise budgets to evaluate alternative crop production systems is selecting appropriate tractor-implement combinations. The difficulty arises in selecting and matching tractor size and implement width for all field operations.

The selection problem is usually thought of in a whole farm context. Any given farm requires a set of machinery capable of performing the tillage operations in the field days available. Such a machinery set is often referred to as a machinery complement. After the machinery complements are selected, tractor-implement combinations can be entered into the Oklahoma State University Enterprise Budget Generator (Kletke) for machinery cost estimation.

Because of the large number of machinery sizes available, many different machinery complements can perform the required field operations. However, the costs of the field operations vary depending upon the machinery complement used. It is very important to find the machinery complement for each system that can perform the field operations with the least-cost. By comparing the costs across systems with optimal machinery complements, a more consistent view of cost can be generated.

An optimal machinery complement is defined as a set of machinery that can perform the required operation in the field work days available with the least total cost. By definition, it requires a machinery selection process where total machinery fixed and variable costs are minimized.

Information regarding required field operations, available machines, and field work days is necessary to estimate least-cost machinery complements for each system. Required field operations are included in Table 1. Available machines and field work days are discussed in succeeding sections.

<u>Available Machines and Machinery Matching</u>

Machinery sizes and list prices were collected from retail price information available in July 1981 (Table 3). For each tractor a maximum implement width was calculated for each field operation. The maximum implement width is a function of the horsepower rating of the tractors, the draft produced per foot of implement, and the desired speed of the field operation (Jones and Bowers). The following equation defines the mathematical relationship used to calculate the maximum widths of implements for each tractor (Jones and Bowers).

$$W = \frac{HP \times HCF \times 375}{S \times D}$$

where

W is maximum implement width in feet;

HP is power take-off horsepower;

HCF is a horsepower conversion factor expressed as a proportion;

375 is a conversion factor with units of miles per hour times pounds divided by horsepower;

S is ground speed in miles per hour; and

D is draft in pounds per foot of implement.

Match of tractor sizes to commercially available implement widths is shown in Table 4. A given tractor can pull any implement smaller than the one specified in Table 4. For example, a 91 horsepower tractor could pull a 3.5, 4.0, or 4.7 foot moldboard plow.

Field Work Days

The amount of time available for tillage operations is a function of the number of days (field work days) in which tillage operations can be performed during a specified period of time and the length of the work day. The number of field work days available for the study area were determined using meteorological data and a field work day simulator developed by Reinschmiedt (1971). The simulator uses historic rainfall data to generate cumulative density functions of the number of field work days during 24 half-month periods.

The cumulative density function is used in evaluating the timeliness of a given field operation. Timeliness refers to the probability of a given number of field work days during a certain time period. For this study an 80 percent timeliness level was used which means during 80 percent of the years the number of field work days equals or exceeds the number specified. A 10 hour work day was assumed. Table 5 lists the cumulative density functions of field work days for Garfield County, Oklahoma.

Machinery Complement Selection

The machinery complement selection system (OMCSS) developed by Griffin was used to select a machinery complement for each wheat production system. The model is a general mixed integer program (MIP) that uses a branch and bound algorithm based on the pioneering research of Land and Doig (for a mathematical notation of the general MIP see Hillier and Leiberman, page 709). The model minimizes the sum of machinery operating costs, tractor operating costs, labor costs, timeliness costs, charges for custom operations, and machinery and tractor ownership costs (Griffin). The constraints of the model include land use, tractor and machinery matches, and timing of field operations.

OMCSS approaches a machinery selection problem in two steps. First, a matrix generator creates a programming matrix for a particular machinery selection problem. The second step uses MIP (IBM) to select a machinery complement which minimizes total machinery costs.

The OMCSS matrix generator requires three sets of input data to calculate machinery costs and build the programming matrix. First, field operations for the wheat production system must be identified (Table 1). The second set of required input data is a list and ranking of alternative machinery items from which the machinery complements can be selected (Table 4). The third set of required data is the field work days available in each period (Table 5). The matrix generator sets up programming activities which account for the costs of each possible tractor-implement combination. Integer activities are generated for the purchase of each tractor and machinery item. The objective function for these activities account for the annual fixed or ownership costs and supply a certain quantity of hours available for use. Linear activities are generated for machine operations (e.g. plowing, spraying, planting). The objective function value accounts for the variable or operating cost of the machines. The matrix generator also formulates the necessary programming constraints. These constraints require the designated operations to be performed in the field hours available. The constraints also tie the tractor-implement combinations together according to the machinery ranking. For a more detailed discussion, see Handke (1982).

Optimal Machinery Complements for Each System

The least-cost machinery complements for each system are given in Table 6. The power and machinery requirements vary widely among the eight base systems. For comparison purposes, power requirements can be expressed in annual horsepower hours

(AHPH), which are equivalent to the sum of each tractor's horsepower multiplied by its hours of annual use. Table 7 includes the annual hours for each tractor in the various systems. The power requirements vary from approximately 179,000 AHPH for the CHS system to 31,000 AHPH for the OTLB system. Thus, the power requirements for the reduced tillage systems are considerably less than for the conventional tillage systems.

The machinery complement for the PLW system includes an 81, 91, and 180 horsepower tractor. The 180 horsepower tractor provides the power to pull a 20.3 foot offset disk, a six-18 inch bottom plow, and a 40 foot conventional drill. The 91 horsepower tractor is used to pull a four-14 inch bottom plow, a 22 foot anhydrous ammonia applicator, and a 13.5 foot field cultivator. The 81 horsepower tractor is used to power a sprayer, three-16 inch bottom plow, dry fertilizer spreader, and 12.5 foot field cultivator. The tractors log 469, 489, and 445 hours annually, respectively, and the system uses approximately 165,000 AHPH.

The machinery complement for the CHS system is powered by two tractors. A 180 horsepower tractor is used to pull a 16 foot chisel and a 27 foot field cultivator. During these two operations the tractor logs 542 hours. The remaining operations are powered by a 131 horsepower tractor, which logs 624 hours annually. These operations include the use of a sprayer, a 13.5 foot offset disk, a 12 foot chisel, a 28 foot anhydrous ammonia applicator, and a 40 foot conventional drill.

The machinery items for the 2TL system are powered by a 180 horsepower tractor. This tractor logs 416 annual hours and supplies approximately 75,000 AHPH. This power is consumed by spraying, sweeping, and drilling operations. The 2TL system is the only system for which one tractor is included in the optimal machinery complement. Field operations are separated such that one tractor can perform all operations.

The 1TLA and 1TLB systems use the same machinery items in their optimal machinery complements. The complements differ only in the numbers of annual hours for the sprayer and the tractor pulling the sprayer. This difference arises because the Bladex plus Paraquat spray operation in 1TLA is replaced in 1TLB by an aerial application of Surflan. The complements are powered by 71 and 111 horsepower tractors. The smaller tractor is used to pull a sprayer and a 13.2 foot stubble drill. The 111 horsepower tractor is the power unit for a 15 foot sweep and a 26.4 foot stubble drill. System 1TLA requires approximately 53,000 AHPH and system 1TLB requires 43,000 AHPH.

System 1TLC has tillage requirements similar to the 2TL system. Both systems apply Bladex plus paraquat and anhydrous ammonia with a sweep, but in 1TLC all the materials are applied in one operation after harvest. Due to reduced field efficiency, 1TLC requires an additional tractor and sweep to complete the operation in the allowed time. System 1TLC uses 91 and 180 horsepower tractors, which supply approximately 60,000 AHPH. The 91 horsepower tractor is used to pull the sprayer and 15 foot sweep. The 180 horsepower tractor supplies power to the 25 foot sweep and 39.6 foot stubble drill. The tractors log 237 and 213 annual hours, respectively.

The zero tillage systems have identical optimal machinery complements. A 70 horsepower tractor is used to pull a sprayer and liquid nitrogen applicator. The wheat is seeded using a 39.6 foot stubble drill pulled by a 180 horsepower tractor. The systems differ slightly in annual hours because of the substitution of a spray operation in OTLA for an aerial spray application in OTLB. As a result of the annual hour differences, OTLA requires approximately 41,000 AHPH compared to 31,000 AHPH for OTLB.

The combination systems can be divided into three sets -- (a) those designed by combining the PLW or CHS system with reduced tillage systems which are not tillage intensive through June, (b) those which consist of combinations of reduced tillage systems, and (c) the PLW/CHS and PLW/2TL combinations.

The PLW/1TLA, PLW/1TLB, PLW/OTLA, PLW/OTLB, CHS/1TLA, and CHS/1TLB systems use three different machinery complements. Systems PLW/1TLA and PLW/1TLB use the same items in their complements with differences arising only in machinery annual hours. The same is true for PLW/OTLA and PLW/OTLB and CHS/1TLA and CHS/1TLB. The reason for the similarities in complements is because the Bladex systems and the Surflan systems have nearly identical machinery requirements. In both the one tillage systems (1TLA and 1TLB) and the zero tillage systems (OTLA and OTLB), a Bladex application is replaced by an aerial Surflan application. Thus, the only machinery requirement difference between system 1TLA and system 1TLB is one spray operation, and likewise for systems OTLA and OTLB.

In the case of systems CHS/OTLA and CHS/OTLB, the deletion of a spray operation is the only machinery requirement difference. However, this difference greatly affects the machinery complements selected. By eliminating one spray operation (system CHS/OTLB) it becomes less costly to use a larger equipment. Thus, system CHS/OTLB uses fewer but larger machinery items than system CHS/OTLA.

The combination conventional/reduced tillage systems generally require a larger number of machines. This increase is due to the increased types of tillage operations for these combinations. A farm using a combination system must stock all the types of tillage implements required for both a conventional and reduced tillage systems. Although these combinations use more machine items per complement, the size of the machines are generally smaller. The economic viability of the combinations then becomes sensitive to the trade-off in costs between machinery size and machine number.

General Observations Regarding Machinery Selection

Several patterns can be observed from the results of the machinery selection in Table 6. No four-wheel-drive tractors, with 229 horsepower, are included in any of the machinery complements. The absence of the four-wheel-drive tractor indicates that they are a more expensive source of power than two-wheel-drive tractors for the case farm. Several factors work together in the model to make the four-wheel-drive tractor a more expensive alternative. With a purchase price of $72,000, it costs about $22,000 more than the 180 horsepower tractor. Since an 81 horsepower tractor costs only $21,000, the additional 48 horsepower gained by moving up to a four-wheel-drive tractor is usually more costly than selecting another small tractor.

The four-wheel-drive tractor also suffers a considerable penalty for the equipment to which it is matched. As equipment widths increase, average cost per foot increases. These increased costs are due to additional wheels, folding mechanisms, and additional structural supports.

It should be noted that four-wheel-drive tractors are partially discriminated against in the study due to relatively cheap operator labor. In the machinery selection procedure, it is assumed that tractor operator labor is available at $4 per hour. The presence of four-wheel- drive tractors on many Oklahoma farms suggests that operator labor is more expensive than $4 per hour. Four-wheel-drive tractors would be feasible at higher wage rates (Kletke and Griffin).

The machinery selection results also identify critical time periods, during the production cycle when the machinery selection problem is most constrained with respect to field work hours. These critical time periods determine to a large extent the machinery sizes. For the conventional PLW and CHS systems the second half of June is the most critical period, while the last half of September is the most critical period for the reduced tillage systems.

All systems require a total of 40 feet of drill width to accomplish the seeding operation. This requirement is met by using one large 40 foot drill or two smaller drills having a total width of 40 feet. In the conventional PLW and CHS system, the drill requirement is met by using one large drill pulled by at least a 111 horsepower tractor. However, the stubble drills required for the reduced tillage systems have a power requirement considerably larger than the conventional drills. As a result, the reduced tillage systems use either a 39.6 foot stubble drill pulled by a 180 horsepower tractor, or two smaller drills pulled by 70 horsepower and 111 horsepower tractors. Thus, in the reduced tillage systems the drill operation largely determines the tractor sizes in the complement. In the conventional systems, the early tillage operations determine tractor sizes more than the drill operation. Based on the engineering parameters (Table 4), a 111 horsepower tractor is capable of pulling a 40 foot conventional drill whereas a 40 foot stubble drill requires a 180 horsepower tractor.

Those combination systems which combine a reduce tillage system with either the PLW or CHS system require a large number of specialized machines. This tends to offset the advantages the combinations offer. Thus, the combinations are an effective means of reducing time constraints in June, but require more diverse complements containing a larger number of specialized machines.

COST ESTIMATES

The Oklahoma State University Enterprise Budget Generator (Kletke) was employed to generate cost budgets for each system. Budget estimates are presented and summarized in this section. Each budget reflects the costs of the operating inputs as well as machinery operating and fixed costs. In addition to the summary of the costs for each system, the quantities of preharvest machinery labor, tractor fuel, and capital are presented. These resource quantities provide additional insights into the cost advantages and disadvantages of the alternative systems.

Operating Input Costs

Operating input costs include those costs which are commonly thought of as variable costs. The operating inputs in Table 9 contain one group of inputs fixed across the systems and three groups of inputs which interact to change total operating costs among systems. The first group of constant inputs include insecticide and application, seed, and custom combine and hauling activities. These inputs are common to all systems.

The second group of inputs change very little among systems. They include fertilizers and fertilizer spreading equipment rental. Small differences in total operating cost arise from the different modes of 18-46-0 application. Whenever possible, the fertilizer is applied with a rented spreader at a cost of $0.11 per acre. With the reduced tillage systems, 18-46-0 is applied through the stubble drill. Additional nitrogen in the form of anhydrous ammonia or liquid nitrogen is applied to each of the systems. If no tillage operations occur, such as in systems OTLA and OTLB, liquid nitrogen and a rented spreader are used. The liquid nitrogen application costs $21.22 per acre verses $15.45 for anhydrous ammonia. Thus, total operating cost for fertilizer varies only slightly across systems unless liquid nitrogen is required.

The third group of operating inputs include herbicides such as 2,4-D, Surflan, MCPA, Bladex, and Paraquat. Herbicide costs range from $1.27 per acre in the PLW and CHS systems to $23.04 per acre in system OTLA. As a result of herbicide costs, systems with fewer tillage operations have larger total operating costs.

The increase in herbicide costs for the reduced tillage systems are partially offset by the fourth set of operating inputs. The quantities of labor, fuel, lubrication, and repairs decrease as tillage operations decrease across systems. Although operating capital charges are usually higher for reduced tillage systems, the net effect of these inputs is to decrease operating costs as the systems become less tillage intensive. Thus, changes in total operating costs across the systems arise from a trade-off between additional herbicides costs and reduced labor, fuel, lubricants, and repair costs. Normally the additional herbicide costs are greater than the operating inputs savings. This causes the reduced tillage systems to have a total operating cost greater than the conventional tillage systems.

The conventional PLW and CHS systems generate the smallest total operating cost of $84.19 and $84.42 per acre, respectively. The zero tillage systems (OTLA and OTLB) generate the largest total operating costs $103.14 and $102.66, respectively. The total operating costs of the lTLA, lTLB, and lTLC systems are approximately equal at $91.45 per acre. The total operating costs of the combinations usually fall between the operating cost range of their component systems. In the PLW/CHS and lTLA/lTC combinations, total operating input costs are slightly less than that of their component systems.

Total Fixed Costs

Total fixed costs (TFC) include machinery depreciation, taxes, insurance, and an opportunity cost on the average machinery investment. The conventional systems, which require more machinery, incur more fixed costs than the reduced tillage systems. Of the base systems, the PLW, CHS, and lTLC have the largest TFC. The PLW system requires a machinery complement capable of plowing 1,240 acres once during the second half of June and the first half of July. Since the chisels in the CHS system have smaller power requirements than the plows of the PLW system, fewer tractors are required. This savings is reflected in lower fixed costs for the CHS system. But, the CHS system has higher total operating costs because the chisels cover each acre twice compared to once for the plow.

System lTLC represents a unique machinery selection problem which results in higher fixed costs. Bladex and anhydrous ammonia are applied by a sweep in one operation during June. Due to the additional spray and fertilizer application, the sweep operation loses considerable field efficiency. Since June is a critical time period, the additional loss of field efficiency translates into large equipment and higher fixed costs.

Systems lTLA and lTLB yield the lowest fixed costs among the base systems followed closely by OTLA, OTLB, and 2TL. Since time constrains operations, the zero tillage systems' fixed costs exceed those of two of the one tillage systems. The 2TL/lTLB combination system results in the lowest fixed costs. This system also has the lowest initial machinery investment (Table 8).

Total Costs

The conventional PLW and CHS systems incur higher fixed costs with relatively lower operating costs. On the other hand, the zero tillage systems incur relatively lower fixed costs and higher operating costs. The total costs of the two zero tillage systems are approximately $13.50 per acre more than the total costs of the conventional systems. They suffer from the timing of field operations, the cost of the additional herbicide application, and the requirement for liquid nitrogen rather than anhydrous ammonia.

The total costs for the eight base systems range from $103.97 per acre for 2TL to $119.64 per acre for OTLA. When systems 1TLC, OTLA, and OTLB are excluded, the range narrows considerably. Only $2.74 per acre separates the estimated total costs of the least and most expensive remaining systems. The conventional PLW and CHS systems, the 2TL system, and the one tillage systems 1TLA and 1TLB, generate nearly equal total costs. Thus, the 2TL, 1TLA, and 1TLB offer viable alternative means of producing wheat on a total cost basis at budgeted prices.

The reduction in the cost of the fuel (at $1.20 per gallon), labor (at $4 per hour), and machinery for the these systems relative to the conventional systems is almost completely offset by the cost of the herbicides. If the prices of fuel, labor, and machinery increase relative to the price of herbicides, the 2TL, 1TLA, and 1TLB systems will become relatively less costly. However, at budgeted prices the reduced tillage systems do not have a significant cost advantage.

SELECTED RESOURCE REQUIREMENTS

Table 10 includes estimates of labor, tractor fuel, average machinery investment, herbicides, and operating capital, across the systems.

Labor

The preharvest machinery labor estimates in Table 10 reflect the time required to complete the field operations listed in Table 1. Machinery hours are a function of machine sizes which were calculated by OMCSS.

Since our objective was to investigate tillage practices, we assumed custom harvesting and custom hauling which are typical for the area. Thus, the estimates do not include any harvest labor. These estimates also do not include time required for management or for scouting for early detection of pests and diseases. Additional management and scouting time may be required for the reduced tillage systems.

The zero tillage systems require only 20 to 37 percent as much preharvest machinery labor as the conventional systems. The other reduced tillage systems require only one-third as much. Only 310 hours of preharvest machinery labor would be required to farm the 1,240 acres with the OTLB system. The same acreage would require 1,550 hours if the PLW system were used. Thus, reducing tillage operations will reduce the amount of labor required. However, labor must be available during critical periods for all systems.

Tractor Fuel

The reduced tillage systems require three to five gallons less tractor fuel per acre than the plow system (Table 10). These estimates are based upon the draft requirements given in Table 4 and fuel requirement estimates of Bowers (1970). They do not include the energy embodied in the herbicides and machinery. Additional fuel use research is being conducted.

Machinery Investment

The reduced tillage systems require the use of a stubble drill which costs 2.5 to three times as much per linear foot as a conventional drill (Table 3). This added cost is more than offset by the reduced number of tillage implements and tractors of the reduced tillage systems relative to the plow system.

Machinery investment requirements are critically tied to the timing of field operations. For example, the 2TL system requires only one tractor. Tillage operations are required in late June and late August - early September. Late September is free for drilling. On the other hand, the zero tillage systems require late September spraying operations as well as drilling in different trips across the field. Thus, the least-cost complement for completing these operations includes two tractors.

The PLW system requires an average tractor and implement investment of approximately $92,000 for the 1,240 acre farm compared to $61,000 for the 1TLA and 1TLB systems. This reduction in machinery investment assumes a complete substitution of a one tillage system for the plow system. The producer would not retain the implements necessary for conventional tillage. In general the combination systems which use the CHS system require a larger machinery investment than the CHS system. However, the PLW/1TLA and PLW/1TLB systems require 10.7 percent less average machinery investment than the PLW system. It was assumed that a producer would trade an existing conventional drill for a stubble drill and that the stubble drill would be used for the entire acreage with the nine conventional/reduced tillage systems. If this assumption had not been made, OMCSS may have selected a combination of conventional and stubble drills for these systems.

Herbicide

Herbicide costs are also reported in Table 10. The percentage increase in herbicide costs in moving from the conventional plow system to the reduced tillage systems is high when compared with other crops in other regions (Crosson, p. 9). Although a cost of $1.27 per acre is included for the PLW and CHS systems, herbicides are not typically used. Perhaps since herbicides have not been used, chemical companies have not been aggressive in seeking clearance. For example, some of the systems depend upon Surflan which has not been cleared for use on wheat in Oklahoma. It has been used under an experimental use permit. Other systems require Bladex which was first cleared for use in 1981.

All systems include a spring application of broadleaf herbicide. The 2TL and one tillage systems require three herbicides. The zero tillage systems require four separate applications. The cost of the chemicals is $21.06 per acre for the OTLB system and $23.04 per acre for the OTLA system. This is substantial when compared with the $1.27 per acre for the PLW system.

Annual Operating Capital

The budget generator was employed to estimate annual operating capital requirements for operating inputs including fuel, lubrication, machinery repairs, herbicides, seed, fertilizer, seed treatment, and other cash expenses. As herbicides are substituted for tillage operations, more annual operating capital is required. With diesel fuel priced at $1.20 per gallon, the fuel, lubricants, and repair cost savings of the reduced tillage systems are less than the additional cost for the herbicides. The zero tillage systems require almost 50 percent more annual operating capital than the conventional systems.

The Surflan based systems both require an application of Surflan in April of the year preceding harvest. This results in a fourteen month carrying period. Thus, the annual operating capital requirements across systems reflect the timing as well as the cost of herbicide applications.

Operating Plus Machinery Capital

The sum of annual operating capital and machinery investment provides an estimate of the total nonland capital requirements. The capital requirements are similar across systems. For example, the 2TL system requires the smallest amount of capital ($98.66/acre), but that amount is 86 percent of that required by the PLW system ($114.89/acre).

Estimates indicate that intermediate term financing would decline relative to short term financing as herbicides are substituted for tillage operations. Short term cash flow planning may become increasingly important.

COSTS AT ALTERNATIVE FUEL PRICES AND WAGE RATES

The analysis summarized in Table 11 indicates how selected alternative wage rates and diesel fuel prices may affect the total costs of each system. Total costs were calculated for nine unique situations. Wage rates of $4, $7, and $10 per hour, and tractor diesel fuel prices of $1.20, $1.70, and $2.20 per gallon were used. All other prices, and inputs other than operating capital, were held constant at the original budgeted levels. Thus, the analysis assumes increases in the price of labor and/or tractor diesel fuel relative to all other factors. This is a simplifying assumption which can be used to detect relatively low labor and/or low tractor fuel using systems.

In general, the 2TL, 1TLB, and 2TL/1TLB are the least-costly systems at the budgeted prices. At $1.20 fuel, the 2TL system is cheapest across all wage rates. At $1.70 fuel, the 2TL/1TLB combination is preferred at $4 and $7 wages, and is close to the 2TL at $10 wages. At $2.20 fuel, the 2TL/1TLB combination is preferred.

The PLW/CHS combination is preferred to either the PLW or CHS base systems across all wage rates and fuel prices. This is directly related to the timing of field operations. Many producers use some combination of moldboard and chisel plows for primary tillage. The results of this analysis confirm their wisdom. At $4 wages and $1.20 fuel, the PLW/CHS system is one of the three least-costly systems.

In general, the zero tillage systems do not look promising. OTLA is the most expensive system for $1.20 fuel at all wages, and for $1.70 fuel at $4 and $7 wages. The CHS/zero tillage combinations are the most expensive for the other price alternatives.

The PLW/CHS system is preferred to all of the PLW/reduced tillage and CHS/reduced tillage systems across all budgeted prices. The analysis assumes that a stubble drill would be used on all acres for the PLW/reduced tillage and CHS/reduced tillage systems. However, a conventional drill is used for the PLW/CHS system. Thus, producers interested in PLW/reduced tillage or CHS/reduced tillage combinations may want to consider some combination of conventional and stubble drills which may reduce the required machinery investment for drills but would require multiple tractors to pull the drills.

The 2TL system is the most promising of the reduced tillage systems. It is one of two systems that requires only one tractor (Table 6). It also has the lowest herbicide cost of the reduced tillage systems (Table 10).

STUDY LIMITATIONS

The estimates presented herein are specific to one location and one size of farm that produces only one crop. Costs for other locations, alternative farm sizes, and multiple crop farms should be investigated.

Research is needed to generate yield and yield variability information for the alternative systems. Potential differences in fertilizer requirements across systems should also be investigated. Additional research may be necessary to determine weed and disease incidence across systems.

Environmental consequences of reduced tillage have been ignored. Benefits which accrue from reduced soil loss should be weighed against the potential impacts of increased herbicide usage.

SUMMARY

This report presents estimates of costs and resource requirements for alternative wheat production systems. The analysis was conducted as part of an ongoing research effort by an interdisciplinary research team at Oklahoma State University. The team provided information regarding operating inputs, field operations, herbicide applications, and timing of operations. A simulation model was used to estimate field work days. A machinery selection program which relies on integer programming was used to select least-cost machinery complements for a Garfield County, Oklahoma, wheat farm. Costs were estimated for 22 alternative systems.

The reduced tillage systems require 69 to 80 percent less preharvest machinery labor, 50 to 82 percent less tractor fuel, and 27 to 34 percent less average machinery investment than the conventional moldboard plow system. But, they require 11 to 47 percent more annual operating capital and their herbicides cost 793 to 1,558 percent more. However, machinery fixed costs are 26 to 33 percent less with the experimental systems. The total operating plus machinery costs of the 2TL system were estimated to be 2.6 percent less than that for the PLW system. However, the zero tillage systems costs 12 percent more than the PLW system.

The cost of a stubble drill relative to a conventional drill, and the requirement to complete field operations in constrained time periods, prohibit a sizable reduction in machinery investment when switching completely from a conventional to a reduced tillage system. If the producer elects to maintain the option for conventional tillage (e.g. PLW/reduced tillage), the reduction is even less. However, the reduction in annual hours of use may be substantial. For example, the zero tillage systems requires a 180 horsepower tractor for only 98 hours per year for the 1,240 acre farm.

The relatively small cost advantage of the experimental systems when coupled with the uncertainty resulting from the lack of yield data, suggests that immediate widespread adoption of reduced tillage systems for wheat production in Garfield County is not likely. However, because of the uncertainty surrounding the experimental systems, a complete substitution of a reduced tillage system for the existing system may not be a realistic assumption. Many produces may be reluctant to dispose of their conventional tillage equipment prior to "experimenting" with the new systems. Thus, a transition period during which the existing machinery complement is supplemented with the services of a stubble drill is likely. There are several circumstances that may justify the cost of the services of a stubble drill and the implementation of reduced tillage on a limited scale. For example, a reduced tillage system may enable producers to convert pasture land which they would be reluctant to plow frequently into crop production. Also, acquisition of a stubble drill may enable a producer to expand acreage without additional tractors.

The development of effective herbicides, tolerant wheat varieties, and improved stubble drills, coupled with the decline in the relative prices of herbicides, may trigger many changes. Additional research is necessary to analyze the economic consequences of these changes.

The information given herein is for educational and research purposes. References to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by Oklahoma State University is implied.

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APPENDIX

Table 1. Field Operations for Alternative Wheat Production Systems

Alternatives Field Operations	Time Period	Systems							
		PLW	CHS	2TL	1TLA	1TLB	1TLC	OTLA	OTLB
Aerial Insecticide Application	Feb. 15 - March 15	XX	XX	XX	XX	XX	XX	XX	XX
Spray 2-4-D	Feb. 15 - March 15	XX	XX	XX	XX		XX	XX	
Aerial Surflan + MCPA Application	April 1 - 15					XX			XX
Spray Bladex + Paraquat	June 16 - 30				XX			XX	
Sweep Applying Bladex	June 16 - 30			XX					
Sweep Applying Bladex and NH_3	June 16 - 30						XX		
Off-Set Disk (first time over)	June 16 - July 15	XX	XX						
Moldboard Plow	June 16 - July 15	XX							
Chisel Plow (first time over)	June 16 - July 15		XX						
Chisel Plow (second time over)	July 16 - 31		XX						
Spread Dry Fertilizer	August 1 - 15	XX	XX						
Off-Set Disk (second time over)	August 1 - 16	XX							
NH_3 Knife Applicator	August 17 - Sept. 15	XX	XX						
Sweep Applying NH_3	August 17 - Sept. 15			XX	XX	XX			
Liquid Nitrogen Applicator	August 17 - Sept. 15							XX	XX
Spray 2-4-D (1/2 total acreage)	August 17 - Sept. 15			XX	XX	XX	XX	XX	XX
Field Cultivator (first time over)	August 1 - 15		XX						
Field Cultivator (first time over)	Sept. 16 - 30	XX							
Field Cultivator (second time over)	Sept. 16 - 30		XX						
Spray Paraquat	Sept. 16 - 30						XX	XX	XX
Conventional Drill	Sept. 16 - 30	XX	XX						
Stubble Drill	Sept. 16 - 30			XX	XX	XX	XX	XX	XX

Table 2. Operating Inputs for Alternative Wheat Production Systems

Operating Inputs	Units	Price	System							
			PLW	CHS	2TL	1TLA	1TLB	1TLC	OTLA	OTLB
Parathion	Oz.	0.086	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Aerial Insecticide Application	ACRE	3.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2 - 4 - D	Pt.	1.70	0.75	0.75	1.125	1.125	0.375	1.125	1.125	0.375
Surflan	Lbs.	10.40					1.25			1.25
MCPA	Pt.	2.09					0.75			0.75
Aerial Herbicide Application	ACRE	3.00					1.0			1.0
Bladex	Lbs.	3.77			2.5	2.5		2.5	2.5	
Paraquat	Pt.	5.85				1.0		1.0	2.0	1.0
18 - 46 - 0 Dry Fertilizer	Cwt.	14.50	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Dry Fertilizer Spreader Rental	Cwt.	0.12	0.88	0.88						
Anhydrous Ammonia (NH_3)	Lbs.	0.15	103.0	103.0	103.0	103.0	103.0	103.0		
Liquid Nitrogen (N)	Cwt.	6.75							3.01	3.01
Liquid N Applicator Rental	Cwt.	0.30							3.01	3.01
Seed Treatment/Bushel Seed	Bu.	0.50			1.0	1.0	1.0	1.0	1.0	1.0
Seed	Bu.	5.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 2. (Continued)

Operating Inputs	Units	Price	System PLW/ 1TLA	PLW/ 1TLB	PLW/ OTLA	PLW/ OTLB	CHS/ 1TLA	CHS/ 1TLB	CHS/ OTLA
Parathion	Oz.	0.086	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Aerial Insecticide Application	ACRE	3.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2 - 4 - D	Pt.	1.70	0.94	0.565	0.94	0.565	0.94	0.565	0.94
Surflan	Lbs.	10.40		0.625		0.625		0.625	
MCPA	Pt.	2.09		0.375		0.375		0.375	
Aerial Herbicide Application	ACRE	3.00		0.4		0.5		0.5	
Bladex	Lbs.	3.77	1.25		1.25		1.25		1.25
Paraquat	Pt.	5.85	0.5		1.0	0.5	0.5		1.0
18 - 46 - 0 Dry Fertilizer	Cwt.	14.50	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Dry Fertilizer Spreader Rental	Cwt.	0.12	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Anhydrous Ammonia (NH_3)	Lbs.	0.15	103.0	103.0	51.5	51.5	103.0	103.0	51.5
Liquid Nitrogen (N)	Cwt.	6.75			1.50	1.50			1.50
Liquid N Applicator Rental	Cwt.	0.30			1.50	1.50			1.50
Seed Treatment/Bushel Seed	Bu.	0.50	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Seed	Bu.	5.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 2. (Continued)

Operating Inputs	Units	Price	System						
			CHS/ OTLB	2TL/ 1TLA	2TL/ 1TLB	1TLA /1TC	1TLB /1TC	PLW/ 2TL	PLW/ CHS
Parathion	Oz.	0.086	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Aerial Insecticide Application	ACRE	3.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2 - 4 - D	Pt.	1.70	0.565	1.125	0.75	1.125	0.75	0.94	0.75
Surflan	Lbs.	10.40	0.625		0.625		0.625		
MCPA	Pt.	2.09	0.375		0.375		0.375		
Aerial Herbicide Application	ACRE	3.00	0.5		0.5		0.5		
Bladex	Lbs.	3.77		2.5	1.25	2.5	1.25	1.25	
Paraquat	Pt.	5.85	0.5	0.5		1.0	0.5		
18 - 46 - 0 Dry Fertilizer	Cwt.	14.50	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Dry Fertilizer Spreader Rental	Cwt.	0.12	0.44					0.44	0.88
Anhydrous Ammonia (NH_3)	Lbs.	0.15	51.5	103.0	103.0	103.0	103.0	103.0	103.0
Liquid Nitrogen (N)	Cwt.	6.75	1.50						
Liquid N Applicator Rental	Cwt.	0.30	1.50						
Seed Treatment/Bushel Seed	Bu.	0.50	0.5	1.0	1.0	1.0	1.0	0.5	
Seed	Bu.	5.00	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 3. Power Units and Implements Available for Field Operations

Name of Machine	Width[a] (feet)	Initial List Price	Name of Machine	Width[a] (feet)	Initial List Price
Tractor NC 70	70.0	$19734.	Tandem Disk	40.3	$26291.
Tractor NC 81	81.0	23401.	Sweep & SF	15.0	9494.
Tractor 91	91.0	33382.	Sweep & SF	20.0	14283.
Tractor 111	111.0	37000.	Sweep & SF	25.0	16528.
Tractor 131	131.0	41256.	Sweep & SF	30.0	20437.
Tractor 156	156.0	48847.	Sweep & SF	35.0	23376.
Tractor 180	180.0	54563.	Sweep & F	15.0	7605.
Tractor 229	229.0	78661.	Sweep & F	20.0	11905.
M.B. Plow 314	3.5	1845.	Sweep & F	25.0	14026.
M.B. Plow 316	4.0	1876.	Sweep & F	30.0	17386.
M.B. Plow 414	4.7	2475.	Sweep & F	35.0	20201.
M.B. Plow 416	5.3	2526.	Field Cultivator	9.5	1591.
M.B. Plow 516	6.7	4150.	Field Cultivator	12.5	2000.
M.B. Plow 616	8.0	4892.	Field Cultivator	13.5	2170.
M.B. Plow 618	9.0	5194.	Field Cultivator	16.5	3549.
M.B. Plow 818	12.0	7201.	Field Cultivator	19.5	4812.
Chisel Plow	8.0	2217.	Field Cultivator	23.5	5732.
Chisel Plow	10.0	2426.	Field Cultivator	27.5	9208.
Chisel Plow	12.0	2609.	Field Cultivator	36.5	11450.
Chisel Plow	14.0	2927.	Anhydrous Applie	15.0	3072.
Chisel Plow	16.0	3194.	Anhydrous Applie	22.0	4092.
Chisel Plow	20.0	3719.	Anhydrous Applie	28.0	4747.
Off-Set Disk	7.8	7602.	Stubble Drill W/F	13.2	12845.
Off-Set Disk	12.5	7727.	Stubble Drill W/F	26.4	26158.
Off-Set Disk	13.5	8460.	Stubble Drill W/F	39.6	39467.
Off-Set Disk	16.8	9936.	Drill W/O Fert.	20.0	7062.
Off-Set Disk	20.3	12094.	Drill W/O Fert.	24.0	9182.
Off-Set Disk	27.0	21638.	Drill W/O Fert.	30.0	10898.
Tandem Disk	12.7	4533.	Drill W/O Fert.	32.0	12445.
Tandem Disk	14.3	5654.	Drill W/O Fert.	40.0	14372.
Tandem Disk	15.7	7507.	Dry Fert. Spread	60.0	0.[b]
Tandem Disk	19.9	11003.	LQD Frt.	40.0	0.[b]
Tandem Disk	22.8	12883.	Sprayer	30.0	3535.
Tandem Disk	27.1	16778.	Sprayer	47.0	3830.
Tandem Disk	30.1	17950.			

[a] For tractors the unit is horsepower rather than feet.

[b] These items are rented rather than purchased.

Table 4. Commercially Available Maximum Implement Widths by Tractor Sizes

Field Operations	Field Speed (MPH)	Field Efficiency (%/100)	Draft/ft. of Implement (Lbs.)	H.P. Conversion Factor (%/100)	Tractor Sizes (H.P.) / Available Implement Width (Ft.) 70	81	91	111	131	156	180	229
Moldboard Plow	5.0	0.75	800	0.55	3.5	4.0	4.7	5.3	6.7	8.0	9.0	12.0
Chisel Plow	4.5	0.75	500	0.55			8.0	10.0	12.0	14.0	16.0	20.0
Off-Set Disk	5.5	0.75	400	0.64	7.8	7.8	7.8	12.5	13.5	16.8	20.3	27.0
Sweep Applying Spray and NH_3	5.5	0.55	275	0.64			15.0	15.0	20.0	25.0	30.0	35.0
Sweep Applying Spray	5.5	0.65	275	0.64			15.0	15.0	20.0	25.0	30.0	35.0
Sweep Applying NH_3	5.5	0.65	275	0.64			15.0	15.0	20.0	25.0	30.0	35.0
Sweep	5.5	0.75	275	0.64			15.0	15.0	20.0	25.0	30.0	35.0
NH_3 Knife Applicator	5.5	0.67	150	0.55	15.0	15.0	22.0	28.0	28.0	28.0	28.0	28.0
Field Cultivator	5.5	0.75	250	0.55	9.5	12.5	13.5	16.5	19.5	23.5	27.5	34.5
Stubble Drill	4.5	0.65	225	0.65	13.2	13.2	13.2	26.4	26.4	26.4	39.6	39.6
Conventional Drill	4.5	0.70	150	0.55	20.0	24.0	24.0	32.0	40.0	40.0	40.0	40.0

Table 5. Enid Area Available Field Work Days

Time Periods	Maximum Number of Days	Timeliness Level 50% (Days)	80% (Days)	90% (Days)	98% (Days)
January 1-16	16	15.25	14.25	13.00	10.75
January 17-31	15	15.00	13.25	12.50	8.75
February 1-14	14	13.25	12.75	11.00	8.75
February 15-28	14	13.25	12.25	11.75	10.00
March 1-16	16	14.75	13.00	11.25	7.50
March 17-31	15	14.00	11.75	9.50	7.50
April 1-15	15	13.00	10.75	8.75	7.75
April 16-30	15	12.75	10.00	8.75	5.75
May 1-16	16	13.00	10.25	8.25	6.00
May 17-31	15	12.00	8.50	6.25	3.50
June 1-15	15	12.50	9.75	7.50	4.75
June 16-30	15	13.25	10.50	9.50	7.50
July 1-16	16	14.25	11.75	10.50	8.25
July 17-31	15	13.75	12.25	10.75	7.50
August 1-16	16	14.75	12.25	11.00	8.25
August 17-31	15	13.75	11.75	10.00	6.75
September 1-15	15	13.50	10.50	8.75	5.50
September 16-30	15	13.25	9.25	6.75	4.00
Ocotber 1-16	16	14.00	12.25	11.00	8.00

Table 6. Machine and Tractor Sizes Selected by the Optimum Machinery Complement Selection System for Alternative Wheat Production Systems

	System							
Machines	PLW	CHS	2TL	1TLA	1TLB	1TLC	OTLA	OTLB
Sprayer[a]	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0
Off-Set Disk	20.3	13.5						
Moldboard Plow (1)[b]	4.0							
Moldboard Plow (2)	4.7							
Moldboard Plow (3)	9.0							
Chisel Plow (1)		12.0						
Chisel Plow (2)		16.0						
Dry Fert. Spreader	60.0	60.0						
Liquid Fert. Spreader							40.0	40.0
Knife NH_3 Applicator	22.0	28.0						
Sweep (1)			30.0	15.0	15.0	15.0		
Sweep (2)						25.0		
Field Cultivator (1)	12.5	27.5						
Field Cultivator (2)	13.5							
Conventional Drill	40.0	40.0						
Stubble Drill (1)			39.6	13.2	13.2	39.6	39.6	39.6
Stubble Drill (2)				26.4	26.4			
Tractor (1)[c]	81	131	180	70	70	91	70	70
Tractor (2)	91	180		111	111	180	180	180
Tractor (3)	180							

[a]Implement size by width in feet.

[b]The number in parenthesis refers to tractor (bottom three rows) used to power the implement.

[c]Tractor size in horsepower

Table 6. (Continued)

Machines	System							
	PLW/ 1TLA	PLW/ 1TLB	PLW/ OTLA	PLW/ OTLB	CHS/ 1TLA	CHS/ 1TLB	CHS/ OTLA	CHS/ OTLB
Sprayer	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0
Off-Set Disk	12.5	12.5	12.5	12.5	16.8	16.8	13.5	12.5
Moldboard Plow (1)	3.5	3.5	4.0	4.0				
Moldboard Plow (2)	5.3	5.3	5.3	5.3				
Moldboard Plow (3)								
Chisel Plow (1)					16.0	16.0	12.0	16.0
Chisel Plow (2)								
Dry Fert. Spreader	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Liquid Fert. Spreader			40.0	40.0			40.0	40.0
Knife NH_3 Applicator	28.0	28.0	28.0	28.0	15.0	15.0	15.0	28.0
Sweep (1)	15.0	15.0			15.0	15.0		
Sweep (2)								
Field Cultivator (1)	9.5	9.5	12.5	12.5	12.5	12.5	12.5	16.5
Field Cultivator (2)	9.5	9.5						
Conventional Drill								
Stubble Drill (1)	13.2	13.2	13.2	13.2	39.6	39.6	13.2	39.6
Stubble Drill (2)	26.4	26.4	26.4	26.4			26.4	
Tractor (1)	70	70	70	70	81	81	70	111
Tractor (2)	70	70	81	81	180	180	81	180
Tractor (3)	111	111	111	111			131	

Table 6. (Continued)

Machines	System: 2TL/ 1TLA	2TL/ 1TLB	1TLA /1TC	1TLB /1TC	PLW/ 2TL	PLW/ CHS
Sprayer	47.0	47.0	47.0	47.0	47.0	47.0
Off-Set Disk					12.5	20.3
Moldboard Plow (1)					3.5	6.7
Moldboard Plow (2)					3.5	
Moldboard Plow (3)						
Chisel Plow (1)						16.0
Chisel Plow (2)						
Dry Fert. Spreader					60.0	60.0
Liquid Fert. Spreader						
Knife NH_3 Applicator					28.0	28.0
Sweep (1)	15.0	15.0	20.0	25.0	15.0	
Sweep (2)						
Field Cultivator (1)					9.5	27.5
Field Cultivator (2)					9.5	
Conventional Drill						40.0
Stubble Drill (1)	13.2	13.2	13.2	39.6	13.2	
Stubble Drill (2)	26.4	26.4	26.4		26.4	
Tractor (1)	70	70	70	180	70	131
Tractor (2)	111	111	131		70	180
Tractor (3)					111	

Table 7. Required Sizes and Estimated Annual Hours of Tractor Use for Alternative Wheat Production Systems

	Annual Tractor Hours Tractor Size (Horsepower)[a]					
System	70	81	91	111	131	180
PLW		445	489			469
CHS					624	542
2TL						455
1TLA	269			312		
1TLB	124			312		
1TLC			237			213
OTLA	333					98
OTLB	188					98
PLW/1TLA	258:332[b]			623		
PLW/1TLB	186:332[b]			623		
PLW/OTLA	300	304		518		
PLW/OTLB	228	304		408		
CHS/1TLA		474				492
CHS/1TLB		400				493
CHS/OTLA	402	218			489	
CHS/OTLB				485		306
2TL/1TLA	233			475		
2TL/1TLB	161			417		
1TLA/1TC	233				288	
1TLB/1TC						319
PLW/2TL	410:351[b]			593		
PLW/CHS					547	559

[a]Tractors of size 156 and 229 horsepower were not selected as part of the optimal complements for any of the systems.

[b]These systems require two 70 horsepower tractors.

Table 8. Initial Machinery Investment Requirements for Alternative Wheat Production Systems

System	Investment ($)	System	Investment ($)
PLW	143,504	PLW/OTLB	127,659
CHS	128,013	CHS/1TLA	132,360
2TL	106,466	CHS/1TLB	132,360
1TLA	96,454	CHS/OTLA	129,028
1TLB	96,454	CHS/OTLB	138,668
1TLC	141,536	2TL/1TLA	98,155
OTLA	105,834	2TL/1TLB	96,454
OTLB	105,834	1TLA/1TC	106,295
PLW/1TLA	132,239	1TLB/1TC	99,948
PLW/1TLB	132,239	PLW/2TL	133,327
PLW/OTLA	127,659	PLW/CHS	132,671

Table 9. Estimation of Per Acre Production Costs for Alternative Wheat Production Systems

	Systems							
	PLW	CHS	2TL	1TLA	1TLB	1TLC	OTLA	OTLB
OPERATING INPUTS:								
Parathion	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Aerial Spray Charge	3.00	3.00	3.00	3.00	6.00	3.00	3.00	6.00
2-4-D	1.27	1.27	1.91	1.91	0.64	1.91	1.91	0.64
Surflan					13.00			13.00
MCPA					1.57			1.57
Bladex			9.43	9.43		9.43	9.43	
Paraquat				5.85		5.85	11.70	5.85
18-46-0	12.76	12.76	12.76	12.76	12.76	12.76	12.76	12.76
Fertilizer Spreader Rental	0.11	0.11						
Anhydrous Ammonia (NH_3)	15.45	15.45	15.45	15.45	15.45	15.45		
Liquid Nitrogen (N)							20.32	20.32
Liquid N Spreader Rental							0.90	0.90
Seed	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Seed Treatment			0.50	0.50	0.50	0.50	0.50	0.50
Custom Combine	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Custom Haul	4.48	4.48	4.48	4.48	4.48	4.48	4.48	4.48
Annual Operating Capital	6.85	7.11	7.63	8.24	8.68	8.49	9.66	10.08
Labor Charges	4.98	4.13	1.61	2.06	1.55	1.59	1.53	1.01
Fuel, Lube, Repairs	13.42	15.24	8.67	5.95	4.81	6.23	5.09	3.69
TOTAL OPERATING COSTS	84.19	85.42	87.30	91.49	91.30	91.55	103.14	102.66
FIXED COSTS								
Machinery								
Interest at 17%	12.68	11.27	9.14	8.36	8.35	12.33	9.22	9.22
Depr., Taxes, Insur.	9.84	8.81	7.53	6.77	6.77	9.91	7.28	7.28
TOTAL FIXED COSTS	22.52	20.08	16.67	15.13	15.12	22.24	16.50	16.50
TOTAL COSTS	106.71	105.50	103.97	106.62	106.42	113.79	119.64	119.16

Table 9. (Continued)

	System						
	PLW/ 1TLA	PLW/ 1TLB	PLW/ OTLA	PLW/ OTLB	CHS/ 1TLA	CHS/ 1TLB	CHS/ OTLA
OPERATING INPUTS:							
Parathion	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Aerial Spray Charge	3.00	4.50	3.00	4.50	3.00	4.50	3.00
2-4-D	1.60	0.96	1.60	0.96	1.60	0.96	1.60
Surflan		6.50		6.50		6.50	
MCPA		0.78		0.78		0.78	
Bladex	4.71		4.71		4.71		4.71
Paraquat	2.93		5.86	2.93	2.93		5.86
18-46-0 Fertilizer	12.76	12.76	12.76	12.76	12.76	12.76	12.76
Fertilizer Spreader Rental	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Anhydrous Ammonia (NH_3)	15.45	15.45	7.72	7.72	15.45	15.45	7.72
Liquid Nitrogen (N)			10.13	10.13			10.13
Liquid N Spreader Rental			0.45	0.45			0.45
Seed	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Seed Treatment	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Custom Combine	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Custom Haul	4.48	4.48	4.48	4.48	4.48	4.48	4.48
Annual Operating Capital	7.61	7.85	8.30	8.32	7.79	8.00	8.40
Labor Charges	4.30	4.05	3.98	3.34	3.42	3.17	3.95
Fuel, Lube, Repairs	10.12	9.61	9.61	7.77	11.33	10.70	10.28
TOTAL OPERATING COSTS	89.12	89.10	94.76	92.80	89.63	89.46	95.50
FIXED COSTS							
Machinery							
Interest at 17%	11.34	11.33	11.13	11.13	11.46	11.45	11.31
Depr., Taxes, Insur.	9.22	9.20	8.93	8.94	9.27	9.27	9.04
TOTAL FIXED COSTS	20.56	20.53	20.06	20.07	20.73	20.72	20.35
TOTAL COSTS	109.68	109.63	114.82	112.87	110.36	110.18	115.85

Table 9. (Continued)

	System						
	CHS/ OTLB	2TL/ 1TLA	2TL/ 1TLB	1TLA /1TC	1TLB /1TC	PLW/ 2TL	PLW/ CHS
OPERATING INPUTS:							
Parathion	0.86	0.86	0.86	0.87	0.86	0.86	0.86
Aerial Spray Charge	4.50	3.00	4.50	3.00	4.50	3.00	3.00
2-4-D	0.96	1.91	1.27	1.91	1.27	1.60	1.27
Surflan	6.50		6.50		6.50		
MCPA	0.78		0.78		0.78		
Bladex		9.43	4.71	9.43	4.71	4.71	
Paraquat	2.93	2.93		5.86	2.93		
18-46-0 Fertilizer	12.76	12.76	12.76	12.76	12.76	12.76	12.76
Fertilizer Spreader Rental	0.05					0.05	0.11
Anhydrous Ammonia (NH_3)	7.72	15.45	15.45	15.45	15.45	15.45	15.45
Liquid Nitrogen (N)	10.13						
Liquid N Spreader Rental	0.45						
Seed	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Seed Treatment	0.25	0.50	0.50	0.50	0.50	0.25	
Custom Combine	16.00	16.00	16.00	16.00	16.00	16.00	16.00
Custom Haul	4.48	4.48	4.48	4.48	4.48	4.48	4.48
Annual Operating Capital	8.61	8.06	8.13	8.35	8.62	7.32	6.94
Labor Charges	2.81	2.51	2.05	1.85	1.13	4.93	3.93
Fuel, Lube, Repairs	9.75	7.89	6.31	5.98	5.88	11.36	14.20
TOTAL OPERATING COSTS	94.54	90.76	89.30	91.43	91.39	87.77	84.00
FIXED COSTS							
Machinery							
Interest at 17%	12.08	8.49	8.35	9.20	8.86	11.42	11.67
Depr., Taxes, Insur.	9.62	6.89	6.76	7.47	7.27	9.29	9.16
TOTAL FIXED COSTS	21.70	15.38	15.11	16.67	16.13	20.71	20.83
TOTAL COSTS	116.2[illegible]	106.14	104.41	108.10	107.52	108.48	104.83

Table 10. Selected Requirements Per Acre for Alternative Wheat Production Systems

Systems	Labor (hours)	Fuel (Gallons)	Average Machinery Investment ($)	Herbicide Costs ($)	Total Operating Capital ($)
PLW	1.25	6.388	74.58	1.27	40.31
CHS	1.03	6.937	66.31	1.27	41.84
2TL	0.40	3.163	57.84	11.34	44.90
1TLA	0.52	2.068	49.17	17.19	48.49
1TLB	0.39	1.675	49.14	15.21	51.10
1TLC	0.40	2.317	72.51	17.19	49.96
OTLA	0.38	1.578	54.24	23.04	56.90
OTLB	0.25	1.185	54.23	21.06	59.32
PLW/1TLA	1.08	4.279	66.69	9.24	44.75
PLW/1TLB	1.01	4.082	66.44	8.24	46.12
PLW/OTLA	1.00	3.993	60.03	12.17	48.84
PLW/OTLB	0.84	3.328	65.49	11.17	48.93
CHS/1TLA	0.86	4.911	67.39	9.24	45.77
CHS/1TLB	0.79	4.684	67.36	8.24	47.04
CHS/OTLA	1.00	4.255	66.57	12.17	49.44
CHS/OTLB	0.70	4.214	71.06	11.17	50.68
2TL/1TLA	0.63	2.667	49.93	14.27	47.39
2TL/1TLB	0.51	2.224	49.11	13.26	47.80
1TLA/1TC	0.46	2.091	54.11	17.20	49.22
1TLB/1TC	0.28	2.219	52.12	16.19	50.78
PLW/2TL	1.23	4.772	67.15	6.31	43.03
PLW/CHS	0.98	6.672	68.62	1.27	40.86

Table 11. Estimated Total Cost Per Acre for Alternative Wheat Production Systems with Alternative Diesel Fuel Prices and Alternative Wage Rates

	Diesel Fuel Prices ($/gallons)								
	1.20			1.70			2.20		
	Wage rates ($/hour)								
System	4	7	10	4	7	10	4	7	10
PLW	106.71	110.46	114.21	110.96	114.71	118.46	115.22	118.97	122.72
CHS	105.50	108.59	111.68	110.12	113.21	116.30	114.74	117.83	120.92
2TL	103.97*[a]	105.17*	106.37*	106.05*	107.25*	108.45*	108.13*	109.33*	110.53*
1TLA	106.62	108.18	109.74	107.98	109.54	111.10	109.34	110.90	112.46
1TLB	106.42	107.59*	108.76*	107.53*	108.70*	109.87*	108.64*	109.81*	110.98*
1TLC	113.79	114.99	116.19	115.32	116.52	117.72	116.85	118.05	119.25
OTLA	119.64[b]	120.78[b]	121.92[b]	120.67[b]	121.81[b]	122.95	121.71	122.85	123.99
OTLB	119.16	119.91	120.66	119.94	120.69	121.44	120.72	121.47	122.22
PLW/1TLA	109.68	112.92	116.16	112.52	115.76	119.00	115.36	118.60	121.84
PLW/1TLB	109.63	112.67	115.70	112.35	115.38	118.41	115.07	118.10	121.13
PLW/OTLA	114.82	117.82	120.82	117.47	120.47	123.47	120.12	123.12	126.12
PLW/OTLB	112.87	115.39	117.91	115.08	117.60	120.12	117.29	119.81	122.33
CHS/1TLA	110.36	112.94	115.52	113.62	116.20	118.78	116.89	119.47	122.05
CHS/1TLB	110.18	112.55	114.92	113.30	115.67	118.04	116.42	118.79	121.16
CHS/OTLA	115.85	118.86	121.86	118.69	121.69	124.69[b]	121.51	124.51[b]	127.51[b]
CHS/OTLB	116.24	118.34	120.44	119.04	121.14	123.24	121.84[b]	123.94	126.04
2TL/1TLA	106.14	108.03	109.92	107.90	109.79	111.68	109.66	111.55	113.44
2TL/1TLB	104.41*	105.94*	107.47*	105.88*	107.41*	108.94*	107.36*	108.89*	110.42*
1TLA/1TC	108.10	109.49	110.87	109.49	110.87	112.25	110.87	112.25	113.63
1TLB/1TC	107.52	108.36	109.20	108.99	109.83	110.67	110.45	111.29	112.13
PLW/2TL	108.48	112.17	115.86	111.66	115.35	119.04	114.84	118.53	122.22
PLW/CHS	104.83*	107.78	110.72	109.28	112.22	115.16	113.72	116.66	119.60

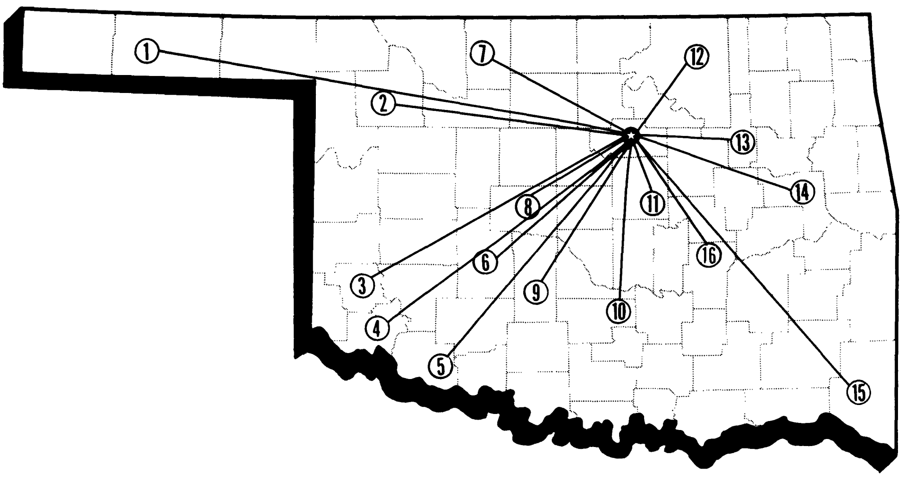
[a]The three lowest cost systems in each column are devoted by asterisks.

[b]The most costly system in the column.

OKLAHOMA

Agricultural Experiment Station

System Covers the State



Main Station — *Stillwater, Perkins and Lake Carl Blackwell*

1. **Panhandle Research Station — *Goodwell***
2. **Southern Great Plains Field Station — *Woodward***
3. **Sandyland Research Station — *Mangum***
4. **Irrigation Research Station — *Altus***
5. **Southwest Agronomy Research Station — *Tipton***
6. **Caddo Research Station — *Ft. Cobb***
7. **North Central Research Station — *Lahoma***
8. **Southwestern Livestock and Forage Research Station — *El Reno***
9. **South Central Research Station — *Chickasha***
10. **Agronomy Research Station — *Stratford***
11. **Pecan Research Station — *Sparks***
12. **Veterinary Research Station — *Pawhuska***
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