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Title: AN ECONOMIC ANALYSIS OF RESOURCE SUBSTITUTION WITH SPRINKLER IRRIGATION SYSTEMS IN USE IN OREGON'S NORTHERN COLUMBIA RIVER BASIN COUNTIES

Abstract approved: ______________________
Frank S. Conklin

The problem of drying wells and lowering water table in Oregon's North Columbia Basin, coupled with the prospects for irrigating an additional 100,000 acres of dryland intensified interest in irrigation development in the area. To facilitate the decision-making by the area farmers on the selection of a sprinkler system, this study was addressed to analyze the technical and economic characteristics of the dominant form of on-farm irrigation systems -- side roll and center pivot.

The objectives of this study were to identify the capital investment (outlay), overhead and operating costs; variability of these costs among farms using an irrigation system and between systems; and to determine the extent to which resource substitution capabilities exist within the technical limitation of these systems.

The average capital outlay for the systems were $219 and $218 per acre for center pivot and side roll respectively. The average overhead cost per acre was $43.62 for center pivot and $37 for side roll. The average annual operating costs were $39 and $36 per acre for center pivot and side roll respectively. Though these cost components were similar between the systems, they vary greatly among the farms. Factors contributing to the differences in capital outlay between farms were due primarily to time of purchase, length of main line, pump size, system size and use of supplemental system. Variation in total annual overhead cost was influenced to varying degrees by each of the four overhead cost components (depreciation, interest, property tax and insurance) and total capital outlay.

The most intensively used resource was capital which constituted 56 and 50 percent of total cost for center pivot and side roll, respectively. Labor accounted for 9 and 18 percent of total cost for center pivot and side roll respectively. Labor used on side roll was twice that used on center pivot. Electricity or pumping cost constituted 24 percent of total cost for center pivot and 21 percent for side roll.

Findings from this study indicated the existence of resource interrelations between the variable resources -- labor, land, capital and water -- and the systems (side roll and center pivot) and flexibility to modify relative resource use over time.

An Economic Analysis of Resource Substitution with Sprinkler Irrigation Systems in Use in Oregon's Northern Columbia River Basin Counties

by

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To Mr. Dan Wilson, extension agent, I express my sincere thanks for his valuable assistance in providing useful information that saved many hours of work.

I dedicate this study and the future it brings to my father, Mr. Godfrey Erhabor, for his financial and moral support throughout my educational career.

GOD BLESS YOU

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INTRODUCTION

Historical Development

It is unlikely that the first settlers in the North Columbia Basin one and one quarter centuries ago envisioned their irrigation efforts would serve as a forerunner of intensive irrigated agriculture in the region. Today irrigation development systems have transformed much of the semi-arid North Columbia Basin into lush farmland of significant importance to the economy of Northeastern Oregon and Southeastern Washington.

A major component of irrigation growth since the mid-1960's has been private investment in deep wells and capital intensive irrigation systems. Large center pivot and side roll systems, using ground water to irrigate sizable tracts of land, have been introduced. This development is a significant departure from previous irrigation development schemes which resulted from public reclamation projects initiated by the Corps of Engineers and administered by the Bureau of Reclamation.

A chronology of irrigation development in the Columbia Basin is presented in Table 1. It shows the first attempt to irrigate drylands in the Columbia Basin took place in

Table 1. Irrigation System Development in the Oregon Columbia Basin.

Project	Funding Source	Water Source	Storage or Resulting Development	Year Completed	Irrigation District	Comments	Acres Actually Irrigated			Total Irrigated Acres
							Flood	Center Pivot	Other Systems (Side roll)*	
First Settler Irrigation	Private	Stream/creek diversions	--	1865	--	Limited	--	--	--	--
Umatilla Project	Public	1. Diversion of Umatilla River	--	1903	--	--	--	--	--	--
		2. Diversion of streams from bottom land	Cold Spring Reservoir	1908	Hermiston	Completed	17,000	--	--	17,000
John Day Project	Public	Diversion of John Day River	--	1916	--	Feasible	122,000	--	--	17,000
Umatilla Project	Public	1. Flood flows of Umatilla River	--	1923-24	--	--	--	--	--	17,000
		2. Diversion of streams from bottom land	McKay Dam	1927	Stanfield and Westland	Completed	25,000	--	--	42,000
Private Development	Private	Wells	--	1965-70	--	--	--	10,000	4,500	56,500
Umatilla Project (Columbia South Side)	Public	Columbia River	--	1974	--	Impractical	--	--	--	56,500
Private Development	Private	Wells & Columbia River	--	1970-76	--	--	--	65,000	5,000	126,500

*Other systems is predominantly side roll.

the mid-1860's when settlers diverted creeks and streams adjacent to bottomlands to irrigate their crops. Only a few hundred acres were irrigated supplementally in the spring as the intermittent streams dried in mid-summer.

The first public attempt to irrigate a relatively large area of dryland, the Umatilla Project, took place in 1903. Initially involved was a desire to divert water from the Umatilla River to irrigate a large body of land on the south side of the Columbia River in Umatilla and Morrow counties. As a part of that project, the Cold Springs Reservoir was constructed in 1908 to divert water from the Umatilla River for flood control and irrigation of about 17,000 acres of land near Hermiston. The canals constructed and lands irrigated became the Hermiston Irrigation District which is shown as the unshaded area lying between 1 and 2 in Figure 1. By 1923-24, the intent to divert the flood flows of the Umatilla River to irrigate both sides of the river west of Umatilla County was deemed impractical due in part to the high cost of the feeder canal required. As an alternative, in 1927, McKay Reservoir was built on McKay Creek, a tributary of the Umatilla River located twenty miles southeast of the Holdman community in Figure 1. Stream flow of the Umatilla River and storage from McKay Reservoir were used to irrigate about 25,000 acres for the Stanfield and Westland irrigation districts depicted as areas 1 and 2 in Figure 1.

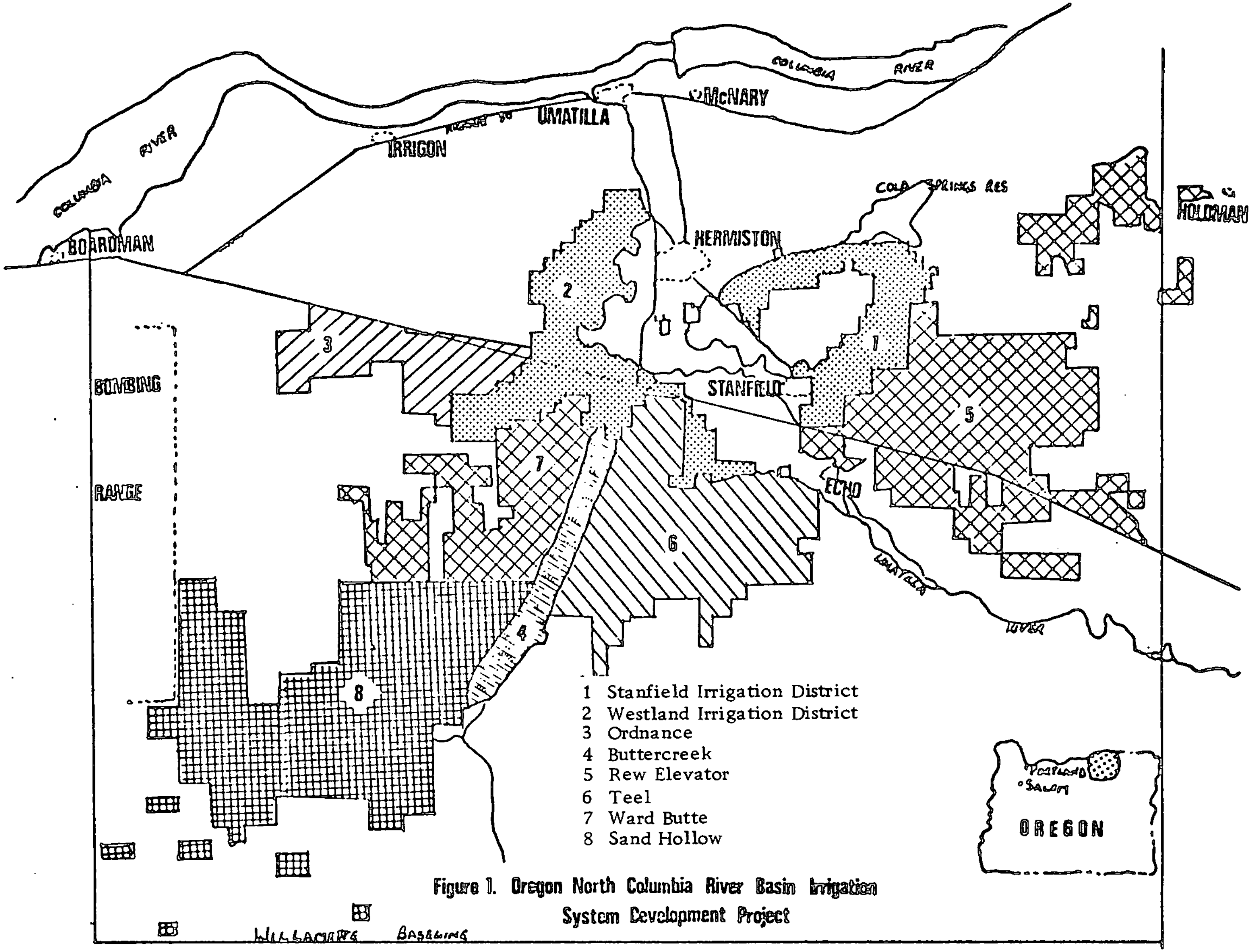

Figure 1. Oregon North Columbia River Basin Irrigation System Development Project

Other public reclamation attempts in the area included the John Day and Columbia South Side Projects, the latter a component of the Umatilla Project. The John Day Project was undertaken in 1913 to ascertain feasibility of constructing Carty Reservoir and irrigating lands in northern Morrow, Gilliam and Umatilla counties by diversion from the John Day River.[1/] The project report, completed in 1916, showed that it was feasible to irrigate about 120,000 acres by gravity diversion of the John Day River and some pumping of water from the Columbia River. The John Day Project was never implemented [39]. In 1974, the U.S. Bureau of Reclamation published a concluding report on the Columbia South Side Project which showed that it was not feasible to pump from the Columbia River to irrigate remaining drylands by flood methods in Morrow and Umatilla counties.

Although the Umatilla, John Day, and Columbia South Side Projects were not altogether successful in their attempt to bring water to all irrigable land in the area, they did, however, represent significant steps in use of flood irrigation systems in the Columbia Basin area in production of a wide variety of crops including potatoes and sugar beets.

[1/] The original Carty Reservoir was not built. However, a reservoir with the same name is now being constructed to provide coolant for a thermal nuclear power plant near Pebble Springs.

Private irrigation development using on-farm center pivot or side roll irrigation systems began in 1965 and has increased to over 700 units in 1976. These systems obtain water from underground aquifers primarily and from the Columbia River to a limited degree. Over the past seven years 70,000 acres of dryland have been converted to irrigation in the area; another 10,000 acres are in the process of being developed and long range projections suggest that an additional 200,000 acres are feasible for irrigation with existing technology. While climate is a dominant factor favoring intensive agriculture in the region, it appears to be enhanced by the apparent advantages of center pivot and side roll automated sprinkler systems in local farm operations, relative to the traditional gravity-flood irrigation systems which dominated the area for over 50 years. Almost no flood irrigation systems now remain in the region.

The Study Area

The Oregon North Columbia River Basin Irrigation System Development Study area was identified by Oregon State University for intensive research and extension efforts in 1975 and 1976 to ascertain feasibility for irrigating 100,000 acres of dryland from high lift pumping out of the Columbia River. The study area is located in Western Umatilla and Northeastern Morrow counties of Oregon and comprises about 421,000 acres of land of which 50,000 acres were irrigated in 1975 [22]. It is bounded by the Columbia River to the north, the easterly limit of Stanfield Irrigation District to the east, Willamette Baseline to the south, and the Ordinance Depot/Bombing Range to the west. A map of the study area is presented in Figure 1.

Topography of the area varies from sandy, gently rolling plains rising 50 to 500 feet above the level of the Columbia River to steeper and more deeply cut gullies and drainways dominated by fine textured silt-sandy loam soils west of Butter Creek.

The climate is temperate and semi-arid, characterized by low annual precipitation, low winter temperatures and high summer temperatures. Precipitation varies from 8 to 20 inches annually with less than six inches falling during the April 1 through September 30 irrigation season. The frost-free growing season ranges from 160 to 200 days.

Traditionally, the major irrigated crops have been small grains, alfalfa hay, cannery peas, some vegetable crops and pasture for grazing purposes as shown in Table 2. Potatoes (early and late) are presently the most rapidly expanding crop within the area -- now becoming recognized as a major potato producing region. Alfalfa hay, although having increased slightly in irrigated acreage in the past nine years, has declined greatly in relative importance during the past decade. The relative importance of

Table 2. Aggregate Cropping Pattern Trend (1966-74) in Oregon's Northern Columbia River Basin Counties (Morrow and Umatilla).

Crop Type	1966		1967		1968		1969		1970		1971		1972		1973		1974	
	Acres (000)	%	Acres (000)	%	Acres (000)	%	Acres (000)	%	Acres (000)	%	Acres (000)	%	Acres (000)	%	Acres (000)	%	Acres (000)	%
Wheat	12	20	15	24	22	30	27	33	33	35	38	36	44	36	50	39	57	37
Alfalfa Hay	35	57	34	53	35	49	38	46	40	43	41	38	41	34	42	33	46	30
Potatoes	0		1	2	2	3	4	5	6	6	6	6	11	9	11	9	19	12
Corn Silage	0		0		0		0		0		2	2	3	2	5	4	10	7
Green Peas	2	3	2	3	2	3	3	3	3	3	4	4	4	3	5	4	5	3
Alfalfa Seed	4	7	3	5	3	4	3	3	3	3	3	3	3	2	3	2	3	2
Vegetables and Miscellaneous Crops*	8	13	8	13	8	11	8	10	9	10	12	11	17	14	11	9	13	9
Total	61	100	63	100	72	100	83	100	94	100	106	100	122	100	127	100	153	100

*Barley, dry beans, sweet corn, green beans, sugar beets, irrigated pasture, soybeans, watermelons, sweet potatoes, sunflower, and other oil seeds.

irrigated acreage of wheat and green peas has been fairly constant. Non-irrigated land continues to be devoted almost entirely to traditional small grain-fallow operations.

Historically, water for irrigation has been delivered through open and unlined canals and laterals to irrigate crops using flood irrigation methods. Flood irrigation is characterized, relative to the modern capital intensive systems, by large labor requirements and high volumes of water runoff. Since the mid 1960's sprinklers have been replacing flood irrigation on the Stanfield-Westland and Hermiston irrigation districts and comprise the sole form of irrigation on newly reclaimed drylands irrigated from ground water. About 20,000 acres are presently irrigated from ground water in the study area.

Problem Statement

New irrigation methods and the subsequent growth of intensive agriculture production in the area have led to increasing demands for water. While water is a renewable resource, it is nevertheless finite in supply at a given moment in time. In the water development planning, single purpose demand for water in the agricultural sector has gradually been replaced with multi-purpose considerations. Competing demands for water are generated by municipal, industrial, recreational, fishery, and transportation needs. Added to the complexity of water allocation decisions in the Columbia Basin region are the location of thermal nuclear energy generation facilities; major expansion in related agribusiness; competition for water to supply irrigated acreages in Oregon, Washington, Idaho and Canada using Snake and Columbia River flows; and the assertion of the Umatilla Indian Tribe, now interested in reclaiming the Umatilla River water for fisheries and irrigation.[2/]

Last but not least, some deep well delivery systems are not assured of a permanent water supply. Rapidly decreasing water tables in the strata from which deep wells pump water, the primary source of water for the area center pivot irrigators, led the Oregon Office of the State Engineer to place a ban on furtherwell drilling in some areas and the possibility of shut-down of some operating wells is imminent.[3/]

The multiple problems caused by area water shortages reinforce the importance of looking at alternative water supply sources and improved technical efficiency in use of existing water. Two primary alternatives are now being evaluated. One involves pumping water from the Columbia River as a high lift operation, and the second involves

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[2/] Umatilla Indians claim to have the primary water rights to the Umatilla River based on an 1855 treaty. This has yet to be tested in the courts.

[3/] The State Engineer has statutory powers to regulate use of ground water and the ban was a result of a study conducted by the State Engineers Office in 1966 and a U.S. Geological Survey completed in the 1970s.

modification of existing production techniques and application procedures consistent with changing technological conditions.

In addition to the water problem, an equally important factor affecting resource use and allocation decisions is the increasing cost of agricultural labor. An agricultural labor shortage, due in part to the increasing demands for industrial labor with its higher relative wage rates, influences the choice of on-farm irrigation technology. The shrinking labor supply has contributed, at least partially, to the shift away from the labor intensive flood systems to capital intensive irrigation systems which require relatively less labor [11].

Faced with the problem of dual resource shortages -- water and labor -- there is need to investigate opportunities for further resource substitution. Farm level substitution possibilities for water; the relative technical efficiency of different irrigation technologies; and the influence of soil type, topography and application rates of water use are central features of the area water problem.

Study Objectives

The aforementioned problem issues generate a need for technical and economic information to be used by private and public decision makers on the probable direction, extent and consequences of growth in the Northern Columbia Basin.

Oregon State University is providing research and educational support to generate information on existing and expected socio-economic impacts of implementing a large irrigation scheme in the Northern Columbia Basin [22]. This study is a component of that broader research effort. The specific function of this study is to analyze the technical and economic characteristics of the dominant forms of on-farm irrigation systems (side roll and center pivot) now in use in the region. Analysis of these systems is intended to provide information in projecting feasibility of irrigating additional drylands in the Northern Columbia Basin and what irrigation systems are most apt to be adopted.

It is then hoped that results and information from this study can be used by public planners and farmers who expect to convert dryland to irrigation. Consistent with that overall purpose, four specific study objectives have been defined:

1. Identify the capital investment, overhead and operating costs associated with center pivot and side roll irrigation systems.

2. Measure the extent of cost variability among farms having the same irrigation systems and among systems.

3. Evaluate how the variability of irrigation costs are influenced by such factors as soil type, topography, water application levels, peak month water demands, water sources, management, and labor requirements.

4. Determine the extent to which resource substitution capabilities exist within the technical limitations of center pivot and side roll irrigation systems.

DESIGN OF STUDY

Considerable technical and economic information of a published nature is available on irrigation systems in general, including studies of irrigation systems in Nebraska, Texas, Washington and North Dakota [25, 15, 16, and 19]. However, they are not comparative in nature nor do they address resource substitution possibilities among inputs.

To produce the information necessary to accomplish the objectives of this study, a survey of 27 farmers in the study area was conducted. The survey included 24 commercial farmers who derived greater than 80 percent of their income from farming and three part-time farmers whose major income source was from off-farm employment. The stratified random sample of 24 commercial farms was drawn from a population of 51 commercial irrigated farms. The three part-time farms were selected, rather than sampled, from an unknown population level of part-time farms in the project area.

Technical and economic information on irrigation systems in use was obtained from each of the 27 sample farms. That information is analyzed to address resource substitution capability by irrigation system within its technical limitations.

This section treats the theory of resource substitution and its application to irrigation technology, sampling procedures employed in the study and the analytical framework used in the study.

Theoretical Considerations

A growing concern has emerged in recent years over increased water scarcity in the North Columbia Basin. Thus, if more water is to be obtained not only for irrigation purposes but also for agriculturally related industries, manufacturing and thermal nuclear purposes, the capital investment and associated costs of acquiring it are expected to increase appreciably. This suggests that the price of water to users may rise relatively more rapidly than other inputs used in irrigated crop production leading to further resource substitution shifts to more capital intensive irrigation systems. Price increases may occur because of (1) greater competition between competing users for limited water supplies thereby bidding up the price of water and (2) exploitation of potential water supplies not already tapped which are more costly to obtain than existing sources because of physical limitations requiring costly technology. The increase in irrigated acreage farmed in the area and probable water price increases are expected to enhance or speed the change to more capital intensive irrigation schemes. The degree or extent to which technical substitution capabilities exists among inputs -- land, labor, capital, management and water -- is an important element in evaluating the direction and rate of potential change.

General Theory of Substitution

Production functions represent combinations of variable inputs which produce varying levels of output. In general,

$$Y = f(X_1, X_2, X_3, \ldots. X_n)$$

where Y is the output and X's are the resources required in production. In this study, Y refers to irrigated crop production, while the required inputs are treated as land, labor, water, capital, and management components. Although all the resources included in crop production can be varied simultaneously, this study will consider, for simplicity of explanation, two variable inputs at a time and treat other inputs as fixed. Thus

$$Y = f(X_1, X_2, \mid X_3, X_4, X_5) \quad .$$

This expression indicates that the amount of output, Y, depends in a unique way upon the amounts of two inputs, X_1, and X_2, used in the production process along with the fixed inputs (X_3, X_4, and X_5). This could be represented by a production surface in a three dimensional diagram or depicted by a two dimensional contour map as shown in Figure 2. Each curve or product isoquant represents possible combinations of input physically capable of producing a given level of output within a given production period [7].

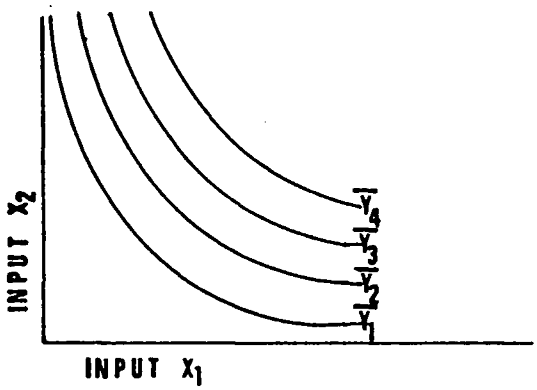

Figure 2. Product contours or isoquants

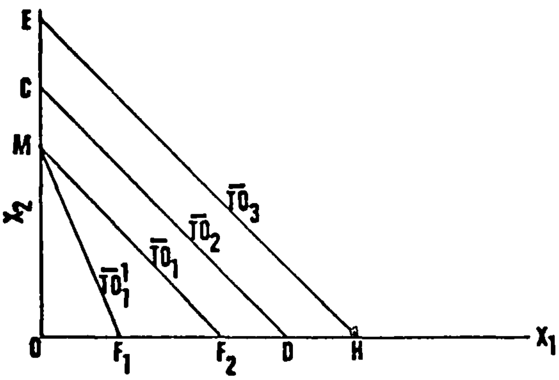

Figure 3. Sets of isocost lines

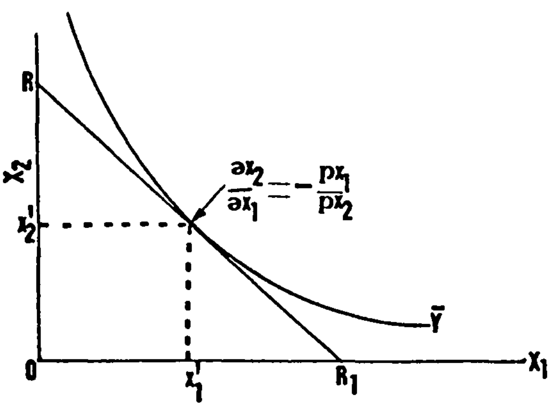

Figure 4. Economically efficient combination of input

The slope of a given isoquant at any particular point indicates the rate at which one resource substitutes for the other for a specified level of output. The marginal rate of factor substitution of factor X_1 for factor X_2 can be expressed as the inverse ratio of the marginal physical productivities of the two resources as follows:[4/]

$$\frac{\frac{\delta Y}{\delta x_1}}{\frac{\delta Y}{\delta x_2}} = \frac{-MPPx_1}{MPPx_2} = \frac{\delta x_2}{\delta x_1}$$

Theoretically, isoquants can be determined for any particular output level, or conversely, each specific output level

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4/ For a production function expressed as $Y = f(X_1, X_2)$ the change in production arising from a change in X_1 or (X_2) is the marginal physical product (MPP) of X_1 (or X_2). Hence the marginal physical product of X_1 is $\frac{\delta Y}{\delta x_1}$ and the marginal physical product of X_2 is $\frac{\delta Y}{\delta x_2}$. An isoquant is given by $f(X_1, X_2) = \overline{Y}$ where $\overline{Y}$ is held constant. Hence the total derivative is set equal to zero:

$$\frac{\delta Y}{\delta x_1} \delta x_1 + \frac{\delta Y}{\delta x_2} \delta x_2 = 0$$

Solving the total differential for $\frac{\delta x_2}{\delta x_1}$ results in

$$\frac{\delta x_2}{\delta x_1} = \frac{\frac{\delta Y}{\delta x_1}}{\frac{\delta Y}{\delta x_2}} \quad \text{where } \frac{\delta Y}{\delta x_2} = MPPx_2 \text{ and } \frac{\delta Y}{\delta x_1} = MPPx_1$$

Therefore $\frac{\delta x_2}{\delta x_1} = \frac{MPPx_1}{MPPx_2}$

has a unique isoquant associated with it [2]. In Figure 2, the further upward and to the right a curve lies the greater is its associated output. The shape of each isoquant and its nearness to the other isoquant is due to the physical, biological, and technological relationships between factors X_1 and X_2 and their resulting combined effect upon output.

Each input X_1 and X_2 has a cost associated with it. To minimize the cost of producing a given output or maximize output for a given level of cost, relative input prices are important. Denoting the cost per unit of X_1 as Px_1, and of X_2, as Px_2, then the total outlay (TO) for those inputs is given as

$$TO = Px_1 X_1 + Px_2 X_2$$

As production surfaces are characterized by a family of isoquants, a family of cost or budget levels can be described by a series of isocost or iso-outlay lines which determine all combinations of two inputs which can be purchased for a given budget. When prices do not change, each possible total outlay or budget is represented by a unique line as shown in Figure 3 with higher total outlay represented by budget lines with higher TO numbers and located further away from the origin. Iso-outlay lines TO_1, TO_2, TO_3 have the same slope when relative input prices Px_1 and Px_2 do not change. However, changes in relative input prices change the slope of the iso-outlay line. For example, an increase in price of input X_1 with Px_2 held constant results in an iso-outlay line TO_1^1 which is steeper than TO_1 since less of X_1 can be purchased for a given budget or total outlay. Similarly, a decrease in price of X_1 relative to X_2 would result in a flatter iso-outlay line than before the price change. The slope of a given iso-outlay line is represented by the price ratio[5/]

$$\frac{-Px_1}{Px_2} .$$

The least cost combination of resources for a given output or for a given budget level is depicted when:[6/]

$$\frac{\delta x_2}{\delta x_1} = \frac{-Px_1}{Px_2}$$

[5/]An iso-outlay line can be expressed algebraically as:

$$TO = Px_1 X_1 + Px_2 X_2$$

which can be rewritten to express X_2 as a function of X_1:

$$X_2 = \frac{TO}{Px_2} - \frac{Px_1 X_1}{Px_2}$$

The slope of the TO function is the derivative $\frac{\delta x_2}{\delta x_1}$, i.e. $\frac{\delta x_2}{\delta x_1} = \frac{-Px_1}{Px_2}$, thus the slope of the iso-outlay line $\frac{\delta x_2}{\delta x_1}$ is equal to $\frac{-Px_1}{Px_2}$.

[6/]See Appendix I.

where $\frac{\delta x_2}{\delta x_1}$ denotes the marginal rate of factor substitution of X_2 for X_1 which is the slope of the isoquant and $\frac{-Px_1}{Px_2}$ is the inverse ratio of their prices which is the slope of the iso-outlay line, depicted as RR_1 in Figure 4. The cost of a given output is minimized when the marginal rate of factor substitution between the resources is equal to the inverse ratio of their prices and the technical isoquant is convex to the origin. That is, the least cost combination of inputs exists when the slope of the isoquant is tangent to the slope of the iso-outlay line. This shows the most economically efficient input mix. The locus of economically efficient input combinations for all output levels is represented by a line called the expansion path.

Technical isoquants as used in this study are hypothesized as being derived from fixed factor proportions resulting in fixed factor ratio rays for varying levels of inputs and linearly segmented isoquants for a given output level. This relationship is expressed graphically in Figure 5. The isoquant is not continuous but rather contains discrete linear segments. This is due, in part, to the technical design of irrigation systems which require fixed factor proportions within certain ranges particularly if operated at full capacity. Taking labor and water as example inputs, fixed but different labor-water input combinations are represented by rays 1 and 2 with ray 1 being more labor intensive and ray 2 being more water intensive

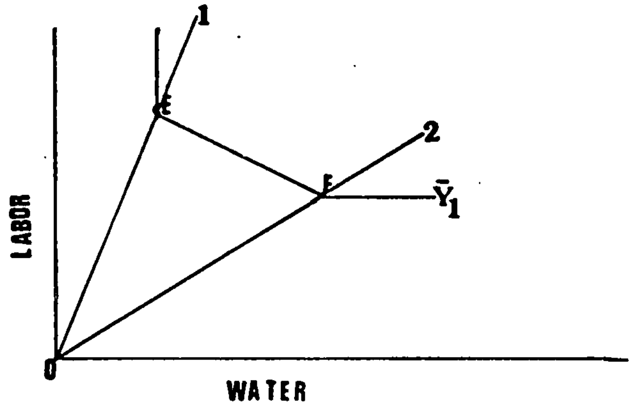

Figure 5. Isoquant map when two fixed-proportions processes are available

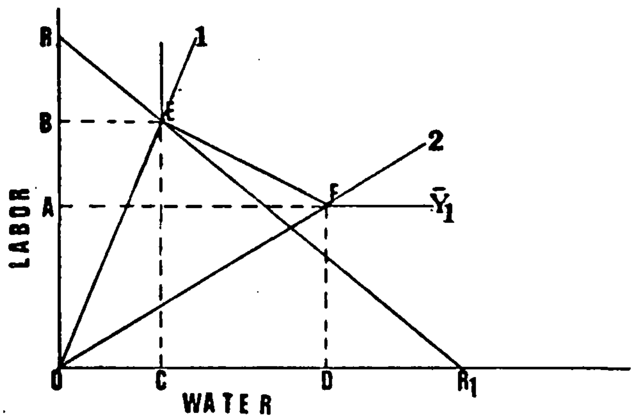

Figure 6. Inputs (labor and water) substitution

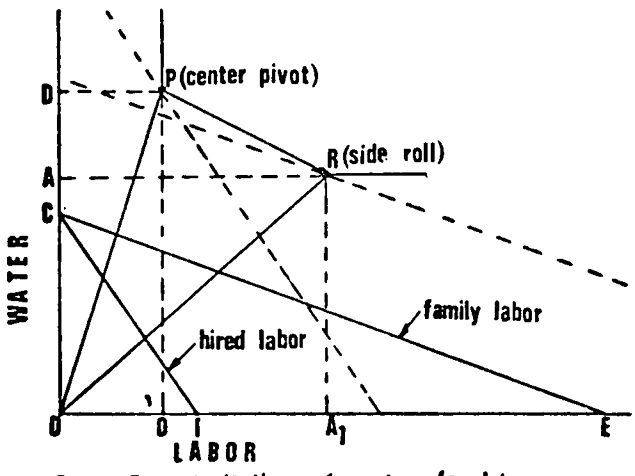

Figure 7. Substitution of water for labor

for a given level of crop output as depicted by points E and F for isoquant $\overline{Y}_1$. The unit isoquant EF in Figure 5 is drawn to reflect two different possible input combinations. Points E and F on this kinked line (one might refer to as water application technology) represents specific systems with different labor-water input proportions capable of producing the same output. No input combination lying on the arc between E and F are feasible, which suggests that all of one system or the other could be used but not a mixture of both because of technological considerations. Each discrete system, however, is assumed effective as a water application technology. By introducing the budget line RR_1 in Figure 6, point E of ray 1 is determined to be the least cost water application technology. OB units of labor and OC units of water are used in the production of the given level of output $\overline{Y}_1$. However, if the price of water were to decrease relative to labor, a flatter budget line would result leading to a shift to point F of ray 2 and a new least cost water application technology, with OA units of labor and OD units of water used in the production of output $\overline{Y}_1$. Therefore, if there is a change in the budget line (price ratio) the same level of output is produced at a lower cost by an input mix which favors more labor and less water at point E and more water and less labor at point F. Labor could, therefore, be substituted for water by moving from ray 2 to ray 1 and vice versa.

Application of Substitution Theory to Irrigation Technology

The theoretical framework presented above provides a basis for analyzing resource (land, water, capital, management and water) substitution possibilities in this study. Cursory observation of irrigation system use in the North Columbia Basin over the past decade suggests considerable resource substitution to have taken place. Until 1970, farmers in the Stanfield-Westland Irrigation District used flood irrigation systems. Since then, nearly all have shifted to more capital intensive side roll or center pivot irrigation systems. Economic theory would suggest that the relative price relationships between water, labor, and capital have changed to provide a stimulus for this type of substitution. An example of this is where labor becomes relatively more expensive. Where reliance is upon unpaid family labor the rate of water (labor substitution) is hypothesized as a function of the opportunity cost or alternative use for that labor. If high because of off-farm employment opportunities, greater reliance upon center pivot or side roll [14] is expected. If low, retaining of flood or handmoved sprinklers would likely occur. In addition to labor cost, if personnel management difficulties and uncertainty of labor hiring are issues, they, too, provide incentive for conversion to more capital intensive irrigation systems which are more labor saving.

The process of converting to more capital intensive-labor saving technology also results in greater water use efficiency. This phenomenon is depicted in Figure 7. Figure 7 represents a given output isoquant, together with two fixed factor proportion irrigation system rays. Point P represents the water-labor requirements using a center pivot system while point R represents water-labor for a side roll system. By using budget line CI, which assumes all labor is hired center pivot is shown as the least cost irrigation system as indicated by the dashed line, parallel to CI and tangent with P. Production will, therefore, occur at point P, and use OD units of water and OD_1 units of labor. Similarly, by introducing budget line CE which assumes unpaid family labor is the major irrigation labor source, side roll is expressed as the least cost irrigation system utilizing OA unit of water and OA_1 unit of labor. The slope of the budget in each case is determined by the price of labor. In this example a change in the price ratio due to increased cost of labor leads to substitution of water for labor. In the actual case of the Columbia Basin, labor and water have been substituted by more capital.

Sampling Procedure

Information from Cooperative Extension Service personnel at Hermiston indicated that two irrigation systems, center pivot and side roll dominate the area. While other systems exist, they appeared to constitute a relatively low percentage of primary systems in use or are used for supplemental irrigation purposes. Evidence was also provided which indicated that center pivot is the dominant irrigation system on the sandy soils where light and frequent water application rate is necessary while the side roll system dominates on loamy soils where water absorption is slower and greater risks of puddling occur. Yet, it was also indicated that some center pivot circles are located on loamy soils and some side roll on sandy soils. Because their number was specified as being small and because soil type might well be an important variable influencing adaptability of these systems, the author desired the use of a sampling system which was randomized but also assured sampling from small unit sub-components of the population. A stratified random sample was chosen as the appropriate means. Consequently, population of irrigated farms in the study area was stratified by (1) dominant irrigation systems in use and (2) soil type criteria.

The mechanics of sampling involved use of a geographic map of the study area overlayed with land ownership patterns, soil type (sand and loam) and irrigation system (center pivot and side roll) patterns to identify the irrigated farm population and each sub-strata. The population totaled 51 commercial irrigated farms. Commercial farms were defined as those which provided the major income source for a farm family. All farmers outside the study area as well as all those owning only non-irrigated land within the area were excluded from the population. A stratified random sample of 24 commercial farmers was drawn from the population of 51 commercial farms. Sample size within each of the four sub-strata was made proportional to sub-strata population relative to total population size. Population and sample size for each of the four strata are shown in Table 3. Each farm in the population was assigned a number with a random number table used to pick the grower sample for each cell in the population.

Part-time farmers in the area have increased in the past few years. This trend may continue in the future, with the assumption that industrial and agribusiness growth in the area will attract workers who prefer to devote their weekends and evenings (when their labor opportunity cost is low) to part-time farming. To better understand the cultural and irrigation practices of the part-time farmers, three part-time farmers were selected by the county extension agent and included in this study. The part-time farmers were selected rather than sampled due to an unknown population level of the farms in the project area.

Each of the 27 growers in the sample was visited by a field enumerator and irrigation information for that farm was recorded on an irrigation technology questionnaire, a

Table 3. Population and Sample Stratification by Irrigation Systems and soil types, North Columbia Basin, Oregon.

Strata	Population of Commerical Farms	Sample Size
1. Center pivot on sandy soil	17	8
2. Center pivot on loam soil	11	5
3. Side roll on sandy soil	11	5
4. Side roll on loam soil	12	6
Total	51	24

copy of which is shown in Appendix II. As a preliminary step in the interviewing process, the questionnaire was pretested in field interviews with four farmers. This pretesting provided the basis for revising and improving the final questionnaire which was used for the interview of all sample farmers. General farm and soil relationships, crop and irrigation characteristics, water supply, irrigation scheduling by crop, annual irrigation labor use per farm and general questions by irrigation system were recorded on the questionnaire. Interviews were conducted in June, 1976, with the information obtained being for the 1975 crop season.

Sample Coverage

Usable information was obtained from 19 of the 24 commercial farms sampled. A comparison was made by cropping pattern and farm acreage reported by the 19 commercial irrigated farms with aggregate cropping pattern and total acreage in Umatilla and Morrow Counties as reported by the Oregon State University's North Columbia Basin research project. This was done to determine if sample coverage appeared to adequately represent the population so that inferences from the sample could be made concerning population characteristics of the commercial irrigated farms in the Oregon North Columbia Basin counties (Umatilla and Morrow).

Area data for Umatilla and Morrow counties on cropping patterns and irrigated acreages was available for 1974 and used to compare with the 1975 sample data in analyzing sample coverage. Results of the comparison are shown in Table 4. The sample of 19 commercial irrigated farms represents 37 percent of the population of commercial irrigated farms in Umatilla and Morrow counties in 1975 and about 19 percent of total irrigated acreage in Umatilla and Morrow counties in 1974. Acreage comparison by major irrigated crop showed the sample accounting for at least 15 percent of total counties' acreage for each major irrigated crop, and a high of 63 percent on sugar beets. Acreage distribution of the crops as a percentage of total irrigated acreage in the sample was very similar to the distributional pattern for the area suggesting that the sample was drawn uniformly across crop types. Potato acreage as a percentage of total irrigated acreage under the sample is slightly higher than that for the counties. The likely reason is that the sample contains a proportionally high number of growers who are in the process of converting dryland to irrigated land. The first crop often is potatoes since no potato disease problems exist on virgin land and because of the generally high return relative to other crops which can be grown in the area.

As part of the sample coverage, the 24 commercial farms sampled by stratification of the population into

Table 4. Comparison of Irrigated Acreage Reported from 19 Sample Commercial Farms and Umatilla-Morrow Farms by Crop.

Crops	Sample[1/]		Umatilla-Morrow Counties[2/]		Sample Acreage as a Percent of Total Umatilla-Morrow County Irrigated Crop Acreage
	Acreage	Percent	Acreage*	Percent	
Wheat	10,736	38	57,000	37	17
Alfalfa hay	8,060	28	46,000	30	19
Potatoes	4,899	17	19,000	12	26
Alfalfa seed	450	2	3,000	2	15
Sugar beets	630	2	1,000	1	63
All other irrigated crops	3,795	13	27,000	18	14
Totals	28,570	100	153,000	100	18.6

*Estimates reported by Oregon State University's North Columbia Basin Research Project.

1/ 1975 crop reporting year.

2/ 1974 crop reporting year.

four strata as used in this study was compared with the stratification used by Oregon State University's North Columbia Basin overall research project which stratified the study area into eight sub-areas. This was deemed important since results from this study will be used by Oregon State University in extension programs. Table 5 provides a distributional comparison of the population of 51 commercial farms; the 24 sample farms by sub-area. Table 5 shows a good distribution of sample population within each of the eight sub-areas suggesting that an evaluation of the sample using geographic stratification of the area is equally valid.

Sample coverage of the three part-time farms selected was not evaluated due to an unknown population level and characteristics of the part-time farms to compare with in the area. Besides this study was designed to analyze the characteristics of the commercial farms using sprinkler irrigation systems in the study area.

Table 5. General Description of North Columbia Basin Sub-areas by Dominant Soil Type, Dominant Irrigation Systems, Number of Commerical Irrigated Farms and Number of Sample Farms.

Sub-area[1/]	Soil Type	Irrigation System	Number of Commercial Irrigated Farms	Number of Sample Farms
1. Stanfield Irrigation District	Sand	Side roll	4	1
2. Westland Irrigation District	Sand and loam	Side roll	8	3
3. Ordinance District	Sand	Center pivot and Side roll	9	5
4. Butter Creek District	Loam	Side roll	8	4
5. Rew Elevator	Loam	Center pivot and Side roll	6	2
6. Teel District	Sand	Center pivot	8	3
7. Ward Butte	Sand	Center pivot	1	1
8. Sand Hollow	Loam	Side roll	7	5
Total			51	24

1/ As specified by Oregon State University's North Columbia Basin Research Project.

GENERAL DESCRIPTION OF IRRIGATION SYSTEMS

Irrigation systems used by sample farms in the North Columbia Basin of Oregon were separated into (1) center pivot, (2) side roll and (3) other system categories for analysis. The third category is a catchall and includes handline, flood, solid set and Trimatic systems.

Center Pivot

This system is the most dominant form of capital intensive irrigation used today in the U.S. and the most often found in arid or semi-arid regions which are relatively flat or gently rolling. The center pivot system was invented by Frank Zybach of Columbus, Nebraska, in 1951 [36]. It is a self-propelled circular system which consists of a series of water sprinklers of the impact type mounted on a lateral that is, in turn, supported by a row of seven or more mobile towers. Water enters the system from a main line at the central pivot point, and the towers carry the system around the central pivot point. The rate at which the towers and the pipe advances is set by the speed of the outermost tower. Micro-switches in each tower detect any laggards and realigns each tower when tolerance limits are exceeded. Thus an advance by the outermost tower sets off a chain reaction of advances beginning with the second tower from the end and progressing toward the center of the circle. Most of the systems are mounted on large steel or rubber wheels driven by electric or hydraulic motors on each tower. Many of the systems are reversible so that they can be backed out of mudholes or repositioned when necessary. The delivery pipe (lateral line) is supported 8 to 12 feet above the ground, generating no problem for tall growing field crops [37]. The sprinklers are spaced so that water is applied at an increasing rate with distance outward along the lateral to compensate for more rapid movement of the system over the ground at its outer extremities. Most of the systems are designed to fit the conventional unit of agricultural land in the U.S., the 160 acre quarter section of land. The circular pattern leaves out the corners of the field so that only about 133 acres are irrigated. The minimum time for the system to rotate through a complete 360° circle is about 12 hours. The farmer can apply a larger or smaller amount of water on one passover by operating the outer tower at a lower or higher rate of advance. Most center pivot regimes call for one traverse every three or four days, with the application of about an inch of water for each revolution on the three or four day pass. The application rate of the system revolutionizes its use in many agricultural areas that are limited in productivity because of coarse-textured or sandy soils. Sandy soils with a high intake rate (two to five inches per hour) hold less than an inch of water per foot of soil depth. As a result, sandy or coarse-textured soils were difficult to irrigate by conventional flood methods without either excessive labor demands or high water loss [36]. Moderately fine-textured soils, along with peats and mucks, are not particularly suited to irrigation by center pivot because of excessive puddling at the outer reaches due to water volume in excess of soil intake rate even with the 12 hour passover rate [24]. Use of flexible couplings at each support tower make it possible for the center pivot system to adjust to quite rolling terrain. Grades up to 30 percent can be accommodated by the towers, although the system is not recommended for grades in excess of 10 percent because of surface erosion and gullying.

Side Roll

The side roll system also was developed in the 1950's. Its purpose was to help reduce the amount and type of labor required with handmove irrigation pipe systems allowing them to be rolled from one set to another [28]. This system consists of a series of sprinklers mounted on a lateral made of aluminum or galvanized steel pipe which serves as the axle for large wheels of six to eight feet in diameter spaced periodically along the lateral. Water is supplied from a main line. When irrigating, the lateral remains in one place until the desired amount of water needed has been applied, usually 12 to 24 hours. Power for moving the lateral across a field is supplied by a small gasoline motor, usually located in the center of the lateral. To change sets, the lateral is disconnected from the main and moved intact across a field in a direction perpendicular to its length. A recent innovation has involved attachment of a wheel cart mounted at a right angle on each main wheel to move the lateral lengthwise across a main line or from one field to another. The main line is usually buried or if above ground, protected with a temporary bridge or mound of soil to permit movement of the lateral system across the main line. The lateral is three to four feet above the ground since it serves as the hub of the six to eight foot diameter wheels. Low clearance of the pipe limits use of a side roll system to alfalfa, wheat and other short growing crops. Sprinkler heads are spaced usually at 40 to 60 foot intervals along the lateral. Loamy soils with high water holding capacity (two to four inches per foot of soil depth) have low intake rates (less than an inch per hour) and can easily become overly wet if not irrigated infrequently and at low application rate. The application rate of the side roll system makes it particularly suited to loamy soils. Side roll system is best adapted to rectangular fields without obstructions and with uniform topography [23].

Other Systems

Other irrigation systems used in the North Columbia Basin area include handline, solid set, and Trimatic sprinklers and traditional flood irrigation. These systems are used mainly for supplemental irrigation except Trimatic which is used as a major system on one sample farm. Handline is used by five, solid set by three and flood by four sample farms.

With flood irrigation water is delivered through open ditches and distributed on to the fields by siphon tubes or cuts in the open ditch (turn-outs) made by hand with a shovel. The flow of water down the field is controlled by borders, corrugations, or furrows.

The handline system was the first to make sprinkler irrigation popular [37]. It consists of a main line and one or more laterals of light weight aluminum pipe with quick attach couplers for easy movement and set change by hand. Generally, the laterals are spaced forty to ninety feet apart. They are either of perforated pipe for direct flow or contain one or two risers -- each carrying a sprinkler head. When irrigating with a single lateral system, the lateral remains in place until the desired amount of water has been applied. To move to a new set the water is first shut off at the pump, the water in the line is drained by disconnecting the lateral at the main line, and the lateral is moved by hand to the next set and reconnected to the main line. Most of the handline work is done in a relatively wet setting especially where tall crops are grown.

The solid set system consists of enough laterals with sprinklers to cover an entire field without handmoving of pipe. It is usually left in place until the end of an irrigation season unless certain machine operations dictate otherwise. Laterals generally are laid out in the field immediately after planting. Some solid set systems are laid on posts for horticultural crops so that they will be overhead and out of the way of cultivation. Some are laid on the ground. When irrigating, all or part of the system may operate at the same time depending on system size, pumping capability and water availability. Individual laterals are operated by opening and closing of hydrant valves located in the main line or at the sprinkler heads.

The Trimatic or side move system is similar to side roll systems except that the lateral is mounted on wheeled A-frame towers [37]. This system permits sprinkler heads to remain upright at all times and to be high enough to move over tall crops such as corn. This system is usually driven by a gasoline powered unit located either in the center or at the end of the lateral. The unit powers a drive shaft connected to the drive wheels located under the towers. Some Trimatics have sub-laterals of small pipe trailing from the main lateral which have sprinklers attached to them. This innovation permits more area to be irrigated at one setting and reduces the number of times a lateral is moved to irrigate a field. Such trailer units are limited to low riser pipe sprinklers to minimize their toppling over.

On the sample farms handline systems were used mostly to supplement side roll systems. The solid set system was used exclusively as a supplemental unit to irrigate corners left by center pivot systems.

CHARACTERISTICS OF SIDE ROLL AND CENTER PIVOT SYSTEMS AS USED BY SAMPLE FARMS

Features of Irrigation Systems

Most of the sample farms in the study area had more than one system, one as a primary system and another as a support or supplemental system as shown in Table 6. Five sample farms reported being single system users. Fourteen sample farms reported being multiple system users with ten using a major and supplemental system jointly, three using center pivot and side roll systems as separate entities on the same farm, and one using three separate major systems as separate entities on the same farm. To understand system use among sample farmers, and measure variability between them, system specification was examined with each sample farm and includes size, length, flow capacity, acres served per system, spacing, and water application per set information.

Center Pivot

Physical and technical features of the center pivot system as used in the North Columbia Basin was provided by ten of the 12 sample farms having center pivot system. That information is presented in Table 7.

The main and lateral pipe lines vary in size and length depending on water source, distance of water source to the

Table 6. Stratification of Irrigation System as Used by Sampled Farms in the Study Area.

Irrigation System Type \ Use	Number of Sample Farms		
	Single System	Major and Supplemental	Major Only
Center Pivot	3	5	3
Side Roll	2	5	1
Others	-	-	
Total	5	14	

Table 7. Design Specifications and Characteristics of Center Pivot Systems Reported by 10 Sample Farms in the North Columbia Basin.

Farm No.	Supplemental System	Water Source	Size (in inches) Main	Size (in inches) Lateral	Length (in feet) Main	Length (in feet) Lateral	Pump (hp)	Flow Capacity (gpm)	Acres Served per Circle	Number of Circles	Total Acres Served by System[1/]
2	Side roll	Wells (200-500')* Irrigation Dist.	6-10	6	2000-6100	700	25-60	300	36	13	445
10	Solid Set	Columbia River	10-54	10	15 miles	1320	600-1000	75,000	130	58	6900
11	--	Wells	10-14	6	1800-2640	1320	100 & 250	1200	120	4	480
13	Side roll	Wells (104')*	10-16	6	1800-6000	1320	60-125	3400	125	4	500
14	Handline	Well, ditch water & pond	6-10	6	5280-10,560	1320	35-100		120-130	3	360
15	--	Deep well	10-14	6	13,000-34,000	1320	100-300	800-2500	130	17	2200
16	Solid Set	Exchange with Irrigation Dist. (WEID)	10-18	6	1400-9500	1320	100-600	20,000	130	23	2565
17	--	Wells	8-16	6	600-2600	1320	200	3000	130	4	520
18	Side roll	Wells	4-12	6	200-4000	1320	40-400	1000-12,000	125	13	1405
19	--	Deep wells	8-12	7	6600-21,520	1320	300 & 400	4000	130	5	650

*The numbers represent depth of well which though not addressed in the questionnaire was reported by two farms using center pivot.

[1/] Total area actually served by a system may be less than design capacity (acres served times number of circles) due to technical, physical and biological limitations on a given farm.

farm, acres served by a system unit, and existence of a supplemental system to irrigate the corners. The size of the main line ranges from four to eighteen inches with ten inches being the most common. A 54 inch main line was used on one farm which gets its water from the Columbia River some 15 miles away, but this is uncommon. The length of the mains range from 200 to 34,000 feet with 1,000 to 14,000 feet the more common. The low of four inches was used by farm 18 whose water source is a well located only 200 feet from the lateral. Farmers with the dominant main line of ten inches get their water from wells located within 1,000 to 14,000 feet of the center pivot circle. Farmers who use surface water from irrigation districts use varied main line sizes due to the variation in distance of the canals and ditches to their farms.

The size and length of lateral lines were found to be quite uniform among the sample farms. A six inch size and one-quarter mile (1320 feet) span is standard since the system's basic design is to fit a 160 acre (quarter section) square area of land. Larger lateral sizes are required to accommodate the added volume of water used to irrigate the corners from supplemental solid set, handline, or corner catcher units. An example of this is farmer 10 who uses a solid set supplemental unit with a ten inch lateral size on the center pivot. Smaller than a six inch lateral are available from the manufacturer for modified circles which irrigate 40 to 80 acre fields. Sample farm 2 purchased a standard size unit and cut it down to accommodate a 36 acre circle using six inch lateral line.

Pumping plants for the system range from single 25 horse power (h.p.) units to multiple units of 1,000 h.p. each with resulting flow capacities ranging from 300 to 75,000 gallons per minute (g.p.m.). Most common in the area are the 100 h.p. and 200 h.p. single unit pumping plants. The horse power of pumps used depends on desired flow rate, depth of well, and distance to water source. The farm having a 75,000 g.p.m. flow capacity system pumped water directly from the Columbia River 15 miles from the farm, and possessed a high range pump of 1,000 h.p. One hundred to 300 h.p. pumps generally are used on wells which pump greater than 1,000 g.p.m. from a distance of 1,400 feet or more to the farm. Only 25 to 60 h.p. booster pumps are required by farmers who pump from the Stanfield or Westland irrigation canals.

The number of circles used by individual sample farms ranged from 3 to 58, reflecting a wide variation in total acres served from 360 to 6900 acres. Seven of the ten farms irrigated 500 or more acres. None of them irrigated less than 360 acres. Farmer 2 had 13 irrigation circles, each serving 36 acres, resulting in 445 total acres served due to the small design capacity of each circle. Sample farms in the area use center pivot on various soil types ranging from sand to loam and from flat to steep slopes. Eight of the sample farms had center pivot on flat land while five were using it on five to twelve percent slope. Production of both tall and short growing crops were reported by the sample farms having center pivot units.

Side Roll

Physical and technical features of the side roll system as used in the North Columbia Basin was provided by 9 of the 11 sample farms having side roll systems. This information is presented in Table 8.

The length and sizes of the main and lateral pipelines depend on water source, distance of water source to the farm, acres served per unit and use of supplemental irrigation systems. The size of the main line ranges from 6 to 14 inches with 8 inches being the most common. The length of the main line ranges from 580 to 7,920 feet. The farm using a 14 inch main line gets its water from a deep well located 1½ miles from the farm. Farmers with the more usual main line diameter size of 8 inches have their water source located ½ to 1 mile from the farm.

The size and length of lateral lines were found to be quite uniform among the sample farms. A five inch size and one-quarter mile (1,320 feet) of span is standard for a 40 acre field. Smaller sizes of three inches and four inches are in use where 25 and 30 acre fields are irrigated. A

Table 8. Design Specifications and Characteristics of Side Roll Irrigation Systems Reported by 9 Sample Farms in the North Columbia Basin.

Farm No.	Supplemental System	Water Source	Size (in inches)		Length (in feet)		Pump (hp)	Flow Capacity (gpm)	Acres Served per unit	Number of units	Total Acres Served by System[1]
			Main	Lateral	Main	Lateral					
1		Wells	6-12	5	6600	1320	100-150	3000	40	10	395
4	Handline and flood	Pit wells and Butter Creek Runoff	8	5	5280	1320	30- 50	675	31	5	140
5	Flood	Wells and Creek	6- 8	4	2640	1320	100	500	30		330
6	Handline	Wells	8-10	3-4	3300-6600	1320-1980	50-300	1250-1500	25-40	19	935
7	Flood	Snow Pack (Umatilla Flood)	8	5	1800	660-1320	25- 40	1000	60	1	60
8	Handline	Umatilla Flood	8-10	5	520-4000	2640	100-125	4000	100	3	280
9		Deep wells (600 ft)*	14	6	7920	1320	100-450	1700-2400	100	4	740
18	Center Pivot	Wells	10	5	4000	1320	40-125	1000	60	17	1020
19		Deep wells	8	5	3960	1320	300-400	4000	40	5	200

*The number represents depth of well.

[1] Total acres served on farm by side roll is not equal to the number of side roll units times acres served per unit since the system could be moved within and between fields.

2,640 foot lateral length was used on a sample farm irrigating a 100 acre field.

Pumping plants for the system range from single 25 h.p. units to multiple units of 450 h.p. Commonly reported by the sampled side roll farmers are the 100 and 125 h.p. single unit pumping plants. The horsepower of pumps used depends on desired flow rate, depth of well and distance of water source. The farmer that possessed the high range pump of 450 h.p. pumped water from a 600 foot deep well located 1½ miles from the farm. The farm with the small 25 h.p. obtained water from a local creek located 1,800 feet from the farm.

The number of side roll units used by the sample farms ranges from 1 to 17, reflecting a range in total acres served from 60 to 1,020 acres. All but three of the farms irrigated 400 or less acres. Farmer 9 with four side roll units irrigates 740 acres by moving the side roll units from one field to another. All of the sample farms using side roll had essentially flat land ranging from 0 to 3 percent slope. The sample farms utilizing side roll units grew alfalfa, wheat and other short growing crops.

Irrigation Scheduling

Irrigation scheduling which reflects ways each sample farmer uses his system was reported according to crop(s) grown. Also reported were length of irrigation season, peak use periods, number of irrigations and water use per season.

Center Pivot

Irrigation scheduling for alfalfa, wheat, potatoes, sugar beets, and to a lesser degree corn and barley, using center pivot system is reported by sample farms in Table 9. The normal irrigation season for alfalfa as reported by six of seven farms is March through September with July and August the peak use periods. The number of irrigations per season was vastly different between farms ranging from a low of 16 to a high of 225. The farmer reporting 225 irrigations indicated that he had adequate water so continued the irrigation 24 hours a day throughout the season. His water source was shallow wells with pumping capacity of 10,925 g.p.m. The farmer reporting 16 irrigations indicated that he had only enough water to irrigate twice a month. His water source was deep wells with pumping capacity of 4,000 g.p.m. The farmer with 225 irrigations used 74 acre inches of water during the crop season, averaging 10.6 acre inches per month. The grower with 16 irrigations used a total of 16 acre inches of water for the crop season for an average of 2.3 acre inches per month. The grower with 225 irrigations produced alfalfa on sandy soil while the one with 16 irrigations was on loamy soil. Both farms reported acreage yields for alfalfa of 7 tons per acre. The central

Table 9. Irrigation Scheduling under Center Pivot as Reported by 11 Sample Farms in North Columbia Basin, Oregon.

	Farm Number										
	2	10	11	12	13	14	15	16	17	18	19
Soil Type	Loam	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Loam	Loam
Alfalfa											
Acres Irrigated		1800	280	1050	500			1000	520		130
Irrigation Season (months)		Apr-Sept	Mar-Sept	Mar-Sept	Mar-Sept			Mar-Sept	May-Sept		Mar-Sept
Peak Use Period (months)		June-Aug	June-July		July-Aug			July-Aug	July-Aug		July-Aug
No. of Irrigations per Season		50		225				142	21		16
Water Use (acre inch)*		54/9	48/7	74/10.6	38/5.6			39/5.7	38/5.6		16/2.3
Wheat											
Acres Irrigated	246	2600				360	1200	565		965	520
Irrigation Season (months)	Apr-June	Apr-June				Sept-Oct Apr-July	Oct-Nov Feb-July	Mar-July		Sept-Dec Mar-June	Mar-June
Peak Use Period (months)	May	May-June				May-June	May	June		May	May
No. of Irrigations per Season	38	30				28	50	82		75	20
Water Use (acre inch)	22/8.8	36/12				30/7.5	25/5	32.5/8		26/5	20/5
Potatoes											
Acres Irrigated	199	2500	200				1000	1000			
Irrigation Season (months)	May-Sept	May-Sept	Mar-Sept				Feb-Sept	Mar-Sept			
Peak Use Period (months)	July	June-Aug	June-July				July	July-Aug			
No. of Irrigations per Season	69	50					70	142			
Water Use (acre inch)	40/8.9	52/10.4	48/8				52/7.4	52/7.4			
Sugar Beets											
Acres Irrigated	95									315	
Irrigation Season (months)	Apr-Oct									June-Oct	
Peak Use Period (months)	July									July-Aug	
No. of Irrigations per Season	92									75	
Water Use (acre inch)	52/8.7									26/5	
Other Crops				(Barley)						(Corn)	
Acres Irrigated				900						125	
Irrigation Season (months)				Apr-July						July-Oct	
Peak Use Period (months)				May-June						July-Aug	
No. of Irrigations per Season				64						50	
Water Use (acre inch)				21/7						17/5.5	

*Numbers represent seasonal water use and average use per month during the irrigation season.

tendency of water use on alfalfa was about 38 acre inches per crop season with yield of 7 to 8 tons per acre.

Irrigation schedule on wheat was reported by seven farms. It extended from as early as February to as late as July, depending upon winter rainfall. The usual spring irrigation season was April through June with May and June being the peak use periods. Fall irrigation from September through November was reported by three farms. Number of irrigations per season varies considerably ranging from a low of 20 to a high of 82. Farm 16 reporting 82 irrigations, indicated an adequate water supply so used 36 hour irrigation sets continually throughout the irrigation season. The water source involved an exchange with an irrigation district with pumping capacity of 20,000 g.p.m. Farm 19 reporting 20 irrigations, indicated only enough water available to irrigate five times per month. The water source was a deep well with pumping capacity of 4,000 g.p.m. The farm with 82 irrigations used 32.5 acre inches of water during the crop season, averaging 8 acre inches per month. The farm with 20 irrigations used 20 acre inches of water during the crop season, averaging 5 acre inches per month. Sample farms 14, 15 and 18 pre-irrigate wheat fields from October to December. Pre-irrigation is used to reduce wind erosion.

Irrigation scheduling for potatoes was reported by five farms. The irrigation season ranged from February through

September with one farm reporting initial irrigation as late as May. The length of irrigation season is reflected by variation in number of irrigations per season which ranged from 50 to 142. All farms growing potatoes indicated they had adequate water to irrigate on an intensive basis. Total seasonal water use was quite uniform ranging from 40 to 52 acre inches per acre.

Sugar beet irrigation schedule was reported by two farms. One indicated an irrigation season from April through October while the other reported June through September. Farm 2 indicated enough water to irrigate through a long season thereby made 92 irrigations applying a total of 52 acre inches of water per acre averaging 8.7 acre inches per month. Farm 18 indicated a willingness only to use enough water to irrigate the crop through the peak use periods in July and August with a total of 75 irrigations. A total of 26 acre inches per acre for the season, averaging five inches per month was applied.

On a total farm basis farmer 2 with irrigation district as his water source, irrigates 500 acres comprised of three crops on an intensive basis. On the other hand, farmer 18 with well as his water source rations his water over 965 acres of wheat and 315 acres of sugar beets. Farmer 2 irrigates only 95 acres of sugar beets. Besides, farmer 10 with water source from the Columbia River irrigates 2,500 acres of potatoes and 5,000 acres of other crops -- alfalfa and wheat, on an intensive basis, and farmer 16 with well as his water source irrigates 1,000 acres of potatoes and 565 acres of wheat on an intensive basis, and 1,000 acres of alfalfa and 835 acres of wheat on a supplemental basis. These facts support the contention that the amount of water available influences the length of season used, acres irrigated and number and types of crops grown.

Side Roll

Fewer numbers of the farms using side roll provided information on irrigation scheduling by crops.

Four farms growing alfalfa and five farms growing wheat provided scheduling information shown in Table 10. The irrigation season for alfalfa ranged from March to October with June and July the peak use periods. Number of irrigations range from low of 3 to a high of 13. Two farms, 4 and 6, reported three irrigations, each using 36 and 12 acre inches of water respectively during the crop season. Farm 4 irrigates 140 acres of alfalfa on an intensive basis and 210 acres of wheat on a supplemental basis. Farm 6 on the other hand, irrigates 220 acres of sugar beets on an intensive basis and 485 acres of alfalfa and 230 acres of wheat on supplemental basis. Farm 1 did not report on water use.

Table 10. Irrigation Scheduling under Side Roll as Reported by 7 Sample Farms in North Columbia Basin, Oregon.

	Farm Number						
	1	3	4	6	8	9	19
Soil Type	Sand	Sand	Sand	Loam	Loam	Loam	Loam
Alfalfa							
Acres Irrigated	345		140	485			200
Irrigation Season (months)	Apr-Oct		May-Aug	Mar-Oct			Mar-Sept
Peak Use Period (months)	May-July		June-July	June-Aug			July-May
No. of Irrigations per Season	13		3	3			8
Water Use (acre inch)*			36/12	12/2			32/4.6
Wheat							
Acres Irrigated	50	200	210	230		640	
Irrigation Season (months)	Apr-July	Apr-June	May-June	Mar-June		Feb-Apr	
Peak Use Period (months)	May-June	Apr-June	May-June	June		May	
No. of Irrigations per Season	5	4	4	2		1	
Water Use (acre inch)		39.6/13	18/9	17/6		8/2	
Pasture							
Acres Irrigated			20				
Irrigation Season (months)			May-Aug				
Peak Use Period (months)			June-July				
No. of Irrigations per Season			6				
Water Use (acre inch)			16/9				
Other Crops				(Sugar Beets)	(Alfalfa Seed)	(Beans)	
Acres Irrigated				220	280	100	
Irrigation Season (months)				May-Oct	Mar-May	May-Aug	
Peak Use Period (months)				July-Aug	Mar-May	June-Aug	
No. of Irrigations per Season				5	2	10	
Water Use (acre inch)				35/8.8	24/8	22/9	

*Numbers represent seasonal water use and average use per month during the irrigation season.

Irrigation season for wheat ranged from February through July with April through June being most common and May and June the peak use periods. Number of irrigations per season ranged from 1 to 5 with 4 being the most common. Farm 1 with five irrigations, indicated enough water to irrigate the 50 acres of wheat throughout the irrigation season. The water source was a well with pumping capacity of 3,000 g.p.m. Farm 9 reporting one irrigation, indicated only enough water to irrigate once for the entire irrigation season. The water source was a well with pumping capacity of 1,700 g.p.m. Farm 9 used a total of 8 acre inches of water per acre during the growing season, averaging two acre inches per month. Farm 9 also reported having a very limited amount of water due to a declining water table from which the well water is pumped. The 1,280 acres of wheat on farm 9 thus is irrigated only on a supplemental basis. Irrigation scheduling involves fall pre-irrigation of 640 acres each year. The other 640 acres is fallowed. The fallow land is not irrigated in the fall and planted to wheat in the spring and irrigated. This procedure is rotated among the two wheat lands every year as summer fallow-wheat rotation. In addition, this farmer also irrigated intensively 100 acres of beans with the same irrigation system.

Water Management

As water becomes an increasingly scarce resource, more concerns are focused upon management schemes which make water use more technically and economically efficient [36]. To determine how water is managed in the North Columbia Basin, sample farmers were asked "how do you determine when to irrigate?" Responses to the question were placed in two basic categories: (1) plant stress evaluated either by technical measurements or subjective evaluations involving crop and/or soil appearance and (2) standard or fixed term scheduling. Results are shown in Table 11. Six of the 11 farmers with center pivot used technical measurement and 3 of the 9 side roll farms did also. Technical measurements include soil sampling by consultant, soil probes and plant test. Soil sampling through a consulting service was the most common and involves taking of soil samples from various parts of the field to be dried in the laboratory to determine the moisture content. Soil probes were used in combination with soil sampling by three of the farmers with center pivot and two side roll farms. This procedure involves checking water penetration depth by digging holes in several locations to be sure the soil is wet throughout the crop root zone. Responses under appearance of the soil as reported by five farms with center pivot and two side roll farms includes "when water is needed by soil," "inspection

Table 11. Factors Determining When to Irrigate as Reported by Sample Farms in North Columbia Basin, Oregon.

	Center Pivot	Side Roll
No. of Farms	11	6
Factors determining when to irrigate:		
A. Plant Stress Evaluation		
1. Technical measurements[a]	6	3
2. Subjective evaluation		
a. Appearance and feel of soil[b]	5	2
b. Appearance of crop[c]		2
B. Standard or Consistent Scheduling		2

[a] Includes soil sampling by consultant, soil probes and plant test.

[b] Includes responses such as "when water is needed by soil," "inspection of soil by feel," and "past experience."

[c] Includes responses such as crop maturity and appearance.

of soil by feel," and "past experience or observation." Crop appearance and standard or fixed term scheduling were methods reported exclusively by farmers with side roll system in determining when to irrigate.

These responses, in general, suggest that water management methods in the area are not highly developed when compared to methods employed in areas such as Nebraska, Texas and California. Soil measuring devices or instruments used in other areas include tensiometer -- which measures the exact amount of water being evaporated from the soil or transpired through the plant leaves, and auxanometer -- a device that automatically monitors the diameter of a plant stem to detect a change in growth rates within three to five minutes [36]. The likely reason these devices are not in use is that presently water is not a serious constraint and the opportunity cost of water to farmers is relatively low. Other methods used in measuring irrigation needs include evapo-transpiration pans, dendrometers and resistance gypsum blocks. Use of these scientific or improved water management techniques afford an opportunity for increasing yield and conserving water use [19].

Capital Outlay

The amount of capital outlay needed to purchase an irrigation system was reported by the sample farms in the

North Columbia Basin under center pivot and side roll systems. Due to the disparity in number of units of system owned and acres served per unit among the sample farms, average capital outlay per farm was standardized on a per acre basis. Ten of the 12 farms using center pivot provided information on capital outlay (Table 12). The capital outlay per acre irrigated ranges from $151 to $500 with $170 to $220 the central tendency. The reasons for the outlay differences were due primarily to time of purchase, length of main line, pump size, system size and use of supplemental unit. Farm 2 had the low capital outlay. It was a standard center pivot unit modified to irrigate 36 acres instead of 130. Farm 15 had the highest capital outlay. It pumped water from a deep well located six miles from the farm. The more typical cases involved water pumped from wells located within three miles of farm as shown in Table 7. Eliminating the off-farm components (main line, pump, well casing, etc.) from farm 15, results in a capital outlay of $204 per acre. The circular irrigation pattern of center pivot provides a usual design capacity of 130 acres. However, supplemental capital investment in corner catchers or solid set units permits irrigation of an additional 22 acres. The additional investment is not only for additional sprinklers and laterals but also for greater pump and lateral size of the main unit needed to deliver the extra volume of water. Farmer 16 uses solid

Table 12. Capital Outlay for Center Pivot Irrigation System from Sample of 10 Farms, North Columbia Basin, Oregon.

	Farm Number									
	2	10	11	13	14	15	16	17	18	19
Total Number of Units of Center Pivot	13	58	4	4	3	17	23	4	13	5
Acres Served per Unit	36	130	120	125	120	130	130	130	125	130
Total Acres Served by Center Pivot	445	6900	480	500	360	2200	2565	520	1405	650
Length of Main Line (Miles)	.4-1	15	.25-.5	.25-1	1-2	2-6.4	.5-.2	.5	1	1-4
Year Purchased	1969-75	1974	1972-74	1967-73	1973	1974-75	1971-74	1972	1971-75	1971
Total Capital Outlay ($000's)	67	2139	84	88	69	1100	1026	80	306	125
Capital Outlay (Per Acre)	151	310	175	176	192	500 (204)	400	154	218	192

set as a supplemental unit resulting in use of a ten inch lateral and a capital outlay of $400 per acre. Year of purchase does influence capital outlay because of the near doubling of equipment prices since 1972 due to inflation effects. This factor also contributed to the high capital outlay for farm 15 and farm 10.

Eight of the 11 sample farms having side roll systems provided information on capital outlay (Table 13). Capital outlay ranged from $100 to $405 per acre. The central tendency of acres served per unit of side roll was 40 to 60 acres. The low capital outlay farm, farm 2, bought a used system which he modified to irrigate a 20 acre field size. The highest capital case, farm 1, pumped water from a deep well located 1¼ miles from the farm, each system serving 40 acres. Farm 9, though, pumps water from a well located 1½ miles from the farm and had a low capital outlay of $143 per acre. Farm 9, with four side roll units each serving 100 acres is used to irrigate 740 acres by moving systems from one farm to another. Farm 6 purchased his system in 1958 and, therefore, has a low capital outlay.

A comparison of capital outlay on a per acre basis for side roll and center pivot presented above shows a definite similarity. Excluding the highest capital outlay under both systems results in an average capital outlay of $218 and $219 per acre for side roll and center pivot, respectively.

Table 13. Capital Outlay for Side Roll Irrigation System from Sample of Eight Farms, North Columbia Basin, Oregon.

	Farm Number							
	1	2	4	6	7	8	9	19
Total Number of Units of Side Roll	10	4.5	5		1	3	4	5
Acres Served per Unit	40	20	31	25-40	60	100	100	40
Total Acres Served by Side Roll	395	90	140	935	60	280	740	200
Length of Main Line (Miles)	1.25	650*	1	.5-1.25	.25	1	1.5	.8
Year Purchased	1973	1975	1970-76	1958	1972	1974	1968	1973
Total Capital Outlay ($000's)	160	9	53	138	11	90	106	50
Capital Outlay (per acre)	405	100	379	148	183	321	143	250

*in feet.

Costs

This section analyzes each irrigation system by analyzing individual cost components. Costs are divided into overhead (ownership) and operating cost categories.

Overhead Costs

Overhead or fixed costs are those costs which a farm incurs regardless of how or whether the system is used. This cost category includes depreciation, interest, property taxes, and insurance. Depreciation, which is defined as the loss in value of a capital asset over time due to age, obsolescence, and wear and tear, was calculated using the straight line method, estimated useful life given by farmers for each system and no salvage value. Interest on investment or outlay constitutes an "opportunity cost" of investment elsewhere. Interest on capital outlay was charged at 9 percent on one-half of the initial investment (average investment). Property taxes given by farmers was used, but where not provided a central tendency among farms of $10 per acre was used. Property taxes depended in part on the crop(s) grown. Insurance, a hedge against damage caused by wind, tornado, lightning and similar hazards, was not provided by most of the farms. To include this cost component, a .6% of average capital outlay was assumed.

The overhead cost components for center pivot as calculated for the ten sample farms reporting is shown in Table 14. Annual overhead cost ranged from a low of $17.62 to a high of $91.50 per acre with $30 to $40 the central tendency. Variation in total annual overhead cost is influenced by each of the four overhead cost components and the total capital outlay. Farm 17 had the lowest annual overhead costs because of a low capital outlay per acre and a 20 year estimated expected useful life of the system.

The high overhead cost farm, farm 15, had the highest capital outlays per acre and a low estimated useful life. The overhead costs for farms 16 and 19 were similar due to the trade-off between capital outlay and estimated useful life.

Overhead cost components for side roll as calculated for eight sample farms reporting is shown in Table 15. Annual overhead cost ranged from a low of $17.75 to a high of $59.78 per acre. Variation in total annual overhead cost is influenced to varying degrees by each of the four overhead cost components and the total capital outlay. Farm 6 had the lowest annual overhead cost because of a low capital outlay per acre and a 20 year estimated expected useful life of the system. The high overhead cost farms, farms 1 and 4, had the highest capital outlays per acre although different estimated useful lives. Their overhead

Table 14. Annual Overhead Cost for Center Pivot Irrigation System from 10 Sample Farms, North Columbia Basin, Oregon.

	Farm Number									
	2	10	11	13	14	15	16	17	18	19
Capital Outlay per Acre	151	310	175	176	192	500	400	154	218	192
Expected Useful Life	10	20	8	15	10	8	12	20	15	5
Annual Overhead Costs:										
Depreciation (Capital Outlay/Useful Life)	15.10	15.50	21.90	11.73	19.20	62.50	33.33	7.70	14.53	38.40
Interest on Average Capital Outlay at 9%	6.80	13.95	7.87	7.92	8.64	22.50	18.00	6.92	9.81	8.64
Property Tax	10.00	10.00	6.25	10.00	10.23	5.00	6.27	2.54	7.50	10.00
Insurance (.006 x average capital outlay)	.45	.93	.53	.53	.58	1.50	1.20	.46	.65	.58
Total Annual overhead Cost per Acre	32.25	40.38	36.55	30.18	38.65	91.50	58.80	17.62	32.49	57.62

Table 15. Annual Overhead Cost for Side Roll Irrigation System from Eight Sample Farms, North Columbia Basin, Oregon.

	Farm Number							
	1	2	4	6	7	8	9	19
Capital Outlay per Acre	405	100	379	148	183	321	143	250
Expected Useful Life	15	10	12	20	20	20	10	10
Annual Overhead Costs								
Depreciation (Capital Outlay/Useful Life)	27.00	10.00	31.58	7.40	9.15	16.05	14.30	25.00
Interest on Average Capital Outlay at 9%	18.23	4.50	17.06	6.66	8.24	14.45	6.44	11.25
Property Tax	12.50	10.00	10.00	3.25	8.00	6.35	1.78	10.00
Insurance (.006 x Average Capital Outlay)	1.21	.30	1.14	.44	.55	.96	.43	.75
Total Annual Overhead Cost per Acre	58.93	24.80	59.78	17.75	25.94	37.81	22.95	47.00

costs were similar due to the trade-off between capital outlay and estimated useful life.

Due to the similarity in capital outlay for side roll and center pivot systems, their overhead costs also were similar. Excluding the highest overhead cost for both systems, the average overhead cost was $33.60 for side roll and $38.30 for center pivot. Differences in overhead costs for both systems are due in part to the useful life difference -- an average of 12 years for center pivot and 15 years for side roll.

Operating Costs

Operating or variable costs are those costs directly related to the use of the system; that is, the more a system is used the larger the total variable costs become. Operating costs include electricity; repairs, maintenance and lubricants; hired and unpaid family labor; and interest on operating cost categories. Family labor, reported in hours, was charged at the same hourly rate as hired labor. Where maintenance costs were not specified, a 3 and 2.5 percent rate of total capital investment for side roll and center pivot, respectively, was used. The rates were obtained from previous studies and reflect that side roll which is moved within and between fields requires more maintenance than center pivot which is self propelled [8]. Interest on operating costs was charged for 6 months at 10 percent.

The variable cost components for center pivot as calculated for ten sample farms is shown in Table 16.

Annual variable cost for center pivot ranged from a low of $21.27 to a high of $62 per acre. Variation in annual variable cost is influenced by the differences in energy required for pumping which depends in part on pump size and distance of water source among the sample farms. The low variable cost farm, farm 14, had a low repair and maintenance cost and used his own labor. In addition, farm 14 with small sized pumps of 35 and 75 pumped water at a rated capacity of 3,000 g.p.m. to irrigate 360 acres and as a result had a low energy cost. The high annual variable cost farm, farm 16, had a high repair and maintenance cost and used hired labor. Farm 16, with a pump size of 600 h.p. pumped water at a rated capacity of 20,000 g.p.m. to irrigate 1,405 acres resulting in a high energy cost. Farmer 10, with multiple 1,000 h.p. pumps, pumped water from the Columbia River some 15 miles from the farm, thus had the highest energy cost. Energy and repair and maintenance costs constituted the major part of the annual variable cost calculated for the sample farms; these costs accounted for over 75 percent of the annual variable cost with energy about 50 percent and maintenance about 25 percent.

Annual variable cost components for side roll as calculated for eight sample farms are shown on Table 17.

Table 16. Annual Variable Cost for Center Pivot Irrigation System from Ten Sample Farms, North Columbia Basin, Oregon.

	Farm Number										Average	
	2	10	11	13	14	15	16	17	18	19	$	%
Variable Costs:												
Electricity	18.00	33.33	25.00	24.00	10.00	19.50	19.91	23.00	20.00	7.69	20.04	51
Repairs, Maintenance and Lubricants	11.11	4.03	4.38	12.00	7.69	15.00	19.10	5.00	5.00	13.85	9.70	25
Labor - Hired	2.88	17.33	-	1.70	-	8.00	20.00	-	-	6.15	5.60	14
- Unpaid Family	.26	-	4.38	1.54	2.57	-	-	1.62	4.32	5.69	2.04	5
Interest on Operating Costs @ 10%	1.61	2.73	1.69	1.96	1.01	2.13	2.95	1.48	1.47	1.67	1.90	5
Total Variable Cost per Acre	33.86	57.42	35.45	41.20	21.27	44.63	61.96	31.10	30.79	35.05	39.28	100

Table 17. Annual Variable Cost for Side Roll Irrigation System from Eight Sample Farms, North Columbia Basin, Oregon.

	Farm Number								Average	
	1	2	4	6	7	8	9	19	$	%
Variable Costs:										
Electricity	15.00	15.00	20.00	15.51	10.00	17.86	5.77	20.00	14.89	42
Repairs, Maintenance and Lubricants	12.00	3.00	6.00	4.50	.50	4.29	8.96	7.50	5.84	17
Labor - Hired	12.50	20.00	8.79	19.25	4.27	9.64	9.00	7.00	11.31	32
- Unpaid Family	-	-	4.63	-	-	4.82	-	1.44	1.36	4
Interest on Operating Cost @ 10%	1.98	1.90	1.97	1.96	.74	1.83	1.19	1.80	1.67	5
Total Variable Cost per Acre	41.48	39.90	41.39	41.22	15.51	38.44	24.92	37.74	35.07	100

Annual variable costs for side roll were very similar among the sample farms with central tendency of $37 to $41 per acre. Farm 7 with low variable cost is an exceptional case since it has one system used on 60 acres and as a result had low variable cost components. However, farm 9, through movement of his system from one farm to another spread his variable cost over a large acreage; as a result had a low variable cost of $25. The major variable cost component for side roll was energy and labor which accounted for over 70 percent of the costs with energy about 40 percent and labor about 30 percent.

Though variable costs between center pivot and side roll were similar, the level of influence of the variable components on both systems varies slightly. Energy constitites the major influence on the variable costs of both systems. The second major influence on side roll is labor while repairs and maintenance are the second major influence on the center pivot system.

Comparison of Cost Components

Information on variable and fixed costs provides a base for comparing and examining the cost components by the systems -- center pivot and side roll. Labor has been a major consideration or cost component in certain irrigation methods -- flood and handline. However, this study and others support the observation that with side roll and center pivot systems labor constitutes a minor part of the total cost -- nine percent for center pivot and 18 percent for side roll as presented in Table 18. Labor for handline constitutes about 54 percent of the total annual cost [20]. Elimination of a significant amount of labor for center pivot and side roll relative to handline and flood systems is associated with a high relative importance of capital -- a substitute for labor. Capital accounted for about 53 percent of total cost for center pivot, and 51 percent for side roll, as compared to 37 percent for hand move or handline reported in the same area by a separate study [20]. The more significant role of capital costs indicate that, relatively speaking, modern irrigation systems today are more capital intensive than labor intensive.

Table 18 provides comparison of the relative importance of the cost components or the percentage contribution of each of the cost components to the total cost between side roll and center pivot. The relative importance difference of capital cost between center pivot and side roll is due in part to useful life differences which influence the depreciation cost. Farmers using center pivot on the average had a 12 year estimated expected useful life and side roll farmers had 15 year useful life. Excluding this factor, capital cost for both systems are very similar.

Labor use on side roll is about twice as high as that used on center pivot. A likely reason is that labor is

Table 18. Comparison of the Relative Importance of the Cost Components Between Center Pivot and Side Roll Systems as Used in the North Columbia Basin Expressed on a Per Acre Basis.

Item	Center Pivot		Side Roll	
	Cost	%	Cost	%
Number of Farms Reporting	10		8	
Annual Overhead Cost	43.62	53	37.00	51
Electricity	20.04	24	14.89	21
Repairs, Maintenance	9.70	12	5.84	8
Labor	7.64	9	12.64	18
Hired	(5.60)	(7)	11.31	(16)
Family	(2.04)	(2)	1.36	(2)
Interest on Operating Cost	1.90	2	1.67	2
Total Annual Cost	82.90	100	72.07	100

employed in moving side roll sets within a field or farm whereas center pivot is self-propelled. Hired labor makes up the greater percentage of labor used with family labor representing an insignificant part of labor use. This tends to suggest labor's importance as one of the possible determinants of farmers' choice of irrigation delivery system.

Electricity (pumping cost) for both systems as percent of total cost are 24 percent for center pivot and 21 percent for side roll. The slight difference might be due to the trade off between energy needed for the added pressure required in moving the center pivot system around in a circle and employment of more technical measurement by center pivot farmers in water management.

Relative importance of repair and maintenance differ between the two systems -- center pivot 12 percent, side roll 8 percent. Since maintenance and repairs are functions of age and use of system, this cost component is not expected at anytime in the future to constitute a major consideration. However, excessive use of system and old age system, might suggest replacing the system to avoid the continual cost increase.

ANALYSIS OF RESOURCE SUBSTITUTION BY IRRIGATION SYSTEM

The previous section on characteristics of side roll and center pivot systems identified that large variation in resource use exists among and between irrigation systems as reported by sample farms irrigating in Oregon's North Columbia Basin. Examination of the Cost information suggests that several factors contribute to these differences and/or variations. With great diversity and variation in irrigation datas collected -- the need to envision what is existing now in the area as a possible base for making projections and hypotheses as to the roles of water, labor, capital and land as decision variables in choice of delivery systems by the farmers is essential. Based on this criteria, the purpose of this section is to transcend system comparisons and (1) analyze the impact of several factors on the variable resources used in the study, and (2) to evaluate the existence of resource interrelations in terms of factor-factor substitution capabilities.

Variable Resources

The fourth objective of this study is to examine the relative degree or extent to which resource substitution capabilities exist within the technical limitation of center pivot and side roll irrigation systems. Considerable variability exists in the data base. Therefore prior to evaluating the issue of resource substitution, the impact of several factors -- inflation, mainline, excess capacity, soil and crop -- on the variable resources is useful in determining whether they are important enough to influence or bias the data as it is readied for inclusion within an isoquant (resource substitution) context.

The major variable resources are water, land, labor and capital. Other variables include -- variable cost other than labor; taxes, interest and insurance; availability of water; and supplemental irrigation. However the bearing the four major variables have on the choice of delivery systems and moreover, the effects of the delivery system on these variables, is the subject of this study. As a consequence no a priori assumptions will be made about the delivery system in terms of these four variables and the choice of delivery system will be considered a management decision.

This section considers a brief working definition of the variable resources and the impacts or effects of inflation, mainline, excess capacity, soil and crops on the resources.

Definition of Variable Resources

Water: The variable water is defined as the delivery of a specified volume of water at a specified rate to the ground on which the crop is growing. This type of system bears a direct relationship to the variable. Water as reported by the sample farmers can be obtained from deep wells, ditches, creeks and the Columbia River. Though capital expense is involved in bringing water to the irrigation system, however, no charge to the farmer for the water itself except for variable cost for pumping from deepwells. As a consequence, water in the study is measured in volume (acre-inches), rather than pumping cost-dollar per acre.

Labor: Variable labor is defined as the effort expended to move the delivery system between irrigations and to operate the systems. Labor in the study involved both family and hired labor and is represented by labor cost -- a component of variable cost. Labor is measured in dollars.

Capital: The variable capital is defined as the dollar equivalent of the delivery systems, including all the pumps and pipelines needed to transfer and apply water from a (hypothetical) still, ground-level source at the edge of or within the irrigated acreage on the cropland. In essence, the variable capital -- represented by capital outlay in the study -- is the outlay expended on the delivery system itself "on farm capital outlay." The capital cost of wells whether within or outside the irrigated area, and of those pumps and mainlines located outside the irrigated area are in the category of "off farm" equipment and are excluded from consideration as capital. In choosing among alternative delivery system (including traditional handline and flood system), the farmer seeks to acquire the system that will meet the needs of his crop-acreage with the greatest long-run economic efficiency. Given that the desired volume of water and timing meet the optimum specification for the irrigated crop, any system would make the same contribution to crop yield and revenue. Therefore the cost issue of the acquisition and use of delivery systems rather than revenue effects once the crop choices have been made will be considered. Capital is measured in dollars.

Land: Defined as a measure of the area of cropland which actually receives the application of irrigation water under side roll or center pivot delivery systems.

In the sample, side roll delivery systems are used to water from 30 to 100 acres per irrigation with laterals from $\frac{1}{8}$ to $\frac{1}{2}$ miles long usually $\frac{1}{4}$ mile. Center pivot delivery systems deliver water to irrigate 36 to 130 acres per irrigation, but usually in the 120 to 130 acre range, with $\frac{1}{4}$ mile laterals.

The economic usefulness of irrigated land can be measured in dollar per acre but since the primary concern is with the interrelationships among land and other variables, irrigated land will be measured in surface acres rather than dollar values.

Effect or Impact of Key Factors on Variable Resources

Mainline effect: To determine the influence of mainline distance on the data base, capital outlay per acre information was plotted against mainline length as shown graphically in Figures 8 and 9 for center pivot and side roll respectively. The trendlines A for center pivot and side roll were positive. This means mainline has an influence on the capital outlay. As a result the mainline costs -- a part of "off farm costs" -- were excluded from the data. Excluding mainline effects on farm 15 using center pivot results in a capital outlay of $204/acre and reduction of the slope as depicted by trendline B, Figure 9. However, removal of farm 2 which had used side roll systems resulted in a negatively sloped trendline. This suggests that other factors rather than mainline distance might be influencing side roll capital data.

Inflation effect: The delivery systems in the sample were purchased as early as 1958 and as late as 1975, though no center pivot system was purchased earlier than 1970. Therefore, besides the influence of useful life, and condition of purchased new or used on capital outlay as indicated in previous chapter, it is expected that the capital costs of irrigation equipment is affected by the rise in the general price level (inflation).

In an attempt to offset the effects of inflation on nominal capital outlay levels, a deflation index based on

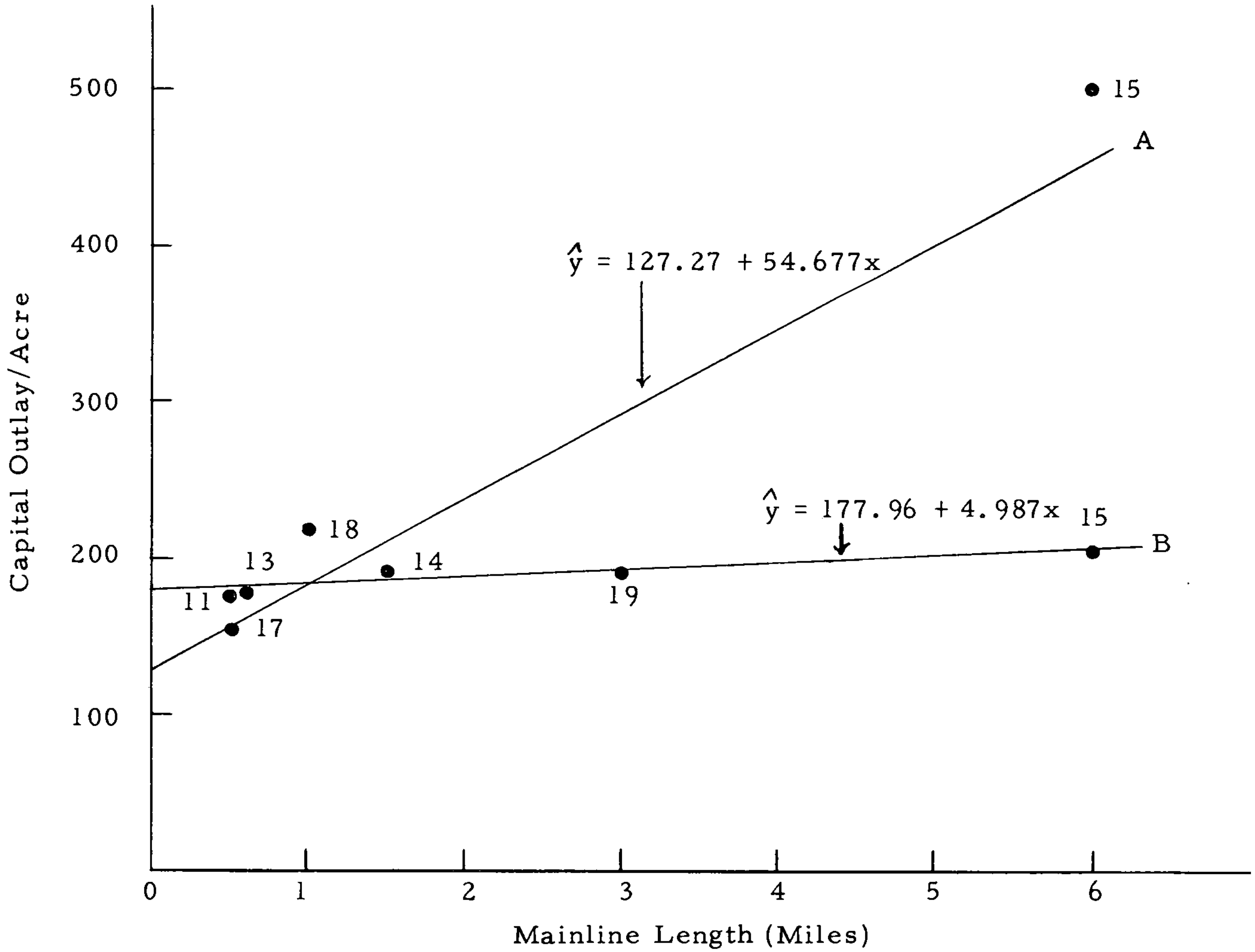

Figure 8. Mainline Effect on Capital Outlay per Acre for Center Pivot System.

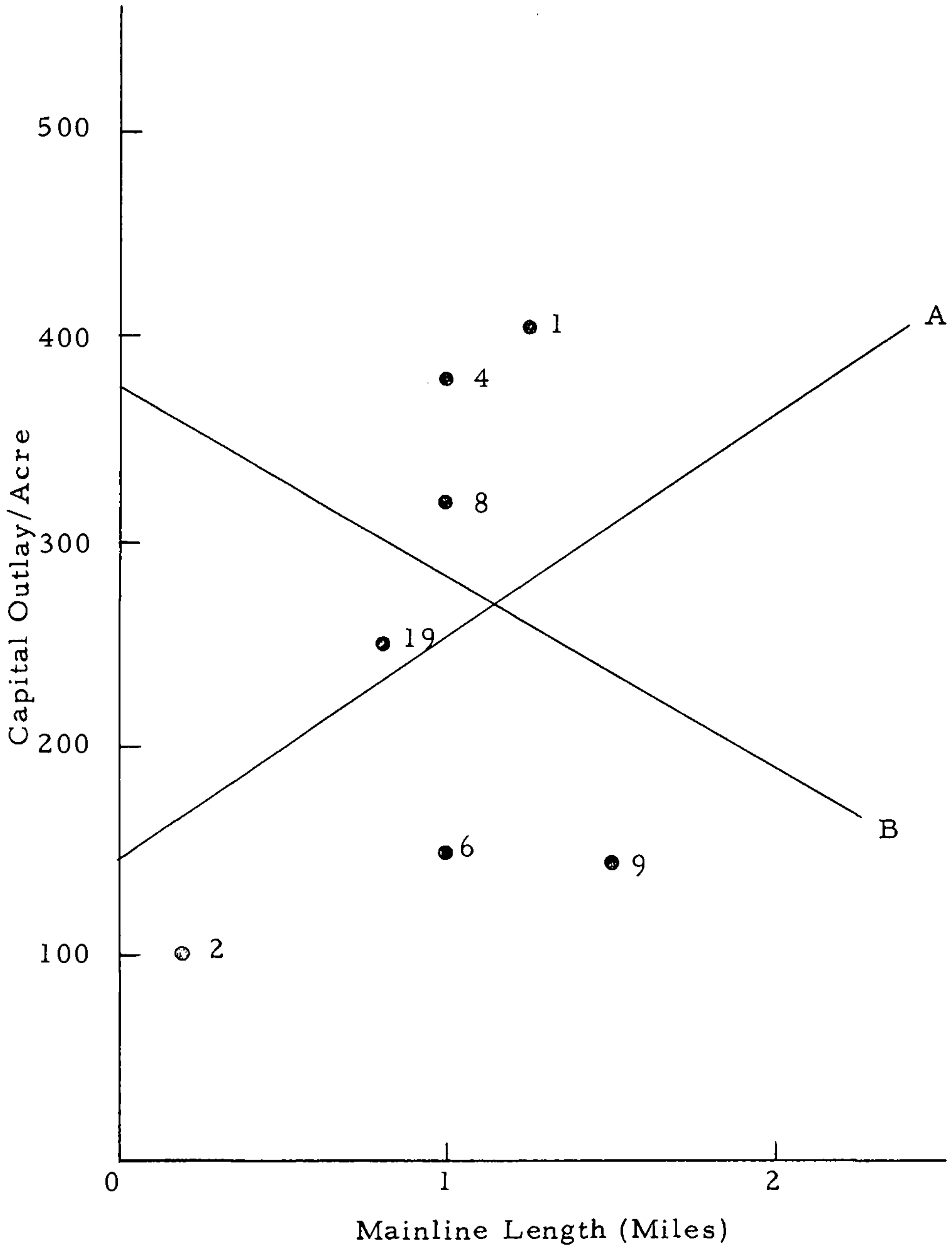

Figure 9. Mainline Effect on Capital Outlay Per Acre for Side Roll System.

data from the agricultural prices publication using 1976 as the base year was calculated (Table 19). In addition to the hypothetical conversion to 1976 real price levels, indexing would tend to provide an indication of real versus nominal price trends for both side roll and center pivot delivery systems. The original data and deflated data are presented in Tables 20 and 21 for both center pivot and side roll respectively. Plotting of the original and deflated data for center pivot and side roll are shown in Figures 10 and 11 respectively. The coefficient of variation (standard deviation/mean) was reduced from 0.22 to 0.17 for center pivot, and from 0.39 to 0.34 for side roll, indicating that some inflation effect existed in the data base and by removing it reduced some variability in the data base. As a result the slope of the trendline for side roll was reduced (Figure 11). However, the trendline for center pivot became negatively sloped (Figure 10). This suggests that the real, rather than money, capital outlay per acre for center pivot has declined overtime. This perhaps might be due to positive technology effects and/or economies of size effects. Consequently, before any definitive conclusion could be drawn from the data on capital, a more rigorous statistical analysis would be necessary.

Soil effects: In the previous chapter center pivot and side roll were used on both loamy and sandy soils. To evaluate the influence of soil on the variables -- water,

Table 19. Price Index Adapted for Estimation of Irrigation Equipment Using 1976 and 1975 as Base Years.

Years	Deflation Index	
	1976 Base Year	1975 Base Year
1957	33	38
1958	35	40
1959	36	41
1960	37	42
1961	38	43
1962	39	44
1963	40	46
1964	40	46
1965	42	48
1966	43	49
1967	45	51
1968	47	53
1969	49	56
1970	52	59
1971	55	63
1972	58	66
1973	62	71
1974	71	81
1975	88	100
1976	100	

Source: Agricultural Prices (Annual and Monthly Summaries), 1959-1976, Statistical Reporting Service, USDA, Washington, D. C.

Table 20. Inflation Effect on Capital Outlay Data for Center Pivot Irrigation System from Eight Sample Farms in North Columbia Basin, Oregon.

Farm Number	Year Purchased	Original Data	Deflated Data
10	74	310	437
11	73	175	282
13	70	176	338
14	73	192	310
15	74.5	204	255
17	72	154	266
18	73	218	352
19	71	192	349
Mean u	72.56	202.63	323.63
Standard Deviation(s)		44.48	55.29
Coefficient of Variation (s/u)		.22	.17
Intercept		-993.86	442.78
Slope		16.49	-1.64

Table 21. Inflation Effect on Capital Outlay Data for Side Roll Irrigation System from Seven Sample Farms in North Columbia Basin, Oregon.

Farm Number	Year Purchased	Original Data	Deflated Data
1	73	405	794
4	73	379	611
6	58	148	423
7	72	183	316
8	74	321	452
9	68	143	304
19	73	250	403
Mean u	70.14	261.29	471.86
Standard Deviation (s)		100.82	161.74
Coefficient of Variation (s/u)		.39	.34
Intercept		-612.98	-143.02
Slope		12.46	8.77

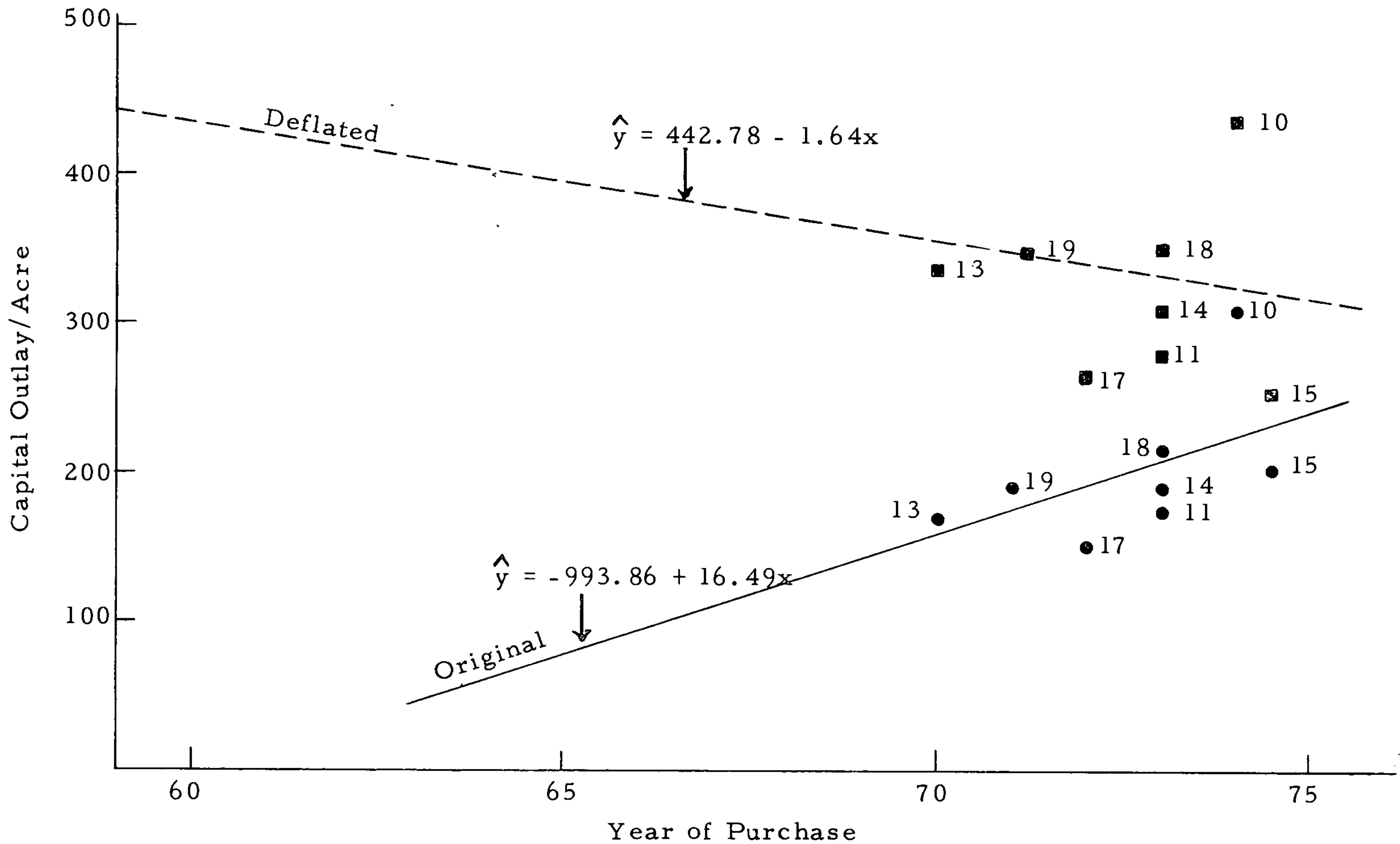

Figure 10. Inflation Effect on Capital Outlay Under Center Pivot.

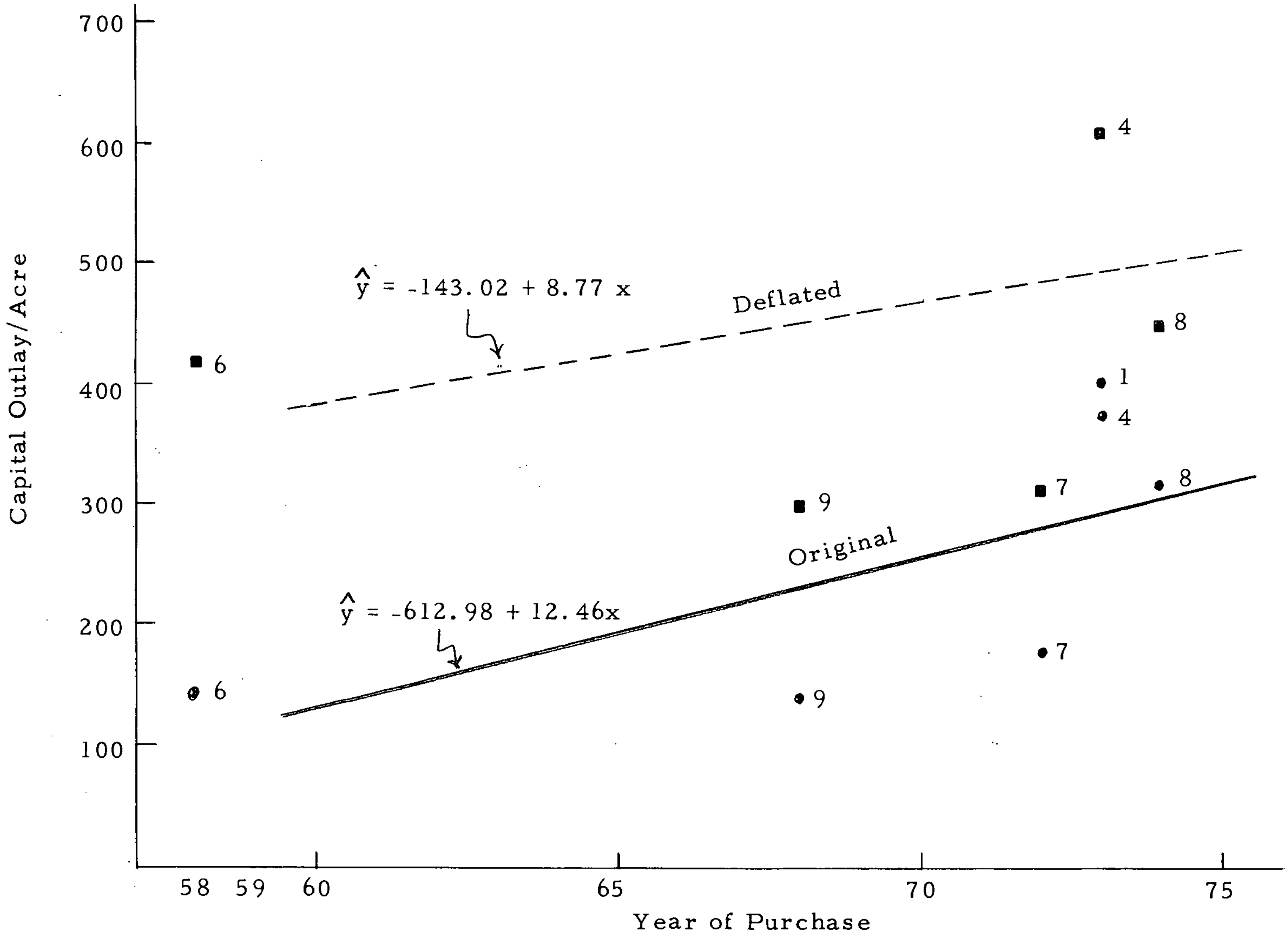

Figure 11. Inflation Effect on Capital Outlay Under Side Roll.

capital and labor, Table 22 was constructed. Table 22 shows that the variables capital and labor are unaffected by the soil types -- sand and loam. The variation in labor (cost/acre) is only reflected between the systems. However, there is a significant different in the water used on sand and loam soils. Sandy soil on the average used a higher acre inches of water than loamy soil. Part of this difference might be due to actual soil effect, while other influences such as the variation and uncertainty of water available to the farmers might dictate water use variability.

Resource Interrelations

The section on variable resources defined the variables and evaluated the impact of factors on these resources. The facts suggest that inflation, mainline and soil exact some influence on the data base. Using the corrected data, this section is designed to evaluate the resource interrelations that exist in terms of substitution capabilities. Although all the resources can be varied simultaneously, this study as specified in the theoretical section will consider two variables at a time and treat others as fixed.

Water and Labor

The relationship between the variable water measured in acre inches and labor in cost per acre is presented

Table 22. Soil Effect (Loam versus Sand) on Variable Resources -- Water, Capital and Labor.

Variable Resources	Center Pivot				Side Roll			
	Loam (3)*		Sand (6)*		Loam (4)*		Sand (2)*	
	Average	Range	Average	Range	Average	Range	Average	Range
Capital Outlay/Acre	284	240-307	276	224-382	347	270-396	616	534-698
Water (acre-inches)	26	19-34	40	30-48	21.25	10-32	30.5	25-36
Labor (cost/acre)	6.43	3.14-11.84	6.19	1.62-17.33	12.79	8.44-19.25	12.96	12.50-13.42

(Numbers represent farms reporting.

graphically in Figure 12. The figure represents different combinations of labor and water reported by the farmers using center pivot and side roll. The trend line depicts that water and labor are positively correlated, with center pivot more water intensive (labor saving) and side roll more labor intensive (water saving). Based on this observation, it could be hypothesized that substitution possibility exists between labor and water depending on the system used. To draw conclusive evidence will require knowledge of the output or yield which will determine different labor-water input proportions capable of producing the same output for the specific systems.

Capital and Labor

The relationship between the variable capital measured in outlay per acre and labor in dollar per acre is presented in Figure 13. The figure represents different labor and capital outlay reported by the farmers using side roll and center pivot. The trendline shows center pivot to be relatively capital intensive and labor saving as compared with side roll which is more labor intensive and less capital intensive. However, taking both center pivot and side roll -- capital cost are very similar -- thus in choosing between both systems cost of capital should be less considered. Substitution between labor and capital is more reflected when these systems are compared with handline,

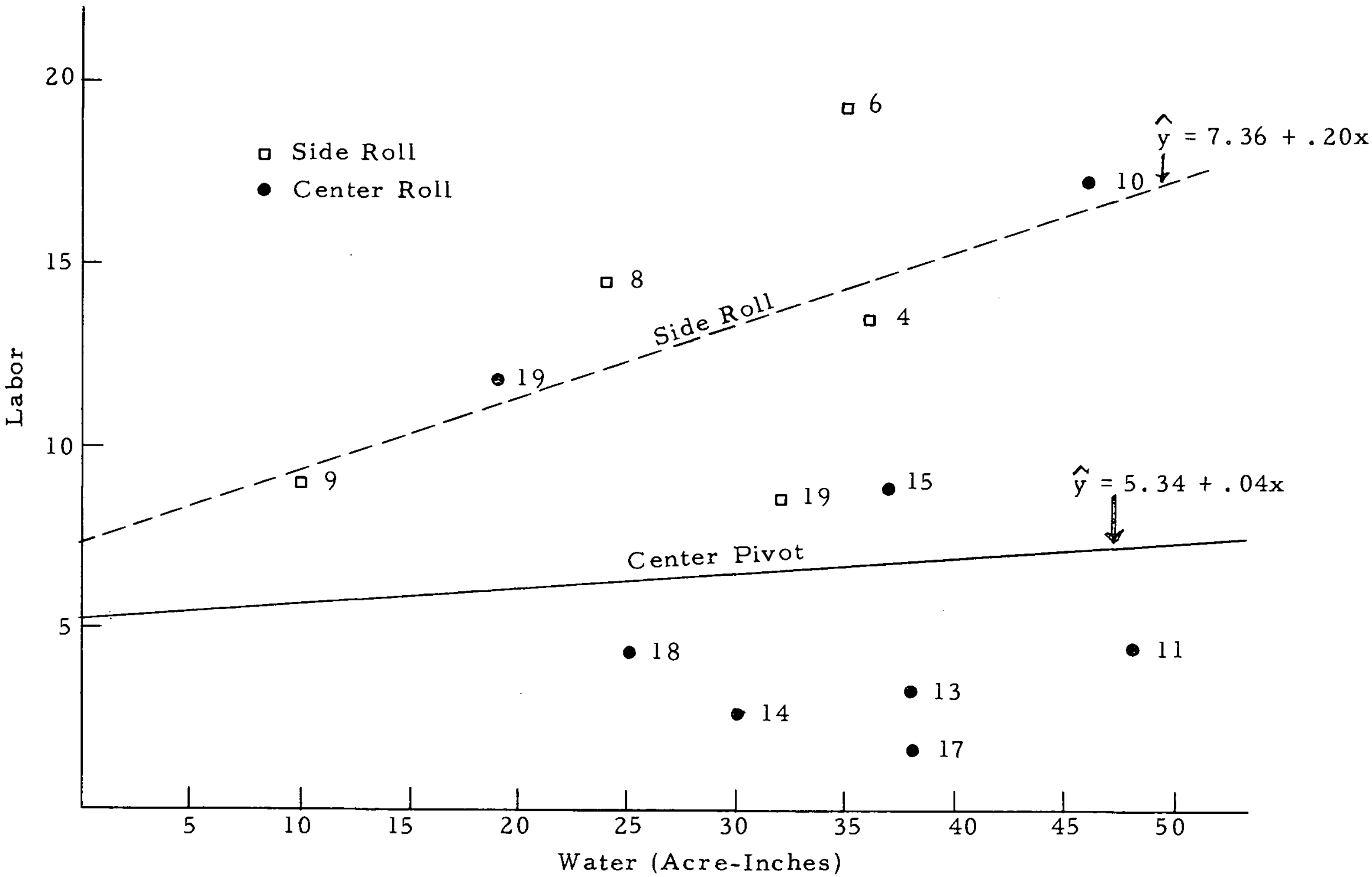

Figure 12. Variables (Water and Labor) Interrelations.

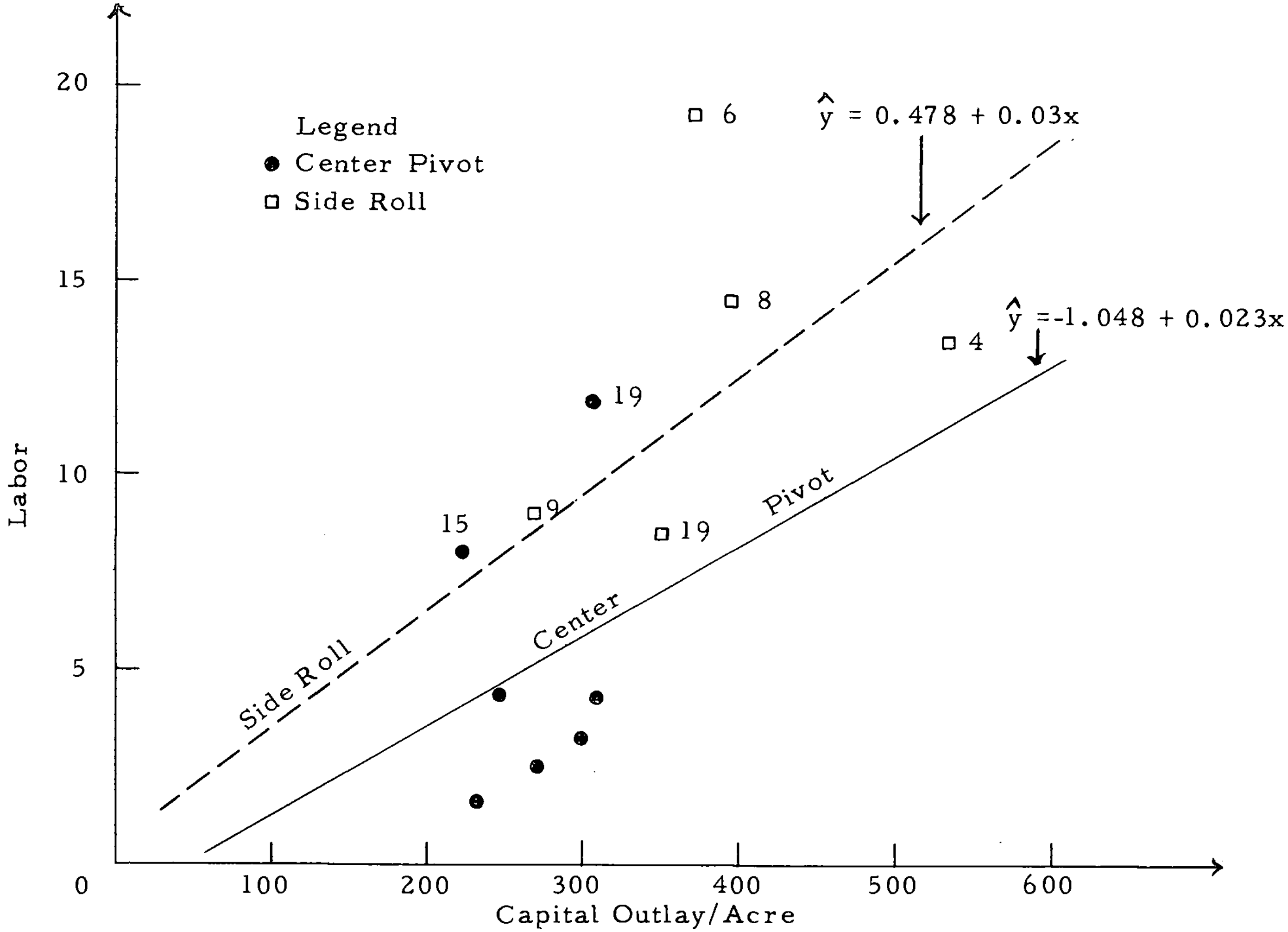

Figure 13. Variables (Capital and Labor) Interrelations.

flood as evaluated under "comparison of cost components" in the preceding chapter.

Land and Labor

The relationship between variable land measured in surface acres and labor in dollar per acre is presented in Figure 14. The trendline suggests that center pivot would be relatively labor saving acre by acre than side roll. This is perhaps due to the relative advantage of center pivot being automatically operated to handle large acreage. On the other hand, the technical design of side roll to be moved from one set to another might have accounted for the high labor cost acre by acre. Also movement of side roll from one field to another to irrigate more than the design capacity as reported by farmers 6 and 9 though it may reduce fixed cost might increase labor cost acre by acre even more. The relative high cost of moving center pivot -- which tend to be fixed once installed might discourage this practice.

Land and Water

The scatter of data points in Figure 15 shows that center pivot delivers more water per acre than side roll. The average water use reported by seven center pivot farms was 33 acre-inches and 19 acre-inches for 5 side roll farms.

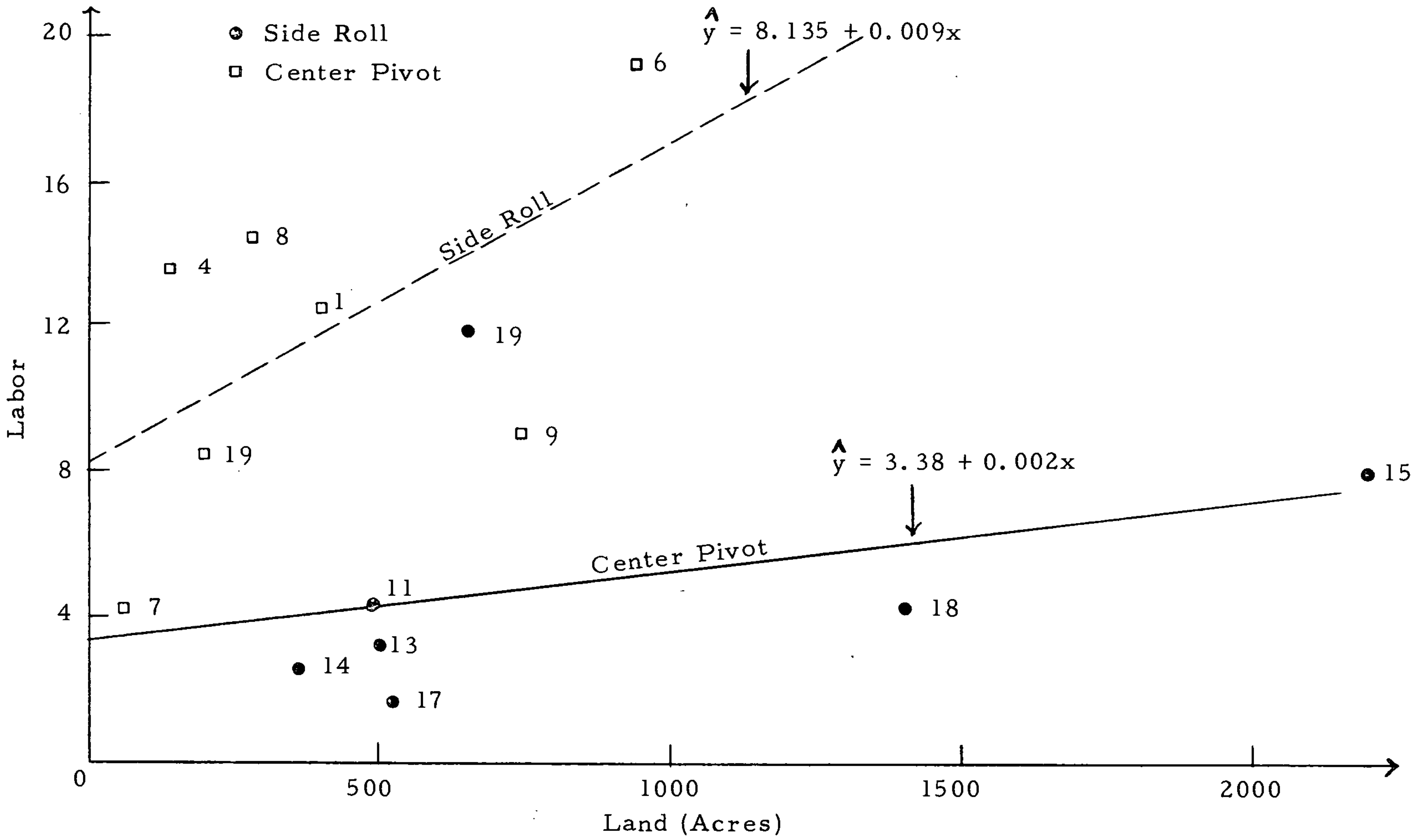

Figure 14. Variables (Land and Labor) Interrelations.

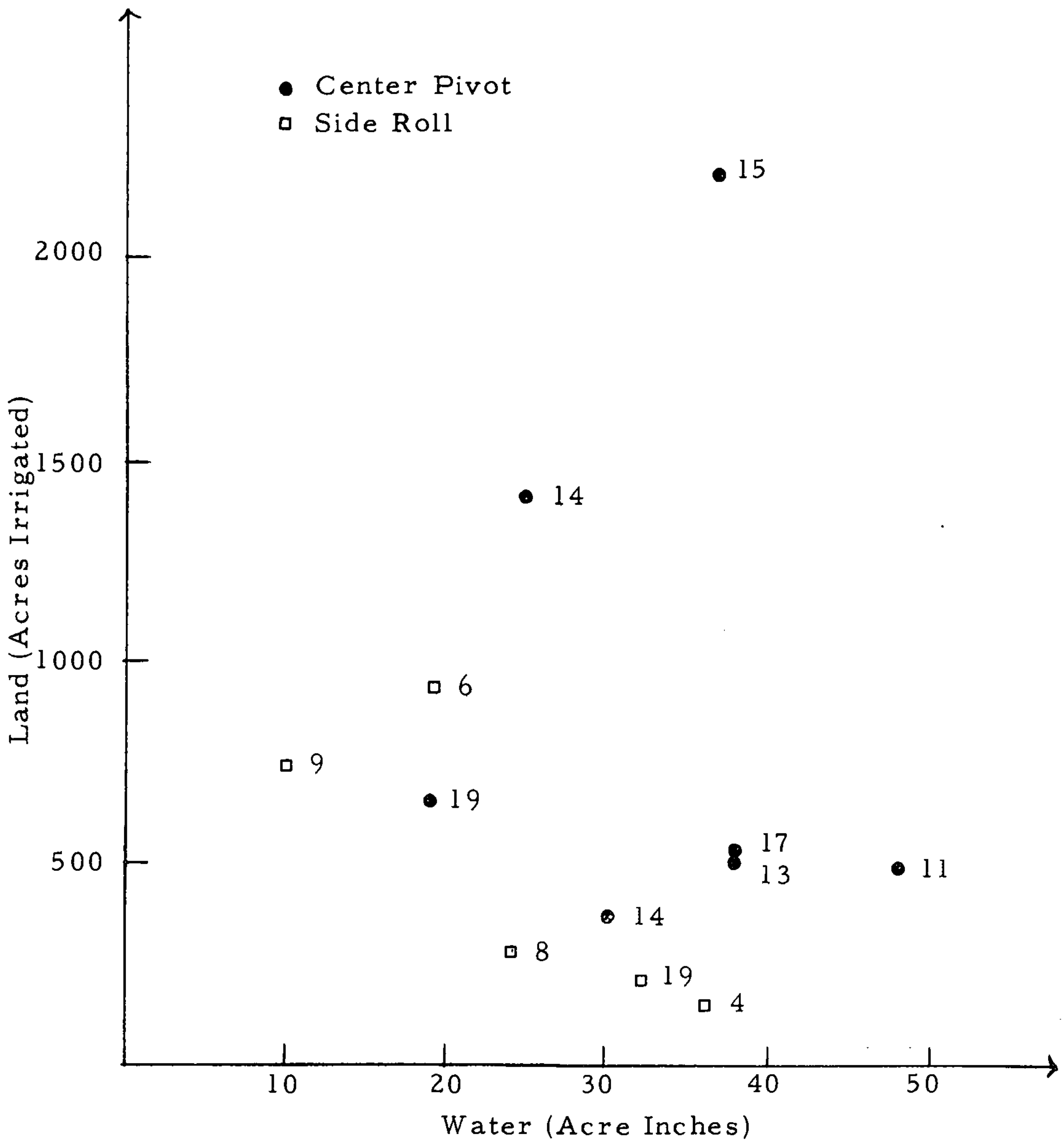

Figure 15. Variables (Water and Land) Interrelations.

Above evaluation on resource interrelation will hopefully be useful to dryland farmers that intend to irrigate and farmers already irrigating but who are deciding on which system to adopt on the 100,000 acres of dryland.

In addition to resource variation between the systems, other factors such as slope, soil types and technical characteristics of the systems, would equally be influential in deciding which system to adopt. Information under systems characteristics identified that center pivot is best under sandy soil and has the flexibility of use under varying slopes ranging from flat to steep. Center pivot system, being mounted on towers, is not limited by crop height. Side roll, on the other hand, is best on loamy soil and is limited to flat land and short growing crops because of the height of the system's lateral.

SUMMARY AND CONCLUSIONS

Prospects for irrigating an additional 100,000 acres of dryland, and the problem of drying wells and lowering water table in the Oregon's Northern Columbia Basin intensified interest in irrigation development in the region. To facilitate the decision-making by Columbia farmers on the selection of a sprinkler irrigation system, this study was developed to analyze the technical and economic characteristics of the dominant form of on-farm irrigation systems -- side roll and center pivot. The objectives were to analyze the cost structure and its variability among farms using irrigation systems and between systems, and then determine the extent to which resource substitution capabilities exist within the technical limitations of these systems.

In relation to these objectives, data were secured by personal interview with 27 farmers which include 24 sample commercial farmers and three selected part-time farmers. Nineteen of the 24 sample commercial farmers provided useful information.

The average capital outlay per acre reported for the systems was very similar, $219 for center pivot and $218 for side roll. The annual total cost per acre irrigated is an important aspect of economic comparison which was separated into overhead and operating cost categories. The average overhead cost per acre irrigated was $43.62 for center pivot and about $37 for side roll. The largest part of the overhead cost was depreciation, a reflection of capital outlay and useful life. The average operating cost per acre irrigated was $39 for center pivot and $35 for side roll. The largest part of the operating cost was electricity. Although the average capital and total annual cost per acre irrigated for center pivot and side roll were similar, these costs varied significantly among the farms. Factors which contributed or influenced cost differences among farms using a particular system, in general, were diverse. Among the factors which assert considerable influence on capital outlay were distance of water source, state of purchase -- used or new -- and year of purchase. Differences in useful life among farms, property tax and variation in capital outlay influenced the overhead cost. Operating cost differences were directly related to use of the system and type of labor -- hired or family -- used.

Comparison of cost components in terms of relative importance of the resources to the total cost showed that both systems -- center pivot and side roll -- are capital intensive with labor constituting a minor part of the total cost. Capital accounted on the average for 53 percent of total cost for center pivot and 51 percent for side roll. Electricity accounted for 24 and 21 percent of total cost for center pivot and side roll respectively. Labor used by side roll was twice as high as that used by center pivot. Family labor generally played a minor roll with hired labor commonly used.

Findings from this study indicate the existence of resource inter-relations or substitution between the variable resources -- water, labor, land and capital -- and the systems. There is a positive relationship between water and labor with center pivot more water intensive (labor saving) and side roll more labor intensive (water saving). Considering land and labor, center pivot is more labor saving acre by acre as compared to side roll. On the other hand, side roll is more water saving acre by acre than center pivot systems. Comparing capital and labor interrelations, center pivot appeared to be more capital intensive (labor saving), and side roll more labor intensive and less capital intensive. However, capital use by both systems are identical. As a result in choosing between the systems, capital cost or outlay should be less considered -- as either of the two systems could be used. Also in considering these systems, careful consideration should be given to mainline, inflation and soil type as they exert considerable influence on the variable resources.

Other important factors that will influence choice of system in the future include soil type, slope and crop height. Center pivot, best suited to sandy soil, is not influenced by land slope and crop height (system is mounted on eight foot high towers). Side roll is suited to loamy soil, flat land and short growing crops but limited by steep slope and tall growing crops.

In applying results from this research, certain limitations have to be pointed out. First, some of the cost items were imputed because not every one of the survey farms provided full data for every item of cost. Secondly, the results are based on data for a single year's operation. To be certain that results are representative of what the average farmer could expect in the future, a number of year's operation ought to be included. A third factor to be considered is the "state of the art" in the development of mechanical irrigation systems. The manufacturers of irrigation equipment are constantly striving to improve their respective products so that a system that excels today may be subject to substantial improvements in the near future.

Continued improvement in technology will, therefore, tend to widen the variety of choices available to the farmer. Improvement in both water management methods and irrigation systems are expected. As a consequence, it will be important for agricultural research and extension workers to keep abreast of the developments in irrigation technology so as to be in a better position to provide competent assistance to farmers who may want it in their decision-making process. Finally, this study supports the hypothesis that resource substitution possibilities between variable combinations -- Capital - Labor, Water - Labor, and Land - Labor, not only exists with capital intensive irrigation systems, but is practiced widely by farmers in the Columbia Basin.

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APPENDICES

APPENDIX I

DERIVATION OF LEAST COST COMBINATION OF RESOURCES

To calculate the least cost combination of resources for a given set of resources we wish to maximize $f(X_1X_2)$ subject to $Px_1X_1 + Px_2X_2 = \overline{C}$ (budget constraint).

The necessary (first order) condition is:

$$\frac{\delta L}{\delta x_1} = \frac{\delta y}{\delta x_1} - Px_1\ \lambda = 0$$

$$\frac{\delta L}{\delta x_2} = \frac{\delta y}{\delta x_2} - Px_2\ \lambda = 0$$

$$\frac{\delta L}{\delta \lambda} = \overline{C} - Px_1X_1 - Px_2X_2 = 0$$

Now the total differential of a production function Y is

$$\delta y = \frac{\delta y}{\delta x_1}\ \delta x_1 + \frac{\delta y}{\delta x_2}\ \delta x_2 = 0$$

which is set equal to zero since we are concerned about evaluation on an isoquant where output (y) does not change but is held constant at $\overline{Y}$. Hence, where $y = f(X_1X_2) = \overline{Y}$, the following relationship holds:

$$\frac{\delta y}{\delta x_1}\,\delta x_1 = - \frac{\delta x}{\delta x_2}\,\delta x_2$$

$$\therefore \frac{\frac{\delta y}{\delta x_1}}{\frac{\delta y}{\delta x_1}} = - \frac{\delta x_2}{\delta x_1} \ .$$

Hence the slope of an isoquant is equal to the ratio ofthe MPP of X_2 $(\frac{\delta y}{\delta x_2})$ to the MPP of X_1 $(\frac{\delta y}{\delta x_1})$ which can be expressed as the marginal rates of technical transformation of X_1 for X_2 or $- \frac{\delta x_2}{\delta x_1}$. Thus, in our maximization equation we are able to take the first necessary condition term over the second

$$\frac{\frac{\delta L}{\delta x_1}}{\frac{\delta L}{\delta x_2}}$$

and express it as

$$\frac{Px_1}{Px_2} = \frac{\frac{\delta y}{\delta x_1}}{\frac{\delta y}{\delta x_2}}$$

or

$$\frac{Px_1}{Px_2} = \frac{\delta x_2}{\delta x_1}$$

or price ratio = MRS where MRS is the marginal rate of technical substitution or the slope of the isoquant.

Sufficiency (second order) condition:

$\frac{\delta^2 x_2}{\delta x_1^2} > 0$ to guarantee that the isoquants are convex from below.

APPENDIX II

OREGON STATE UNIVERSITY
DEPARTMENT OF AGRICULTURAL & RESOURCE ECONOMICS
IRRIGATION SYSTEM TECHNOLOGY SURVEY

(MORROW - UMATILLA AREA)

1976

NAME ______________________________ NO. ________________

ADDRESS ____

PROJECT DISTRICT LOCATION __________________________________

ORGANIZATION ____
(Single, Proprietorship, Lease, Corporate & Others)

GENERAL FARM CHARACTERISTICS

TOTAL ACRES ________________ ACRES IRRIGATED ________________

IRRIGATION SYSTEM IN USE ___________________________________

CROPS	ACRES IN 1975

CROP ROTATION? ________ YES ________ NO

SPECIFY, COMMENT OR DESCRIBE ______________________________

____

____

____

GENERAL SOIL CHARACTERISTICS

	Fields		
	________	________	________
Slope[a/]	________	________	________
Depth of Soil[b/]...............	________	________	________
Soil Type[c/]..................	________	________	________
Drainage[d/]...................	________	________	________
Intake (in./hr)	________	________	________
Holding Capacity (in./hr.)....	________	________	________

FACTORS LIMITING LAND USE ________________________________

____

WATER SUPPLY

SOURCE ____________________ AMOUNT AVAILABLE (GPM) __________

SEASONAL VARIATION ____________ GPM TO ________________ GPM

HOW DO YOU DETERMINE WHEN TO IRRIGATE? ____________________

____

IS FARM IN IRRIGATION DISTRICT? ______ YES ______ NO

WHAT DISTRICT? ________________________________

HOW IS WATER PRICED?	BY ACRE	TOTAL ACRE	AC/FOOT	OTHER
Pumping cost.........				
O&M Charge...........				
Variable Use Charge..				

FURTHER COMMENT ________________________________

[a]Slope: Soil slope is expressed in percent. It is the change in elevation in feet for each 100 feet horizontal distance.
- Nearly level - slope ranges from 0-1%
- Gently sloping - 1-3%
- Moderately sloping - 3-5%
- Strongly sloping - 5-8%
- Steep - 8-12%
- Very steep - >12%

[b]Depth of soil. Depth refers to surface and subsoil thickness plus any parent material that is favorable for root development and available moisture retention.
- Deep soils - >36"
- Moderately deep - 20"-36"
- Shallow - 10"-20"
- Very shallow - <10"

[c]Soil type - Sandy
- Loamy

[d]Drainage is based upon the relative runoff rate, soil permeability, and the addition of water from adjacent slopes that influence the presence or absence of excess water within the root zone.
- Poor - Water is removed so slowly that the soil remains wet for a large part of the time.
- Fair - Water is removed from the soil slowly enough to keep it wet for significant periods of time.
- Good - Water is removed from the soil readily but not rapidly (intermediate textured soil).
- Excessive - Water is removed from the soil rapidly to very rapidly.

CROP CHARACTERISTICS

1975 Yield			
Usual or Normal Yield......			
Yield in Poor Year			
Yield in Very Good Year ...			

WHAT CAUSES GOOD OR POOR YEAR (CROP YIELD VARIABILITY)_____

____

IRRIGATION SCHEDULE BY CROP

	Crop		
Major Irrigation			
Irrigation season (months).........			
Peak Use Period (month)............			
No. of Irrigations (per season)....			
(per month).....			
(per peak period)....			
No. of Irrigation Sets/Irrigation..			
Hours of Labor/Irrigation Set......			
Water Use (specify unit)...........			

	Crop		
Supplemental (off-season) irrigation			
Irrigation Season (months).........			
Peak Use Period (month)............			
No. of Irrigations (per season)....			
(per month).....			
(per peak period).....			
No. of Irrigation Sets/Irrigation..			
Hours of Labor/Irrigation Set......			
Water Use (specify unit)...........			

SPECIFY WHY SUPPLEMENTAL IRRIGATION IS USED ______________

____

____

FURTHER OBSERVATIONS OR COMMENTS ____________________

____

IRRIGATION CHARACTERISTICS

A. DESIGN SPECIFICATION

	MAIN	LATERAL	PUMPING SYSTEM
Size			
Length			
Flow Capacity (GPM, Acre Ft.)			

Acres Served per System[a]

Sprinkler Head Spacing

Water Application Efficiency

No. of Sets per Day

Time of Application per Set (hours)

Comments:

[a] Is the system physically moved during the year to utilize more acres than suggested by design capacity?

_______Yes _______ No

B. CAPITAL INVESTMENT

System type........................ ____________

Design Capacity (acres)............ ____________

Year Purchased..................... ____________

Capital Cost (investment).......... ____________

Estimated Useful Life.............. ____________

Loan Involved (yes, no)............ ____________

Sources (PCA, Bank, Ins. Co., etc.). ____________

Loan Payment: Rate ____________ Year ____________

Did your irrigation system work the way you thought it should? ______Yes ______No

Describe any operational problem ____________

C. COST

Annual Fixed Cost

Depreciation....................... ____________

Interest........................... ____________

Property Tax....................... ____________

Insurance.......................... ____________

Other (specify).................... ____________

Comments (specify nature of repairs) ____________

Annual Variable (Cash) Cost

Energy (fuel or electricity)....... ____________

Lubricants, Repairs, Maintenance.... ____________

Hired Labor (out-of-pocket costs)... ____________

1. Hourly.................... ____________
2. Monthly................... ____________
3. Supervisory Labor.......... ____________

Others................................. ____________

Comments ____________________________

ANNUAL IRRIGATION LABOR USE/FARM

Total Farm Annual Cash Cost for Irrigation Labor $__________

Estimated Number of Hours of Unpaid Labor (family & operator) Used on Farm for Irrigation Purposes Annually:

Operator Labor .... __________

Family Labor............... __________

Other (specify)............ __________

Total Unpaid Labor......... __________

Labor Available Throughout the Day or Only at Selected Times

____

Could you get extra labor when needed? Yes______ No ______

If Yes, What is Current Wage: Hourly __________

Monthly __________

If No, Why Not? __________

____

Supervisory or Other Labor Requirements for Irrigation[a/]

Crop	Irrigation Hours

[a/] Supervisory labor used for scheduling, maintenance, obtaining new irrigation information, etc., necessary for maintaining and improving irrigation system operations.

GENERAL QUESTIONS ON IRRIGATION SYSTEM

In your opinion what are the main advantages of your system?

____

____

____

____

____

What are the main disadvantages?____________________________

____

____

____

____

____

Why did you adopt this irrigation system?____________________

____

____

____

____

Do you know of another type or form of irrigation system which you would like to have to replace your existing system? ________ Yes ________ No

If yes, describe it. ____________________________________

____

____

____

THANK YOU FOR YOUR TIME AND COOPERATION.