AN ABSTRACT OF THE THESIS OF

Mary Cora Stoff for the degree of Master of Science in Agricultural and Resource Economics presented on September 9, 1994.

Title: The Effects of Farm and Operator Characteristics, Knowledge, and Attitudes on Farm-Level Improvements in Irrigation Efficiency in the Central Willamette Valley

Redacted for Privacy

Abstract approved: ____________ ____________

Joe B. Stevens

A study was conducted using data collected from a sample of mint and vegetable farmers in the Willamette Valley of Oregon. The study identifies the influence of demographic differences, economic factors and irrigator attitudes on irrigation efficiency.

Only two of the 19 characteristics theorized to influence irrigation efficiency proved to be statistically significant in both of two models. These significant variables, crop type (CROP), soil type (SOIL) suggest that a farmer's irrigation efficiency is unaffected by personal characteristics or attitudes. According to these results, the irrigator apparently applied the water that she deemed necessary, a decision based solely on the needs of the crop and the water-holding capacity of the soil.

The Effects of Farm and Operator Characteristics, Knowledge, and Attitudes on Farm-Level Improvements in Irrigation Efficiency in the Central Willamette Valley

by

Mary Cora Stoff

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed September 9, 1994

Commencement June 1995

APPROVED:

Redacted for Privacy

Professor of Agricultural and Resource Economics in charge of major

Redacted for Privacy

Acting Head of Department of Agricultural and Resource Economics

Redacted for Privacy

Dean of Graduate School

Date thesis is presented September 9, 1994

Typed by researcher Mary Cora Stoff

ACKNOWLEDGEMENT

Without the following I would have been lost:

To my major professor, Dr. Joe B. Stevens, for his patient support, his unflagging optimism, and his ability to ask simple questions without simple answers.

Dr. Greg Perry, for his faith in me, his open door policy, and his willingness to drop his work to discuss mine.

Dr. Rich Adams, for his sound advice on topics ranging from fly fishing and car mechanics to optimal employment strategies. He's batting 1.000 so far.

Dr. Steve Polasky, for his successful and ongoing efforts to demystify and humanize econometrics for me and the masses. Duty above and beyond the call.

Dr. Marshall English, for his patient and endless help in negotiating the marvelous but technical world of efficiency, ET, and crop coefficients.

To my sundry Friday evening drinking companions, soccer buddies, and softball teammates (Go Marginalists!). You are all bums. Get a job.

To my father, John Brockert, who taught me responsibility, tolerance, and never to take myself too seriously.

To my mother, Breeda Brockert, a feminist well before her time. She taught me independence, resilience, and never allowed anyone (including me) to limit my horizons.

To my husband, Bruce G. Stoff, the most wonderful man in the world. Thank you isn't enough.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

THE EFFECTS OF FARM AND OPERATOR CHARACTERISTICS, KNOWLEDGE, AND ATTITUDES ON FARM-LEVEL IMPROVEMENTS IN IRRIGATION EFFICIENCY IN THE CENTRAL WILLAMETTE VALLEY

CHAPTER ONE
MOTIVATION AND JUSTIFICATION

In recent years the public's concern over the distribution of the West's limited water supply has increased. Agricultural interests have historically appropriated a large portion of the water supply in much of the West[1]. Many rapidly-growing urban areas are now beginning to view agriculture's water bounty with an eye toward acquisition. Cities that require more water are having difficulty meeting the needs of their residents, who are the largest voting block in the West. The institutional structure that guides western water allocation has been slow in demonstrating the flexibility necessary to reallocate along society's changing priority guidelines.

Water is clearly an increasingly scarce resource in many areas of Oregon (*Capitol Press*, 1993). Attempts are made in each session of the Oregon Legislature to pass legislation that reallocates water to uses other than irrigation, primarily to urban or instream uses. Water agencies are routinely challenged through appeals and other legal devices to reallocate water. In the 1993 session alone, more than 130 water-related measures were introduced (Merriman, 1993). Even though the doctrine of prior appropriation seems to secure its water supply,

---

[1] Up to 90% of total water consumption in the western states is attributed to consumptive use for irrigated agriculture (El-Ashry and Gibbons, 1986, p.1)

irrigated agriculture is under pressure to show that it is using water without significant waste (El-Ashry and Gibbons, 1986; Livingston and Miller, 1986; DuMars and Tarlock, 1989; Negri and Brooks, 1990; Wilkinson, 1992; *Capitol Press*, 1993). Irrigators generally do not view any of their water as "wasted", and they are sensitive to any implication that they do not need, or are not fully utilizing their current water supply. Irrigators, however, are only as efficient as their irrigation equipment.

Irrigation Technologies and Efficiencies

There are three main types of irrigation systems, each with many subtypes and variations. The three main types are surface, trickle and sprinkler irrigation. Surface irrigation is the oldest of the three types; it is done by flooding the entire field through the use of ditches, furrows, or pipes. Trickle or drip irrigation is among the most modern. It consists of surface or subsurface pipes laid in rows with outlets spaced to apply a controlled amount of water directly to the root zone of the plant.

Sprinkler irrigation has many variations, three of which - handline, side roll and solid set systems - are the methods of particular interest in this study. All three consist of sprinkler heads spaced along a length of pipe. The differences lie mainly in the labor required and the permanence of each system. Handline, as the name implies, is the most labor-intensive; it requires the irrigator to move the pipes by hand. Side roll means that the pipes and sprinklers are mounted on wheels and can be propelled and controlled automatically. Solid set is generally a more permanent setup, often using buried laterals with movable risers to enable the irrigator to alternate between rows (Withers and Vipond, 1980).

Some irrigation systems are more efficient than others. Furrow or ditch irrigation is generally the least efficient because of losses from seepage and surface evaporation. Sprinkler irrigation is generally more efficient, but it is subject to various external factors like winds and temperature-induced evaporation that may offset the efficiency gains. Trickle or drip irrigation, by contrast, has no spray and little evaporative loss. It is not labor-intensive once installed but it is more costly than less efficient alternatives (Withers and Vipond, 1980).

Various measures can be taken by irrigators to increase the efficiency of existing systems. Canals and ditches can be lined to prevent seepage or covered to limit evaporation. Land leveling, the installation of gated pipe, and the adoption of surge irrigation techniques (Verplancke *et al*, 1992) can also increase the efficiency of a open furrow system. Sprinkler efficiency can be increased by irrigating for longer periods on calm days (Verplancke *et al*, 1992) and by replacing sprinkler nozzles that wear out over time due to abrasion from water-borne sand and grit. Regular replacement of worn nozzles provides more efficient application. Combined with the use of timers to prevent overirrigating, these measures can increase the efficiency of most sprinkler systems.

Potential Gains from Water Conservation

Improvements in irrigation efficiency have the potential to mitigate some of the current water shortages in western states. Estimates put the amount of water used by western agriculture at 80% to 90% of the available supply (El-Ashry and Gibbons, 1986, p.1; Reisner, 1986, p.9). Much of this is consumptively used in comparatively low-valued uses. Urban users are generally willing to pay much more than irrigators for water. Even relatively small conservation efforts on the part of agriculture could have large payoffs for increased western water supplies. A relatively small conservation savings by agriculture (5%, for example) could increase the amount of water currently available to non-agricultural users by 25% to 50%[2].

In the early 1980's, the city of Casper, Wyoming reached an agreement with the Alcova Irrigation District to modernize the local irrigation system and increase the municipal water supply at the same time. Casper financed a canal lining and conservation program for the local irrigation district and appropriated the conserved water for municipal use. The city found this to be the most "cost-effective way to increase its water supply" (Shupe *et al*, 1989, p.420). For

---

[2] If agriculture is using 80% of western water then non-agricultural uses are receiving 20%. If the agricultural share is reduced to 75%, this 5% would mean a 25% increase in the available supply to non-agricultural uses. If agriculture uses were 90% of western water use, the non-agricultural increase would be 50%.

irrigators, however, there are usually disincentives to conserve water due to the traditions of prior appropriation.

The Doctrine of Prior Appropriation

The doctrine of prior appropriation - "first in time, first in right" - has shaped the structure of surface water law in the western states since the mid-nineteenth century. While riparian law holds sway east of the 100th meridian and has formed part of the basis for water law in California, it has had only a small effect on the allocation of water in most other arid western states. Under prior appropriation, the first person to divert a water source has senior right status. Her right generally cannot be denied as long as she continues to put her water right to a beneficial use[3] on the acreage specified in the original right.

As articulated by prior appropriation's "use it or lose it", most beneficial uses are consumptive by definition. Running water has historically been viewed as waste; such instream uses of water as wildlife habitat or recreation have not been legally or traditionally viewed as beneficial uses. This is changing in many western states[4]. The law as it has existed in many states requires that flows be diverted from the stream and consumptively used in order to be retained by the

---

[3] A beneficial use has generally been considered to be water for domestic, municipal, power development, mining, industrial or agricultural use.

[4] Root, 1993, p.51.

rightholder. If the holder of a right does not use her traditional allocation beneficially at least once every five years, she may forfeit her right to the unused portion. Efforts on the part of the irrigators to conserve water is implicitly discouraged because any conserved water may be lost to the rightholder. Putting conserved water to use on land other than that specified in the original water right is illegal in most western states. This practice, known as "water spreading", is considered to be illegal even if the conserved water is put to beneficial use.

Not all irrigators get their irrigation water from surface sources. Many Willamette Valley irrigators draw their irrigation water from wells. Oregon groundwater law has developed separately from surface water law but it reflects many of the same traditions. Oregon groundwater law is based on the concept of reasonable use; it allows landowners the right to use water from the underlying common property resource, but it mandates beneficial use and prohibits the waste of water[5]. The same administrative procedures generally hold for groundwater as for surface water in Oregon[6]. A water right must be obtained to use groundwater and the user must show beneficial use. Thus, whether the irrigator is drawing from a surface or a groundwater source, the same "use it or lose it" rules seem to apply and the act of conserving water still increases the possibility of forfeiting it.

---

[5] Clark, 1983, p.194; Oregon Law Institute, 1983, p.130.

[6] Oregon Water Rights booklet, 1993.

The potential increase in western water supplies from irrigation conservation make efforts to emphasize efficiency of irrigation technology and water conservation within the agricultural sector seem worthwhile. Laws regarding water use must be adapted to prevent irrigators who practice conservation from losing their water right. Also, the personal and farm-level characteristics that may influence the adoption of conservation practices must be uncovered because ignorance of the motivations behind conservation may result in ineffective legislation.

Oregon's Legislative Effort

In Oregon, where the major urban population centers are located within the rainy western region of the state, there may be some lingering perception that there is no shortage of water. Unfortunately there are many areas in the state with "no unappropriated water available during periods of seasonal low flows"[7]. As the population grows, these areas will require more water. However, prior to developing additional storage facilities, state government should explore the potential savings to be gained from reducing inefficient water use.

In 1987 the Oregon Legislature passed Senate Bill 24 (SB 24), a highly touted effort to set up a water conservation program that would allow irrigators to

[7] Oregon Water Management Program, 1990, p.4.

conserve water without losing their rights to it. Through SB 24, farmers can keep up to 75% of any amount of water conserved from their level of historical use. A new water right with the same priority date as the original right is issued for 75% of the amount conserved. The right holder can legally use this water on fields not included in the original water right (previously "water spreading"), or lease or sell it in a water market. It can also be stored instream for future use by the right holder. In return the right holder gives up 25% of the conserved water to the state, which is then instructed to use it to enhance instream flows.

On paper Senate Bill 24 appears to hold water. Puns aside, many observers, economists and lawyers alike, have applauded the law (Shupe, 1989; Wilkinson, 1989; Colby, 1990; Harbison, 1991; Kaufman, 1992). Unfortunately their praise has been premature. Unwieldy administrative requirements, uncertainty in quantifying historical water use, and difficulty in tabulating the amount of water actually conserved have proven to be nearly insurmountable barriers.

Also, the law stipulates that conservation projects must not cause injury to other users. While this is a laudable goal both economically and morally, it is nonetheless difficult to prove that a project will not cause harm to other users. In the seven years of SB 24's existence only three applications have been made to the Water Resources Commission, which is the administrative group charged with managing the conservation program. One application has been denied, one withdrawn, and the third, an application made by the Arnold Irrigation District for a canal lining project, is still pending.

Objective of the Thesis

Before the Oregon Legislature works on another bill like SB 24, it is imperative to learn what factors might be influencing some Oregon irrigators to be more efficient than others in their irrigation practices. When policymakers have a better idea of the demographics and attitudes underlying increased conservation of irrigation water, they may be able to better motivate conservation among Oregon irrigators and can craft water conservation legislation accordingly. It is economically and politically inefficient to continue passing "hit or miss" legislation.

Some irrigators may adopt water-conserving practices before others due to economic factors or demographic differences. For example, age, education, years of irrigation experience as well as farm income vary among Oregon irrigators. These differences may affect irrigation efficiency, as will be argued in the next chapter. Equally important may be their differences in attitudes toward and knowledge of water rights and water use. All these factors may influence decisions by irrigators that affect the efficiency of water use at the farm level.

To test the validity of these ideas, this study focuses on variations in water use efficiency among Oregon irrigators as a function of personal characteristics and attitudes toward and knowledge of water rights, as well as various individual and farm-level economic factors. The objective of the study is to identify significant factors that influence the efficiency of irrigation among mint and vegetable growers in Linn, Benton and Marion counties.

Organization of the Thesis

Chapter Two consists of a literature review that encompasses both the environmental sociology literature (to identify the individual characteristics that may influence irrigation efficiency), and the soil and water conservation literature (to review previous studies regarding influences on adoption of conservation practices). Chapter Three outlines the economic theory which views the farmer as a profit-maximizer and identifies the accompanying economic factors that are potentially important in individual decisions about irrigation. Chapter Four outlines the econometric model, discusses the formulation of the dependent variable and presents the hypothesized signs of the proposed independent variables. Chapter Five discusses the questionnaire format, survey methods, and the response rate from the survey. Chapter Six reports and examines the econometric results. Chapter Seven summarizes the study and draws some conclusions about the characteristics that may be influencing irrigator efficiency.

CHAPTER TWO
LITERATURE REVIEW

Any attempt to determine the demographic and attitudinal characteristics that might influence a farmer's attitude toward irrigation efficiency and water conservation would be fruitless without a thorough examination of the relevant literature. Toward that end, material from various disciplines was reviewed; in particular, environmental sociology and soil and water conservation. The goal was to find any recognized attitudinal influences on irrigation efficiency. Unfortunately, no literature was located that explicitly addresses the influences of attitudes on irrigation efficiency. There is, however, a body of related literature that addresses attitudinal and economic influences on the adoption of both soil and water conservation practices.

The multidisciplinary approach was crucial for several reasons. While the economic view of irrigators as either profit or utility maximizers is the basis of Chapter Three, additional guidance is needed to select the appropriate predictor variables for this model, particularly the attitudinal variables. Environmental sociology focuses on explaining the behavior of the irrigator within the framework of her attitudes and beliefs. The soil and water conservation literatures explain the actions of the irrigator within the context of economic theory and also incorporate elements of the attitudinal approach to behavior. This is due to the fact that many economists publish in the soil and water conservation literature. The literature examined here deals primarily with attitudinal influences rather than the traditional economic influences of price or marginal value. The behaviors explained in the different studies range from adoption of conservation practices to environmental attitudes, conservation behavior, and adoption of innovations.

Environmental Sociology Literature

The adoption of improved farm practices is positively associated with farm ownership, higher levels of education and income, larger farm size, and increased social participation in some early environmental sociology literature (Marsh and Coleman, 1955). Later literature suggests the importance of years of formal education (Hooks, Napier and Carter, 1983; McDowell and Sparks, 1989). Additionally, according to McDowell and Sparks:

> The main lesson...seem(s) to be that habitat conservation is akin to a luxury afforded only by the most wealthy...Within this perspective, subjects are effectively "only as affluent as they believe themselves to be", and their spending patterns (including that on conservation) follow partly as a consequence thereof (McDowell and Sparks, 1989 p.196).

Other variables suggested by Kreutzwiser and Pietraszko (1986) are gender, education and age of the individual, size of the land, number in family, and tenure of property, including the number of years the individual has owned/resided on relevant property, and years of ownership by individual's family.

Attitudes are also cited as relevant variables. In an article assessing landowner attitudes toward wetlands, Kreutzwiser and Pietrasko (1986) determine that the individual characteristics that seem to "evoke differences in attitudes" are occupation, educational level, and rural vs. urban setting. "Correlations between farmer's attitudes and behavior showed that attitudes to farm productivity, efficiency and tidiness dominated management decisions to the exclusion of wildlife considerations" (Carr and Tait, 1991, p.281). Stern et al (1993) also cite age as a factor influencing environmental attitudes and actions. Their findings contradicted those of McDowell and Sparks (1989), who found that there was no empirical relationship between age and conservation behavior.

Jones and Dunlap (1992) tested for possible changes in the sociopolitical correlates of environmental concern. Their study included eleven independent variables frequently thought to be good predictors of environmental concern: age, gender, race, education, family income, occupational prestige, industrial sector, current residence, residence at age 16, political ideology, and party affiliation. Their results show that age was clearly the best predictor of environmental concern; younger adults were more environmentally concerned than were older adults. The researchers named education as one of the next best predictors and noted that many of the other predictor variables produced inconsistent results.

Hooks, Napier and Carter (1983) used a version of the diffusion model[8] to explain the adoption of farm technologies and innovations as a result of the

[8] Diffusion research views the farmer as an actor responding to stimuli concerning improvements in agricultural technology (van Es, 1983)

farmers' access to information. Their model hypothesized that once farmers are made aware of the options available to them they will act, implementing technologies and innovations that reduce labor while simultaneously increasing the productivity and efficiency of their farm.

Water and Soil Conservation Literature

This literature incorporates work from both sociologists and agricultural economists. Again, the primary focus of this literature review is attitudes rather than traditional economic variables. Within the conservation literature, attitudes regarding stewardship obligations have generally been found to have significant but modest positive impacts on the adoption of conservation practices. There has been a tendency for farmers to use the same conservation practices whether they own or rent (Buttel *et al*, 1990). This could be because many farmers both own and rent land, and that they may use uniform practices over both types of land.

Many studies have found farm size, farm income, and educational level to have a positive relationship to adoption of soil conservation practices (Buttel *et al*, 1990). Higher farm incomes were also found to be associated with high degrees of soil conservation by Lee (1980). Carlson et al (1977) found that gross income, education, and acres farmed were significantly related to the adoption of soil conservation practices among farmers and absentee landowners in Idaho. Age seems slightly less related; while younger farmers seem to be higher adopters, age was less important than income and size of farm, both of which were inversely related to age. Carlson contended that the relationship of conservation to gross income and farm acreage proved that the farmer's financial wherewithal was a crucial factor in the decision to conserve. The study's major conclusion, however, was that the characteristics of the farm and the farmer were neither the only nor the most important influences on the adoption of conservation practices. Factors such as the attitudes and values of the farmer could also have a significant effect on adoption (Carlson, 1977).

Ervin and Ervin (1982) found a positive relationship between education and soil conservation decisions and practices. Important economic factors also included farm income levels, off-farm income, risk aversion, and the discount rate and planning horizon of the farmers. The discount rate and planning horizon were reflected in the farmer's expectation of eventually transferring the farm to a child. Lower discount rates and longer planning horizons were thought to encourage conservation decisions (see also Lee, 1980; Lovejoy and Napier, 1986). Younger farmers appear more receptive to adoption of conservation practices due to higher education levels, heightened perception of the existence of a problem, and to slightly lower levels of risk aversion (Seitz and Swanson, 1980). Risk-averse farmers were found to exploit the soil more than risk-neutral farmers (Ardila and Innes, 1993).

A farmer's willingness to assume risk has been a very consistent estimator of conservation practice adoption. A strong positive relationship has been found between risk-taking propensity and the adoption of tillage conservation practices

(Buttel *et al*, 1990). Bosch and Eidman (1987) also found a positive relationship between increased irrigation and risk-aversion, reflecting the use of irrigation as insurance. Ervin and Ervin make an interesting point regarding risk:

> Different views can be taken to the role of risk in conservation practice use. Farmers who avoid risk may be reluctant to sacrifice short-run returns for the less certain benefits of conservation practices. However, one could also argue that risk-averse farmers might be expected to adopt practices to avoid the chance of a long-term productivity decline, whereas risk takers might not adopt under the belief that new technology will be developed to substitute for topsoil (Ervin and Ervin, 1982, p.285).

In a 1977 study of adoption of soil conservation practices among Illinois farmers, Pampel and van Es reported that farm experience was the best predictor of adoption of conservation practices for environmental reasons, while the size of the farm was the best predictor of the adoption of conservation practices for commercial reasons. Size and income were found to be "indicators of the ability to make an investment"[9] in soil conservation. Size of operation was found to be important in other studies (Rahm and Huffman, 1984), as was soil type and drainage characteristics (Rahm and Huffman, 1984; Negri and Brooks, 1990).

Negri and Brooks (1990) found that the probability of adopting water-saving technology increases with the price of water, and that the irrigator responds to scarcity of labor by shifting to less labor-intensive irrigation systems. Dinar and Yaron (1990) agreed that the price of water was important. The cost of the

---

[9] Lovejoy and Napier, 1986, p.34.

power needed to run the irrigation pumps is suggested as a positive influence on adoption (Caswell and Zilberman, 1985). They found that farmers who use groundwater for irrigation are more likely to adopt modern technologies than are farmers using surface water for irrigation.

Summary of Important Influences

While none of the studies reviewed here deal explicitly with attitudinal influences on irrigation efficiency, they do offer some potentially useful information. Based on this literature review, the most important influences on irrigator attitudes toward soil and water conservation seem to include the following: farm acreage, off-farm income, gross farm income, power and water costs, age and experience of the operator, level of education, operator's perception of a soil or water loss problem, planning horizon and discount rate, technical assistance, attitudes, and level of risk-aversion. All of these need to be reflected in the choice of predictor variables.

CHAPTER THREE
ECONOMIC THEORY

In determining the approach to exploring influences on irrigation efficiency, an analysis of the underlying economic theory was important, though the primary focus of the study was the influence of attitudes. Nonetheless, an economic analysis should explain many of the financial motivations in a farmer's irrigation practices. This analysis is presented in this order: the case of profit maximization with unconstrained inputs and perfect information, the case of profit maximization with imperfect information, and the case of profit maximization with input constraints.

Theory of Profit Maximization

Farmers are interested in the success of their farm and the survival of their family. The main goal of most farmers is making a living on a day-to-day basis. In economic terms this is viewed as maximizing profits and minimizing the costs of earning these profits. Farmers earn profits by producing and selling a crop; in the simplest models they use capital and labor as the inputs in the production process[10].

[10] The amount of land available for cultivation is also an input of production; in this model it is assumed to be a form of capital.

The output of the farm is determined by the state of technology and the inputs that the farmer chooses, a relationship formally known as the production function. This relationship can be written as

$$q = f\,(x_1\,,\,.\,.\,.\,x_s\,|\,x_{s+1}\,,\,.\,.\,.\,.\,,\,x_n\,) \tag{1}$$

where q is output, f is an unspecified functional form, x_1 through x_s represent variable inputs, and x_{s+1} through x_n represent fixed inputs (Beattie and Taylor, 1985). Which inputs are variable and which are fixed depends on the time frame. Three inputs are assumed in this model: labor (L), capital (K), and water (W). Water and labor are assumed to be variable over the short-run; capital is assumed to be variable over the long-run.

If we define profit as total revenues (TR) minus total economic costs (TC), maximizing profits means making the difference between TR and TC as large as possible. We can define TR and TC as

$$TR = Pq \tag{2}$$

$$TC = r_1\,L + r_2\,W + r_3\,K \tag{3}$$

where P is the price received by the farmer for her output, and r_1, r_2 and r_3 are the market wage for labor, the market price of water and the market rate of interest for capital respectively. Price is assumed constant and exogenously determined in keeping with the assumptions of perfect competition. Profit is then

$$\pi = Pq - r_1 L - r_2 W - r_3 K \tag{4}$$

or

$$\pi = P f(L,W,K) - r_1 L - r_2 W - r_3 K \tag{5}$$

where f(L,W,K) represents a general, constant returns-to-scale production function of our farmer. Constant returns-to-scale (meaning that if all inputs are increased by some multiple, output is increased by the same amount) is a necessary assumption for a proof later in the chapter.

Perfect Information and Unconstrained Maximization

One of the key assumptions made by economists in this simple model of production is perfect information, which implies certainty. Economists assume that managers would not choose technologically inefficient combinations of inputs if the managers have perfect information regarding the production possibilities of their firm. Therefore, the assumption of perfect information implies that production functions are technologically efficient, that it is not possible to produce a particular level of output q by using less of one input and no more of another input. If information is perfect and costless, there is no reason to expect technological inefficiency (Binger and Hoffman, 1988).

In an unconstrained model, a profit-maximizing farmer will chose inputs and outputs in such a way as to achieve maximum profits. Because the production function for our farmer includes not only labor and capital but water as well, we can examine how changes in the price and availability of water impact the farmer's production, revenues and costs.

In this simple model without uncertainty, if using less water is consistent with the farmer's goal of profit maximization, then less water will be used. Our profit-maximizing farmer will make production decisions based on what occurs at the margin. She will vary those inputs that are under her control until her profits are as large as possible. This involves comparing the incremental (or marginal) profit obtained from producing an additional unit of q with the cost of the accompanying increase in input usage.

This can be shown by setting up a standard unconstrained optimization problem (Equation 5), taking the partial derivatives and setting them equal to zero to yield the following results:

$$\frac{\partial \pi}{\partial L} = P\frac{\partial f}{\partial L} - r_1 = 0 \qquad (6)$$

$$\frac{\partial \pi}{\partial W} = P\frac{\partial f}{\partial W} - r_2 = 0 \qquad (7)$$

$$\frac{\partial \pi}{\partial K} = P\frac{\partial f}{\partial K} - r_3 = 0 \qquad (8)$$

These first-order conditions tell us that a profit-maximizing farmer should hire each input up to the point where the marginal addition to revenues[11] is equal to the marginal cost incurred by hiring the additional unit of input (Binger and Hoffman, 1988). The partial of the production function with respect to each input represents the marginal product of the input. When multiplied by P, the price received for the output, this term becomes the value of marginal product (or VMP) of each input. Profit is maximized when the input's VMP equals the input's price.

If the price of the input water (r_2) changes, with all other variables fixed, the relationship between the price and the VMP also changes. This equality is restored by using less (more) of the input if the price increased (decreased), thus increasing (decreasing) the marginal product of the input:

$$r_2 = P\frac{\partial f}{\partial W} \tag{9}$$

where

$$P\,\frac{\partial f}{\partial W} = P\,MP_W = VMP_W \tag{10}$$

When the price of an input changes, the response of the irrigator will be to substitute other inputs. The direction of the substitution will depend on the relative price changes among the inputs. If, for example, water is the relatively

---

[11] The marginal addition to revenues is equal to the price of the output, P, multiplied by the marginal product of each input.

lowest-priced input, additional water will be substituted for higher-priced inputs. If the price of water increases relative to other inputs, substitutions of other inputs such as water-conserving but capital-intensive irrigation systems may be made.

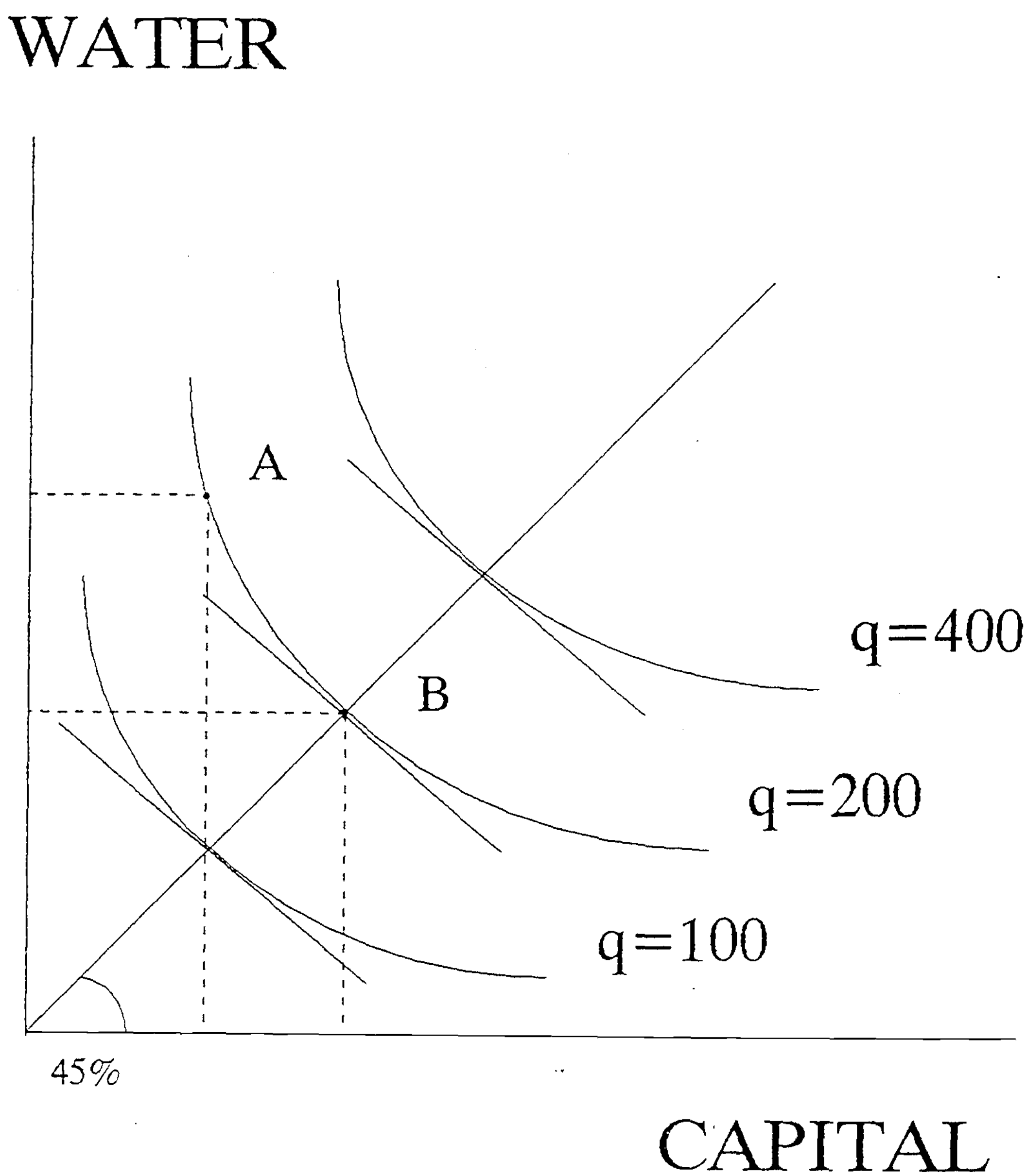
The various levels of production, q_i, can be represented graphically by isoquants (Figure 1). These show the alternative combinations of inputs that can be used to produce each level of output. Their slope illustrates potential substitutions between inputs while holding output constant along the isoquant. This rate of potential substitution is referred to as the marginal rate of technical substitution (RTS). The RTS is the inverse of the ratio of the marginal products of the inputs:

$$RTS = \frac{MP_2}{MP_1} = \frac{MP_K}{MP_W} \tag{11}$$

Because the farmer's production function in the simple model is assumed to reflect constant returns-to-scale, the ray through the origin represents points where the RTS is constant between the two inputs. Away from this ray, the rate of technical substitution is diminishing when moving from high ratios of the input on the vertical axis to the input on the horizontal axis. For example, when the MP_W is lower than the MP_K (point A), large amounts of water can be given up if another unit of capital becomes available (Nicholson, 1992). In moving from point A to point B, the MP_K decreases and the MP_W increases.

FIGURE 1

Production Isoquants and Input Substitutability



Imperfect Information and Constrained Maximization

Unfortunately, farmers live in a world of imperfect information regarding productive capabilities. This gives rise to uncertainty and introduces risk into a formerly risk-free model. Among the most important uncertainties introduced are the price and quantity of available labor or capital, as well as the revenue generated by the crop. All these factors will influence the use of water. This is now the case of constrained maximization with imperfect information. The farmer will attempt to maximize profit within the constraints imposed by input limitations, hampered by a lack of information about production possibilities and uncertainty regarding input and output prices.

The presence of uncertainty in the constrained model introduces the element of risk, an important influence in economic decisions. In this instance both the potential profit from the crop as well as the irrigator's attitude toward risk are important influences. The two issues must be balanced.

On one hand, the irrigator can increase whatever profit potential exists by controlling variable costs, in this case the frequency of irrigation. By irrigating her crop less frequently the irrigator can lower costs and increase profit. But on the other hand, by irrigating less frequently the irrigator runs the risk of stressing the crop and reducing the yield. If the costs of using more water are not as high as the perceived risk of lowering yield through less frequent irrigation, the risk-averse irrigator is likely to irrigate more frequently as a form of insurance and produce the maximum possible yield (Bosch and Eidman, 1987).

Risk-Reducing Inputs

Under certain conditions, inputs such as irrigation can be viewed as risk-reducing inputs, or as a form of insurance. Just and Pope (see Robison and Barry, 1987) derive a model with seven conditions to be satisfied in order for an input to be viewed as risk-reducing. In their model, the production function becomes:

$$q = f(x) + h(x)\epsilon$$

where x is the risk-reducing input, irrigation and h'(x) is a term relating the error term to the risk-reducing input. It is assumed that

$$f'(x) > 0 \;,\; f''(x) < 0,\; h'(x) \lesseqgtr 0$$

and that the error term epsilon is distributed normally.

$$\epsilon \sim (0, \sigma_\epsilon^2)$$

The seven conditions of the model with irrigation as a risk-reducing input are:

$$E(q) = f(x) > 0$$

$$\partial E(q)/\partial x_i > 0$$

$$\partial^2 E(q)/\partial x_i^2 < 0$$

$$\partial E(q)/\partial \sigma^2 \sigma_\epsilon^2 = 0$$

$$\partial \sigma^2(q)/\partial x_i \lesseqgtr 0$$

$$\partial \sigma^2(\partial q/\partial x_i)/\partial x_i \lesseqgtr 0$$

The seventh condition is that the production function, f(x), exhibit constant stochastic returns to scale, an assumption made earlier in this chapter.

The first two conditions, positive output and positive marginal product for irrigation, are met through the initial assumption regarding the positive value of first derivative.

The third condition, diminishing marginal productivity, is met by the second of Just and Pope's initial assumptions; if the sign of the second derivative is negative, the slope of the function is decreasing.

In order to prove that the fourth and fifth conditions are satisfied, the variance of q must be calculated.

$$\sigma^2(q) = E[f\ (x) + h(x)\epsilon - f\ (x)]^2 = [h(x)]^2\sigma_\epsilon^2$$

Differentiating this with respect to irrigation, we get:

$$\partial \sigma^2(q)/\partial x = 2\ h(x)h'(x)\sigma_\epsilon^2$$

Our initial assumption regarding the sign of h'(x) means that this satisfies condition five, that the change in variance associated with a change in the input is not constant in sign. A ratio of this equation and

$$\partial E(q)/\partial x = f'(x)$$

gives the following expression:

$$\partial E(q)/\partial\sigma^2(q) = f'(x)/2h(x)h'(x)\sigma_\epsilon^2$$

Again, our initial assumption regarding the sign of h'(x) allows us to satisfy condition four, that expected output can be held constant while reducing the variance of the random component.

Condition six can also be satisfied based on the assumption regarding h'(x) and on the lack of information regarding the sign of h''(x). The initial assumption of a constant returns-to-scale production function ensures that condition seven is met for this model.

By satisfying all of the assumed conditions in the proof outlined above, this model meets Just and Pope's criteria for a risk-reducing input. Thus we can argue that irrigation can be used by the irrigator as a form of insurance and that overirrigation might result from an irrigator's response to risk.

The irrigator's attitude toward risk is also important because a risk-averse irrigator is unlikely to implement system changes without first gaining information that these changes will be productive. Moving from less efficient to more efficient irrigation systems involves less labor but more capital investment; the returns may not be as large or as well documented as a risk-avoiding irrigator would wish.

Risk and Information

Farmers may not have full and certain information on their production capabilities or on the exact nature of input substitutability. The farmer's knowledge of both the technical and economic aspects of her operation depends upon the success of her search for information. The basis of the diffusion model discussed in Chapter Two is that access to the information regarding a particular technology is the principle stimulus leading to adoption. The farmer's acquisition of this information reduces the uncertainty and the level of risk, and it generally leads to a decision regarding adoption.

This search for information under uncertainty involves the issue of allocative ability and human capital. The human capital literature considers allocative ability to be how people "perceive changes and respond to changes in economic conditions" (Huffman, 1977, p.59). It hypothesizes that allocative ability is acquired through education and the seeking of information. A farmer's allocative ability, for example, might involve correctly choosing a mix of inputs that will produce a profit-maximizing level of output under conditions of uncertainty. This requires correctly judging the economic and production conditions and making management decisions accordingly. Thus, with imperfect information, farmers who seek out information through education, experience, or some other means are improving their allocative ability. They should respond better to uncertainty and be better able to allocate efficiently productive inputs including water (Huffman, 1977).

The search for information will also serve to reduce some of the uncertainty and resultant risk for the farmer. Improved allocative ability of the farmer enables her to evaluate and make better decisions under uncertainty. As a consequence, farmers with more information should have less risk than those without, all other things equal. The farmers with more information have improved their allocative ability and are better able to make risky decisions under uncertainty. This is true whether the farmers are risk-averse or not. Additionally, Bosch and Eidman (1987) found that the value of information increases with the level of risk aversion of the individual.

Maximization with Constrained Inputs

Economic constraints may prevent farmers from adopting practices that they might otherwise embrace. Farmers may wish to adopt a technology or innovation once they become aware of it, but they may be precluded from doing so because of input constraints (Hooks, Napier and Carter, 1983). Arising out of scarcity, these economic constraints can involve capital, labor, or water.

As an example, a farmer may decide that the installation of water-conserving irrigation systems is a sound economic decision for the farm, but she may be unable to purchase or install the system because of capital constraints. Irrigation systems are generally capital-intensive. The least-costly system of irrigation is the open ditch, which is also the most inefficient in conserving water (Caswell and Zilberman, 1985). Sprinklers are more efficient than unlined open ditches, but they are also more expensive[12]. Farmers operate within some constraints; they may be able to substitute water for capital if water is available and capital is not. Thus, inefficiency in water use may be a profit-maximizing decision for the farmer within certain constraints.

Similarly, a constraint such as scarcity of labor may force a farmer to delay changing irrigation sets. This may occur because low-cost labor is unavailable or because of off-farm labor by the principal irrigator. In either case the result is the same. The delay in changing irrigation sets may lead to overwatering one area of the field or one entire field. Eliminating overwatering not only saves water but reduces irrigation costs. The pumps that are the most common means of moving irrigation water from its source to the field are electrically powered. Energy used in overwatering is a wasted cost for the farmer. If a farmer is overwatering, she is paying a higher electric bill than is actually required. Not surprisingly, groundwater irrigators are more likely than their surface water counterparts to adopt modern irrigation technologies (Caswell and Zilberman, 1985). Because groundwater irrigation generally involves more extensive pumping, the pumping costs should accordingly be higher for these irrigators. Conservation of irrigation water through the implementation of modern irrigation technologies would mean that less water needed to be pumped, thus reducing pumping costs to the irrigator.

[12] Data obtained from irrigation equipment business owners in central Oregon.

Surface water generally requires less pumping than groundwater. As a result, it is generally a relatively low-cost input and can be substituted when cost or availability constrains the use of labor or capital. Where water is the constrained input, the other inputs could be substituted within the biological limits of the crop. In this case, capital and labor are imperfect substitutes. The magnitude of the various substitutions would be determined by the relative prices of the inputs and the rate of technical substitution. As water increases in scarcity, both its increasing price and its decreasing availability work to reduce its role as an input of production.

Clearly, economic analysis has important contributions for this study. In all but the most rudimentary economic models several factors - input scarcity, imperfect information and risk - all hamper a profit-maximizing irrigator in reaching the optimal solution. This implies that the important economic influences on the irrigation efficiency of a profit-maximizing irrigator are her attitude toward risk, her level of information, and the relative scarcity of inputs of production, all of which must be reflected in the choice of predictor variables for this study.

CHAPTER FOUR
ECONOMETRIC MODEL

Several important influences on irrigator behavior were consistently suggested by the literature that was reviewed in the two previous chapters. Consequently these influences were chosen as predictor variables for an econometric model. This model develops a dependent variable, relative irrigation efficiency, using these previously identified influences as predictor variables. The values of the predictor variables were constructed with data from a sample of Willamette Valley irrigators.

The model is as follows: **(12)**

$$Y = \beta_0 CROP + \beta_1 AGE + \beta_2 ED + \beta_3 INC + \beta_4 OWN + \beta_5 SIZE + \beta_6 LABON$$

$$+ \beta_7 LABOFF + \beta_8 WAGES + \beta_9 PWRCST + \beta_{10} CHILD + \beta_{11} KNOWLAW$$

$$+ \beta_{12} KNOWCERT + \beta_{13} RISK + \beta_{14} GENEFF + \beta_{15} H2OCAP$$

$$+ \beta_{16} SOIL + \beta_{17} EXPECT + \alpha_1 \hat{ATT} + u_1$$

where Y, the dependent variable, is an index of relative irrigation efficiency to be calculated by a method outlined later in the chapter. ATT represents an endogenous variable which is the predicted value of irrigator attitudes.

Values of the endogenous variable on the right hand side, irrigator attitudes, were determined by the following equation:

$$\hat{ATT} = \gamma_1 AGE + \gamma_2 ED + \gamma_3 KNOWLAW + \gamma_4 EXP + \epsilon_1 \tag{13}$$

where

$$ATT = \sum (ATTOR + ATTNAT + ATTGEN) \tag{14}$$

The 22 independent variables from equations 12, 13 and 14 are discussed in detail at the end of this chapter and defined in Appendix A.

The equations above represent a standard two-stage least squares (2SLS) regression, with the predicted value of attitudes from equation (13) used to replace the actual value of the endogenous variable, attitudes, in equation (12) in the final OLS regression procedure.

Two-Stage Least Squares

One of the important assumptions of the classical linear model (CLM) is that the predictor variables are independent of the error terms and can be considered fixed (or stochastic) in repeated samples. Simultaneous equations violate this assumption because the endogenous variable is random, not stochastic. A change in the error term affects the endogenous variable and thus influences all the other simultaneously-determined endogenous variables as well. Instead of being independent, the endogenous variables are correlated with the disturbance terms in all equations of the model. The OLS estimator is biased and inappropriate, and an alternative must be found (Kennedy, 1993). This is even a problem in a simple system such as equations 12 and 13, with only one endogenous variable.

One common method of circumventing this bias is 2SLS. This mitigates the problem of correlation between the endogenous variable and the error term. The reduced-form regression equation (13) yields estimated values for attitudes that are less correlated with the error term than were the original values (Johnston, 1984). These newly-predicted values replace the corresponding endogenous variables in equation (12). This procedure is known as two-stage least squares because OLS is used in two stages; first, to estimate the predicted value of the endogenous variable with a reduced form regression equation [equation (13)]; second, to estimate the full equation (12) with the endogenous variable replaced by its predicted value.

The Dependent Variable: An Index of Relative Irrigation Efficiency

An index of relative irrigation efficiency was created by using the numerator and denominator outlined below. This index is the dependent variable in the econometric model. The index is a ratio of total crop water requirements (evapotranspiration[13]) to the sum of rainfall and irrigation water applied to the

[13] Evapotranspiration (ET) is a measure of water transferred from the earth's surface to the atmosphere through evaporation from the soil and plant surface and water transpired by the plants (ASCE 70, 1990). ET is used by agronomists as a measurement of the water needed by crops in order to survive and grow.

crop during the 1993 irrigation season. The closer the index is to one, the more closely the applied water matches the needs of the crop. The index can take on any positive value.

$$INDEX = Seasonal\ ET / Water\ Applied \geq 1 \qquad \textbf{(15)}$$

Values greater than one would mean that the crop was receiving an amount of water that was less than the actual evapotranspiration needs of the crop. Values less than one would mean that the crop was receiving more water than its evapotranspiration needs required. A ratio of one would mean that the crop was receiving exactly the amount of rainfall and irrigation equal to its evapotranspiration needs.

Irrigation Efficiency

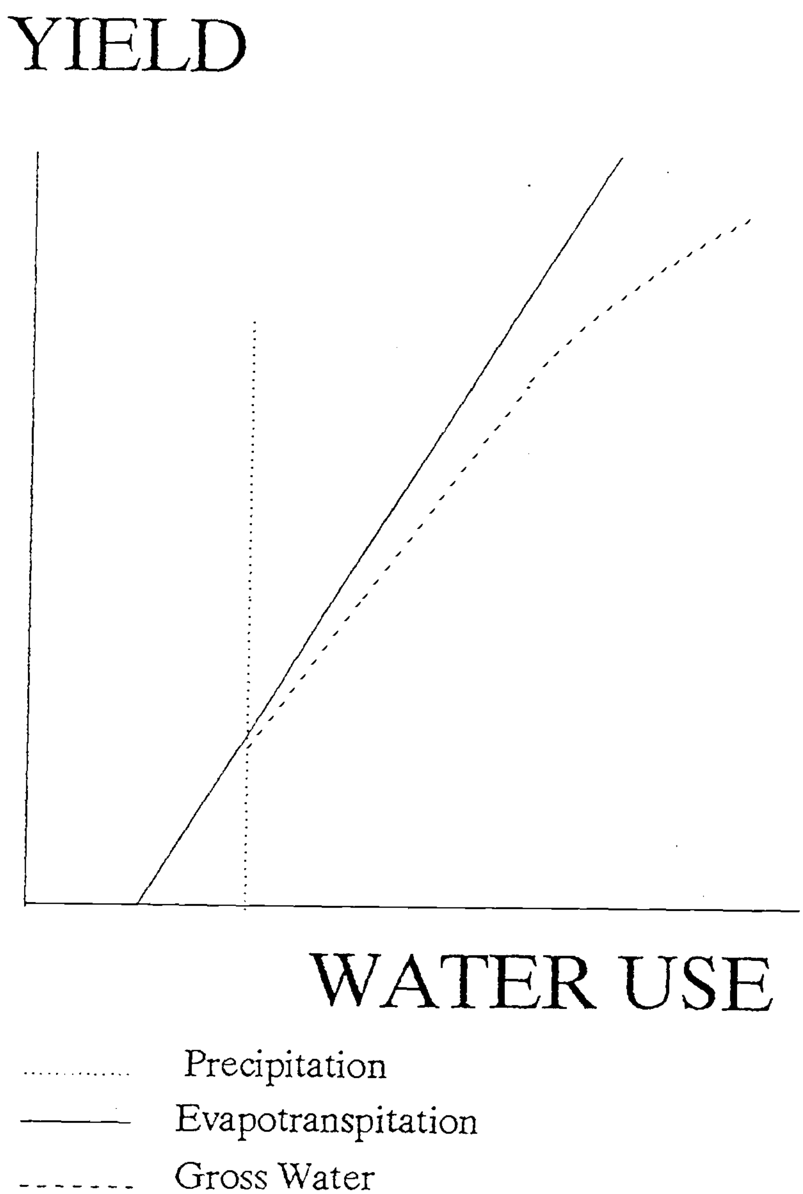
This index of relative irrigation efficiency is similar to a basic model of irrigation application efficiency as defined by English et al (1986):

$$Eapp = \sum \left(\frac{Water\ depletion}{Water\ delivered}\right) \qquad \textbf{(16)}$$

Although there are many definitions of efficiency in irrigation engineering, most of them are similar to the definition of application efficiency above (English *et al*, 1986; Whittlesey, 1986). In comparing our study's efficiency index with equation 16, English's measure of water depletion is similar to our study's seasonal ET, and water delivered is similar to water applied. Because the information available in

FIGURE 2

Relationship Between Yield and Efficiency



From English et al, 1986.

the survey here does not include the date of crop emergence, the antecedent water (water in the soil previous to irrigation), or the harvest date of the crop, the dependent variable is not an absolute measure of irrigation efficiency. It does, however, incorporate measures of both evapotranspiration and water applied to yield an estimate of relative irrigation efficiency.

The concept underlying efficiency in water use is demonstrated in Figure 2 (English *et al*, 1986). The solid line represents the linear relationship between yield and evapotranspiration. The dotted lines represent precipitation and gross water applied to the crop through irrigation. At low levels of yield, evapotranspiration needs of the crop can be met by precipitation (English *et al*, 1986). If precipitation is inadequate to meet the crop water requirements, irrigation applications should occur. When irrigation applications are relatively light, gross water and evapotranspiration are close to each other. Low amounts of irrigation are less likely to generate runoff or percolate below the root zone of the crop. At this point the narrow gap between the two functions is primarily due to spray losses from heat-induced evaporation and wind drift. As the amount applied increases, the two functions begin to diverge. This is due to the additional factors of surface runoff and deep percolation. The horizontal gap between the ET line and the gross water curve can be viewed as a measure of irrigation inefficiency.

The graphical relationship demonstrates that achieving maximum yield levels requires more frequent and more thorough irrigations to maximize yield across the entire field. These heavier and more frequent irrigations increase water losses; thus the relationship between yield and efficiency is a negative one. The gap between the functions will moderate with weather conditions, various soil types, across crops with differing ET needs, and for different types of irrigation systems. The essence of the relationship, however, will remain unchanged.

The Numerator

The procedure for calculating the index of relative irrigation efficiency is outlined below. First, the actual crop-water requirements for each month were summed from base evapotranspiration tables specific to the geographic region and calculated for a reference crop, either grass or alfalfa. The base ET data tables were measured by Agrimet stations in Forest Grove and Corvallis. The unit of measure is tenths of an inch. The Forest Grove measurements were used as a base for calculations for Marion county; the Corvallis data were used for Linn and Benton counties.

For example, if a representative farmer from Marion county had an irrigation season that began June 1 and ended August 30, the numerator for this farmer used the Marion county base data and were carried out for each month from June through August. The base ET for July was measured: **(17)**

$$JULY\ Crop\ H2O\ Needs = \Sigma\, ET\ (\ JULY\ 1 + 2 + \ldots + JULY\ 31)$$

or numerically

$$5.214 = \Sigma (.15 + .21 + . . . + .24)$$

The monthly summations were then multiplied by a number specific to each different crop, known as the crop coefficient. This is necessary in order to "customize" the base data to the particular crop under consideration. The same reference crop should be used to develop the crop coefficient as was used for the reference evapotranspiration. In this case, alfalfa was used as the reference crop for both. The crop coefficients were calculated on a monthly basis by using historical ET data on mint and vegetable crops in the Willamette Valley (Extension 8530, 1992). The same crop coefficients were used for all three counties. This information was used to calculate monthly crop coefficients for mint, peas, and sweet corn. For example, if our representative Marion county irrigator was growing mint, the crop coefficient for mint in July was:

$$Crop\ Coeff = \frac{Mint\ \ ET}{Alfalfa\ ET} \qquad \textbf{(18)}$$

or numerically

$$.86 = 120\ inches/139\ inches$$

This coefficient was multiplied by the number in equation 17 in order to calculate the actual ET needs for mint in July. This process was repeated for each month or part of the month included in the irrigation season for the particular irrigator, in this case, June through August.

TABLE 1

Monthly Evapotranspiration in Inches for the Willamette Valley

	April	May	June	July	Aug.	Sept.	Oct.
Beans	–	0.20	3.03	4.29	–	–	–
Field Corn	–	0.04	1.02	5.91	5.00	0.94	-
Sweet Corn	-	0.12	2.13	6.38	5.08	0.87	-
Peas	0.20	2.13	1.46	-	-	-	-
Tomatoes	-	0.12	2.83	6.57	2.64	-	-
Mint	0.08	2.01	3.70	4.37	2.245	3.43	2.13

From Extension Miscellaneous: 8530, 1992.

The coefficients for vegetables were calculated by using peas as a proxy for the early season vegetable crop (March through May) and sweet corn for the latter half of the growing season (June through September). Among the vegetable crops commonly grown in the Willamette Valley, peas have a lower ET rate than do most early season crops; sweet corn has a middle to high ET rate among late season crops (see Table 1).

After each summation of monthly ET was multiplied by the appropriate crop coefficient, the totals for the irrigator's irrigation season were added to yield the seasonal ET for the specific crop and region. This number became the numerator in the index of relative irrigation efficiency.

The Denominator

The denominator, gross water applied, is an approximation derived by using data supplied by the irrigator. These data include length of irrigation season, number of irrigation sets each month[14], and the length of time of each set. These were used to create a monthly total of hours irrigated. Our Marion county mint farmer irrigated four times during July (four irrigation sets); each set lasted six hours. Therefore, the total number of hours irrigated during the month of July is calculated as:

---

[14] Each time an irrigator begins to irrigate a field, this is known as a "set".

$$JULY\ Hours = JULY\ Sets \times Hours\ per\ Set \qquad \textbf{(19)}$$

or numerically

$$24\ hours = 4\ sets \times 6\ hours/set$$

Data on nozzle size and nozzle pressure (gallons per minute) were used to approximate the amount applied in inches per hour. This amount was then multiplied by hours irrigated for the month to derive an estimate of inches of irrigation water applied during a month. The amount applied by our mint irrigator was .22 inches/hour; thus, the total amount of water applied during July was calculated as:

$$JULY\ Total = JULY\ Applied \times JULY\ Hours \qquad \textbf{(20)}$$

or numerically

$$5.28\ inches = .22\ inches/hour \times 24\ hours$$

Adding the monthly totals across the length of the irrigation season created the seasonal total. Rainfall for the same period was added to the seasonal total to form gross water applied; this became the denominator in the index of relative irrigation efficiency.

$$Gross\ H2O\ Applied = Rain + \Sigma\ Monthly\ Totals \qquad \textbf{(21)}$$

or numerically

$$15.12279 = 1.55 + 13.57279$$

The index of relative irrigation efficiency is listed for each irrigator in Appendix F.

The Predictor Variables

An exhaustive literature review (Chapters Two and Three) identified 20 key variables that may influence irrigation efficiency. The expected signs for the coefficients of these predictor variables are explored below. A detailed description of the definitions and measurement procedures for the predictor variables is located in Appendix A.

Variables Related to the Individual

AGE is included as a predictor variable because younger irrigators may be more conservation-oriented and less set in their ways with regard to traditional irrigation practices. This may be due to both generational differences in experiences during formative years and to influences on beliefs from exposure to differing scientific information (Stern *et al*, 1993). Perhaps the beliefs might be those regarding water scarcity and environmental protection. The expected sign on the parameter is negative; the literature has found that older irrigators are less efficient than younger irrigators (Ervin and Ervin, 1982; Kreutzwiser and

Peitraszko, 1986; Jones and Dunlap, 1992). Increases in the value of the AGE variable would reflect decreasing irrigation efficiency.

The hypothesized relationship between relative irrigation efficiency and EDUC (education) is positive. Both the environmental sociology and soil conservation literature suggest that more educated irrigators are likely to be more efficient in their adoption and application of conservation practices (Marsh and Coleman, 1955; Carlson *et al*, 1977; Huffman, 1977; Ervin and Ervin, 1982; Rahm and Huffman, 1984; Jones and Dunlap, 1992).

EXP (years of irrigation experience) is hypothesized to have a positive relationship with the dependent variable in both the equation predicting the value of attitudes, (ATT) and the equation predicting relative irrigation efficiency. Intuitively, the more years that farmers have worked with irrigation, the more efficient they should become. In the literature, however, the effects of experience on adoption of conservation practices is not so clear cut (Pampel and van Es, 1977; Huffman, 1977; Rahm and Huffman, 1984). Dinar and Yaron (1990) suggest that this contradiction could arise out of the correlation of increased experience with increased age. Age, as mentioned earlier, is expected to be negatively related to adoption of conservation practices. Rahm and Huffman (1984) conclude that the relationship of EXP with adoption is uncertain. Due to this uncertainty within the literature, EXP is hypothesized to directly affect ATT and thus to indirectly affect the relative efficiency index. EXP is not used in the main regression equation, however, due to expected problems of multicollinearity with the predicted value of attitudes, pATT.

The relationship between RISK and relative irrigation efficiency should be positive (Ervin and Ervin, 1982; Buttel *et al*, 1990; Ardila and Innes, 1992). A higher value for the RISK variable indicates a less risk-averse individual. Risk-averse farmers may be more reluctant to invest in efficient irrigation technologies with uncertain outcomes because of imperfect information. They do not have the same attitude toward conservation that less risk-averse farmers do (Lynne *et al*, 1988). They are also more likely to overirrigate their crop to negate risk of underirrigation, something which might reduce yield (Bosch and Eidman, 1987).

The KNOWLAW variable is a measure of an irrigator's knowledge of four specific aspects of Oregon water law. The variable should be positively related to both the relative efficiency index and the predicted value of attitudes (pATT). This assumption is supported by the human capital literature, which maintains that information and education reduce a farmer's uncertainty, decreases risk, and increases her ability to make efficient resource allocation decisions (Huffman, 1977).

The KNOWCERT variable indicates whether an irrigator knows the maximum amount of diversion allowed by her water right certificate in either cubic feet per second (cfs) or gallons per minute (gpm). The relationship with relative irrigation efficiency should be positive. This variable is again motivated by the literature on human capital and allocative ability (Huffman, 1977). The additional information reduces uncertainty and hence the risk-aversion level of the irrigator.

H2OCAP measures whether an irrigator could answer a specific question about the available water-holding capacity of their soil. This is an important number for efficient irrigation because the need for irrigation is dependent on soil type as well as slope, salinity and soil depth. Water capacity figures are available to farmers from irrigation scheduling companies and extension agents. Irrigators who are committed to conservation practices would likely know this number; thus, it should be positively related to the dependent variable.

The pATT (predicted attitudes) variable is the predicted value from an econometric regression of AGE, education (ED), years of irrigation experience (EXP) and KNOWLAW on irrigator attitudes (ATT). The ATT variable is a summation of the three attitudinal questions in the survey: the national benchmark question (ATTNAT), the Oregon benchmark question (ATTOR), and a more general attitudinal question (ATTGEN). These are defined in Appendix A. Because farmers' attitudes have been slow to influence the adoption of conservation practices (Carlson *et al*, 1977; Buttel *et al*, 1990), predicted attitudes (pATT) should be positively related to relative irrigation efficiency.

Family ownership of farms (OWN) is a yes/no question derived from the environmental sociology literature (Marsh and Coleman, 1955; Kreutzwiser and Pietraszko, 1986). The hypothesized relationship is positive; family ownership implies better stewardship and ties to the land, thus making efficient conservation practices more attractive.

The CHILD variable is a measure of whether the irrigator plans to transfer the farm to a child at some point in time. It may serve as a proxy for a farmer's discount rate, as suggested by Ervin and Ervin (1982). They suggest that a farmer's intent to transfer the operation to a child indicates that the farmer uses a lower discount rate and thus a longer planning period. High discount rates are generally associated with short planning horizons, while low discount rates are associated with longer planning horizons. CHILD should be positively related to relative efficiency because the irrigator's lower discount rate makes an initial conservation investment for a long-run payoff more attractive than it would be in a short-run framework (Lee, 1980; Ervin and Ervin, 1982; Lovejoy and Napier, 1986).

Variables Related to the Farm

According to the literature, a positive relationship should exist between INC (income) and relative irrigation efficiency because farms with a higher after-tax income are less constrained in purchasing more efficient and sometimes expensive irrigation systems (Carlson *et al*, 1977; Kreutzwiser and Pietraszko, 1986; Ervin and Ervin, 1982; Buttel *et al*, 1990). Greater access to financial resources also increases the ability to adopt innovations (Nowak, 1987).

Similarly, larger farms (SIZE) may be efficient in their irrigation practices. Results in the literature suggest that larger farms generally have a higher level of income (Marsh and Coleman, 1955; Buttel *et al*, 1990). It is also possible that they have a greater ability to purchase efficient irrigation systems (Carlson *et al*, 1977), as well as receiving a higher net return per acre from adoption of soil conservation practices (Rahm and Huffman, 1984). Larger farms have potential for greater access to financial resources; they also have more ability to diversify and reduce the risk and uncertainty associated with innovations (Nowak, 1987). This implies a high degree of correlation between SIZE and INC, which creates a potential problem with multicollinearity. If the two variables are too highly correlated, the effects will be inseparable. One variable may have to be dropped from the empirical model.

The power cost (PWRCST) variable represents the cost of electricity for irrigating the representative field during the 1993 season, exclusive of demand charges or annual fees. The PWRCST coefficient should be positively related to the dependent variable, irrigation efficiency. As the cost of electricity increases, power-intensive irrigation, such as that involving the pumping of groundwater (common in the Willamette Valley) should respond by decreasing demand for this input (Caswell and Zilberman, 1985). One method of cutting back is by practicing more efficient irrigation, thus lessening the total amount of water to be pumped.

The LABON variable represents total hours of on-farm labor by the principal farm operator, the spouse/partner, and one other adult over the season, adjusted to a per-acre basis. The LABOFF variable represents total hours of off-farm labor for the same individuals over the season, adjusted to a per-acre basis. WAGES represents the per-acre costs for non-principal labor for the farm during the season, i.e. the per-acre intensity of labor. The signs of the LABON and WAGES coefficients should be positively related to irrigation efficiency due to the types of irrigation examined in this survey, that is, solid set, hand line and side roll. Each of these systems requires more labor than do center pivot or big gun sprinkler systems. Because the irrigation systems in this survey are labor-intensive, farms with more available labor (and therefore a higher unit intensity of labor as represented by WAGES) are more likely to practice more efficient irrigation. WAGES also represents the labor in the production function. Input substitution between labor and water may imply that if more labor is available, less water will need to be used.

The sign of the LABOFF variable might be positively related to the dependent variable because labor used off-farm indicates supplemental income for financing conservation practices. However, it might be negatively related to the dependent variable because time spent working off-farm is time that the principals do not have to change an irrigation set. The sign is thus indeterminate.

Other Variables

CROP is a dummy variable for the type of crop grown by the irrigator, in this case mint. Anecdotally, mint is considered to be an overirrigated crop in the

Willamette Valley; it is postulated here to have a negative relationship with relative irrigation efficiency.

GENEFF (general efficiency) is the sum of three conservation measures that an irrigator could implement at a relatively low cost with her existing irrigation system. These measures include practicing offset[15], installation of a timer on the sprinkler system, and replacing the sprinkler nozzles every one to two years. Irrigators who implement these conservation measures should be more efficient; thus, GENEFF will be positively related to the dependent variable.

The efficiency of sprinkler irrigation also depends on physical characteristics such as soil texture, as measured by SOIL. Irrigators farming on land that has a low water-holding capacity (sandy soils) are more likely than those farming high water-holding capacity (clay) soils to switch to sprinkler irrigation which is a water conserving practice (Rahm and Huffman, 1984; Caswell and Zilberman, 1985; Negri and Brooks, 1990). Soils with a low water-holding capacity hold less water in the root zone area for the use of the plant; they also drain more rapidly, forcing more frequent irrigations (Table 2). The expected sign of SOIL is positive.

The EXPECT (expectations) variable is related to the irrigator's early season expectations regarding the condition of the water source later in the

---

[15] Offset involves installing a flexible extension from the lateral at the head of the row; moving this extension allows irrigation of alternate "rows" every other set.

TABLE 2

Available Water Holding Capacities for Various Soil Types

SOIL TYPE	RANGE mm water/m soil	AVERAGE mm/m
COARSE SAND	50 - 70	60
FINE SAND	75 - 95	85
LOAMY SAND	90 - 110	100
SANDY LOAM	105 - 125	115
FINE SANDY LOAM	120 - 140	130
VERY FINE SANDY LOAM	130 - 150	140
CLAY AND CLAY LOAM	120 - 180	150
SILT LOAM	160 - 210	185
PEATS AND MUCKS	160 - 250	210

From Hoffman et al, 1990.

season. The relationship to the dependent variable is indeterminate because it depends on the soil type. An irrigator who is expecting her water source to dry up or produce less later in the summer may heavily irrigate a clay soil field, thinking that the high water-holding capacity of the clay would retain the moisture through much of the dry season. An irrigator expecting a dry season, but having a field with low water-holding capacity sandy soil may irrigate less now, hoping to save some of the water until later.

Though these 20 variables are not definitive, a complete analysis of all variables relevant to irrigation efficiency and the adoption of conservation practices is beyond the scope of this study. These predictor variables do, however, cover the key influences as discussed in the relevant literature. The next step was to collect data on these variables through a field survey. This process, and the distribution and response to the survey itself, are detailed in Chapter Five.

CHAPTER FIVE
SURVEY METHODS

Initially this study was intended to focus on the relative efficiency of sprinkler, center pivot and big gun irrigation near the towns of Bend and Redmond in central Oregon. Irrigation in that area is routed through irrigation districts. The irrigation district as an organization usually holds the water rights; members contract for their irrigation water from the irrigation district. Unfortunately the focus of this study, relative irrigation efficiency, was politically sensitive and the leaders of the local irrigation districts, while cooperative and helpful, felt unable to endorse the distribution of any surveys to their members.

The study was then moved to the central Willamette Valley where farmers do not contract their water through irrigation districts, but divert it from existing streams or, more commonly, pump it from wells. Mint and vegetable crops were recommended as common irrigated crops in the Willamette Valley[16]; growers of these crops were selected for our sample of irrigators.

The survey as originally planned included face-to-face interviews with approximately 40 irrigators. The interviewers were to be graduate students from Oregon State University. It was determined that the sample size should be increased from 40 to several hundred irrigators, and that a mail survey would be the most economical way to collect data.

---

[16] Conversation with Bob Rackham, Benton County Extension Agent.

Questionnaire Design

The survey questions were written primarily by the author with the exception of the question regarding risk and the questions on which the ATTOR and ATTNAT variables were based. The latter variables were based on questions that attempt to measure the pro-business or pro-environment attitudes of the irrigators in this study. The questionnaire (See Appendix G) had two main sections: farm characteristics and irrigator characteristics. The questions regarding farm characteristics were used in calculating the dependent variable: relative irrigation efficiency. These questions were written with the assistance of irrigators and irrigation engineers. They covered a range of technical information such as the horsepower of the pump and the nozzle sizes of the sprinklers used to irrigate a particular field. The choice of the field that the irrigator was to use when answering the technical questions was difficult to determine. There were several choices: the field closest to the farmhouse, the field in a particular location, or the largest field growing either mint or vegetables. The latter method of field choice was the one selected by the author as being the simplest and least biased.

The demographic questions concerned the predictor variables that were identified in Chapter Two. These are age, education level, years of experience both as an irrigator and on the farm currently occupied, farm income, labor costs, children present, length of family ownership of the farm, knowledge of Oregon water law, attitudes towards risk and attitudes towards environmental protection and economic growth.

The final design and layout of the questionnaire was done with expert assistance from Pamela Bodenroeder, a senior research assistant with the Survey Resource Center at Oregon State University. She has extensive experience with survey design and is spoken of in hushed tones of reverence by those who have worked with her.

Questionnaire Mailing and Follow-up

The questionnaire and cover letter were closely modeled on the total design method that has been developed by Don A. Dillman of Washington State University (Dillman, 1978). The mailing of the questionnaire and the follow-up postcard, with a few necessary modifications, proceeded along the same guidelines.

The sample consisted of 456 individuals who were listed as vegetable and mint growers in Linn, Benton and Marion counties. These lists were provided by the three county extension offices; they promised to be the best available sources of addresses for mint and vegetable growers. The questionnaire was pretested by mail among a group of ten mint and ten vegetable growers selected at random from these lists. The pretest response rate was 55%, with no major problems indicated other than the excessive length of the questionnaire.

The initial mailing of the final version consisted of the questionnaire, a pre-stamped and addressed return envelope, and a cover letter signed by the three county extension agents, the project director, and the author. These items were mailed to the entire 456 people in the population. One week after the initial mailing, follow-up postcard reminders were mailed to all those who had not returned their questionnaires. Two weeks after the postcard reminders were sent, phone calls were initiated to a random sample of fifty non-respondents to determine non-response bias. This differs from the Dillman method, which recommends several follow-up letters before making phone calls. Due to the outdated lists from which we were working, the potential returns from additional mailings did not seem to be sufficiently large to outweigh the increase in additional mailing costs.

The questionnaire itself included filter questions that eliminated non-mint or vegetable growers and irrigators who did not use solid set, handline or side roll irrigation systems. This was accomplished by asking irrigators whether they grew mint or vegetables and whether or not they used a handline, side roll or a solid set irrigation system. The limitation by method of irrigation was dictated by the length of the questionnaire. Big gun and center pivot irrigators were eliminated from the sample. Including them would have added additional pages to a 12-page questionnaire and would have reduced the response rate.

Survey Response

Responses began to be received immediately and trickled in for several weeks. Unfortunately, many of those on the lists had incorrect addresses, had retired or died, or were not farmers at all. There was also some overlap between the mint and vegetable grower lists because of the frequency of growers who rotate these two crops. Mint can only be grown a few years at a time before it must be rotated out of the field for disease prevention. Mint fields are frequently rotated with row crops such as vegetables. By choosing both mint and vegetables, we get some of the same growers in various stages of the mint-vegetable-mint rotation.

Of the 456 surveys mailed out, 247 responses were received by Oregon State University. These 247 responses included 207 surveys returned through the mail, 21 telephone calls and 19 postal notifications of incorrect addresses. The apparent number of non-respondents, therefore, was 209. The apparent response rate to the survey was 54%.

TABLE 3

Survey Response and Non-Response

Respondents	247
Non-Respondents	209
Total Surveys Mailed	456

TABLE 4

Ineligible Responses Received

Growing Crop Other Than Mint or Vegetable	38
Non-farmer or Consultant	22
Retired	19
Incorrect Address	19
Survey Returned Completely Blank (assumed ineligible)	18
Big Gun or Center Pivot System	16
Two Surveys Sent To Same Person	4
Deceased	3
Wrong County	1
Total Ineligible Responses Received	140

The 247 responses were separated into eligible and ineligible responses. An eligible response was one in which the respondent was currently farming either mint or vegetables and using a handline, side roll or solid set irrigation system. Ineligible responses included those not eligible for one of the reasons above, those with incorrect addresses or duplicate mailings, or those who were deceased or retired. The breakdown of the ineligible responses is listed in Table 4. The final total of ineligible responses was 140. Of the 207 surveys returned through the mail, 107 were from eligible respondents. However, 14 of these surveys lacked key information, leaving a final tally of 93 usable surveys. Usable means not just that the respondent was eligible, but that all key technical questions were answered as well.

Sample of Non-Respondents

From the sample of the 209 non-respondents, we attempted to contact 50 by phone to determine non-response bias and to learn approximately what percentage were eligible. The questions asked were:

a.) Are you a grower?

b.) Acres of mint/vegetables?

c.) Type of irrigation system used?

d.) Years operating farm?

The results are noted in Table 5. Of the 33 non-respondents who could be reached by phone, 22 were eligible: the 17 who met the criteria but had not responded to the mail survey and the five who sent in the survey after phone contact. Using this breakdown, the percentage of non-respondents who were eligible to participate is 67%. This information was used to calculate an adjusted response rate. The process is outlined below.

TABLE 5

Results From Phone Survey of Non-respondents

Could Not be Reached by Phone	17
Met Criteria but did not Respond to Mail Survey	17
Survey sent in after Phone Contact	5
Incorrectly Listed as Growers	11
Total Non-respondents Surveyed	50

Adjusted Response Rate

Calculation of an adjusted response rate is necessary due to the out-of-date nature of the lists of growers. It can be calculated as the ratio of eligible responses received to the sum of eligible responses and eligible non-responses. It removes from the calculation those who were ineligible: those incorrectly listed as farmers, growing the wrong crop, using the wrong irrigation system, retired, deceased or with incorrect addresses. Considering the number of non-responses to be 209 (Table 3), we used the percentage of eligible non-respondents calculated from the bias sample (see Table 6) to separate the eligible and ineligible among the 209 non-responses.

TABLE 6

Eligible and Ineligible Respondents

	ELIGIBLE	INELIGIBLE	SUM
RESPONSE	Eligible Responses Received = 107	Ineligible Responses Received = 140	Total Responses Received = 247
NON-RESPONSE	Eligible Non-respondents = 140 (67% of 209)	Ineligible Non-respondents = 69 (33% of 209)	Total Non-responses = 209
SURVEY TOTAL	TOTAL ELIGIBLE = 247	TOTAL INELIGIBLE = 209	TOTAL = 456

The number of eligible responses received (107) is the total of the 93 usable surveys and the 14 surveys that lacked key information. The total number of eligible non-respondents, on the other hand, is 140 (67% of the 209 apparent non-respondents). The adjusted response rate is thus:

$$107/107 + 140 = \frac{107}{247} = 43\%$$

Non-response Bias

Of the fifty non-respondents contacted, those reached by telephone (see Table 5) were primarily vegetable growers who used handlines to irrigate their crops. The mean and variance of their years of irrigation experience and acres farmed are compared with the those of the respondents in Table 7.

TABLE 7

Comparison of Means and Variances for Respondents and Non-respondents

	Years of Experience		Acres Farmed	
	Mean	Variance	Mean	Variance
Non-respondents from phone survey (n=22)	21.24	146.0662	292.79	89404.59
Respondents (n=93)	28.78	142.82	500.763	334990.46

A variance ratio test was performed for the two variables to ascertain whether or not there was a difference in the variance between respondents and non-respondents in both years of experience and acres farmed. In both cases the calculated F-value was less than the critical value of $F_{(24,120)}$. This meant a failure to reject the null hypothesis that there was no difference in variance between the two groups.

Next, t-tests were performed to test for differences between the mean values for respondents and non-respondents. In both cases the calculated t-value was less than the critical t-value. This meant that the null hypothesis that the differences were equal to zero could not be rejected; hence no detectable response bias seems to exist.

Clearly a survey of relative irrigation efficiency in dry Eastern Oregon would have been interesting, but the pressures of urban population growth on the water sources west of the Cascades make the Willamette Valley focus equally valuable. A more accurate mailing list could have resulted in a higher response rate, but a 43% response rate is statistically acceptable.

CHAPTER SIX
RESULTS

The completed surveys yielded a wealth of information including personal characteristics of the farmers and characteristics of their farms. To determine what characteristics most influenced irrigation efficiency, those data were analyzed using econometric procedures. The procedure used, difficulties encountered, and the results are reported below. The original hypotheses regarding the expected signs of the predictor variables are reviewed and compared with the actual signs of the coefficients. Possible explanations for certain findings are discussed.

Personal and Farm Characteristics

The sample consisted primarily of vegetable growers (77.4%), with less than a quarter growing mint (22.6%). The personal characteristics of the sample are presented in Table 8. The characteristics are shown separately for mint growers and vegetable growers. A representative mint irrigator is between the ages of 46 and 60, has either a high school diploma or some 2-year technical school education, and reports a net farm income above the $100,000 level. A representative vegetable irrigator is somewhat younger and has more education.

When looking at the entire study population, the respondent's experience with irrigation ranged from a low of two years to a high of 56 years. The mean level of experience with irrigation was 28.7 years, with twenty and thirty years

TABLE 8

Personal Characteristics of the Sample and Specific Crop Growers

AGE	SAMPLE	MINT	VEGETABLE
Under 30	2.2	0.0	2.8
31-45	39.8	33.3	41.7
46-60	37.6	52.4	33.3
Over 60	20.4	14.3	22.2

ED	SAMPLE	MINT	VEGETABLE
8th grade or less	3.2	0.0	4.2
Some High school	5.4	9.5	4.2
H.S. grad or GED	23.7	23.8	23.6
Some Tech or 2-yr	15.1	23.8	12.5
Tech or 2-yr grad	10.8	9.5	11.1
Some 4-yr college	5.4	4.8	5.6
Bachelor's degree	26.9	9.5	31.9
Some Grad school	1.1	4.8	0.0
Grad or Prof.degree	8.6	14.3	6.9

INC	SAMPLE	MINT	VEGETABLE
25,000 or less	26.4	28.6	25.8
25,001 to 50,000	13.8	9.5	15.2
50,001 to 100,000	18.4	23.8	16.7
Over 100,000	41.4	38.1	42.4

tying as the most common response to the study's question on irrigation experience (16.1%). Total farm size ranged from one acre to 3240 acres, with a mean of 500 acres. The most common source of irrigation water was a well (66.7%) and the most frequently-used form of irrigation was the handline (55.9%). Most irrigators used a timer (92.5%), approximately half practiced offset (50.5%), and almost 20 percent of the sample changed their irrigation nozzles every two years or less (19.6%). Most (36.6%) reported that they chose the sprinkler system on the field surveyed because it was the "best system for that specific crop and soil". Additional details on farm characteristics are listed in Appendix C.

Regression Procedure

The econometric model was represented by a linear equation estimated from the logged values of the dependent and non-dummy independent variables. The regression and subsequent examination of the results were performed in SAS, a software system designed for statistical analysis. The initial regression included all 20 independent variables. A problem with multicollinearity, however, required that a variable be dropped from the original model.

Problems with the Original Model

The results from the initial econometric regression did not indicate any problems. To insure the integrity of the results, however, tests were performed to detect the presence of heteroskedasticity[17] and multicollinearity[18].

A Breusch-Pagan test for heteroskedasticity was performed on the regression results using all 20 variables. It failed to indicate the presence of heteroskedasticity.

Auxiliary regression equations were used to test for the presence of multicollinearity. This process involves regressing each of the independent variables on the other 19, as in the following example:

$$CROP = AGE + ED + INC + \ldots + pATT$$

Either a high R^2 or a low sum of squared errors is indicative of a collinear relationship involving the independent variable (CROP in this example). The values of the sum of squared errors from the auxiliary regression equations indicated a problem with the OWN variable. The problem involved a lack of variation in the values of OWN around its mean. This created a linear

[17] Heteroskedasticity is a violation of the classical linear model. Heteroskedasticity violates the assumption of constant error variance; the variance of the error term is not constant for all observations. The presence of uncorrected heteroskedasticity can lead to inefficient estimators and inappropriate standard errors. Because standard errors are used to compute confidence intervals and perform hypothesis tests, inappropriate standard errors can lead to incorrectly accepted or rejected hypotheses (Griffiths *et al*, 1993).

[18] Multicollinearity means that the variables move together systematically, such that the effects of individual variables cannot be separated out. As a result, estimation of the variable parameters is imprecise and the estimates themselves are fragile and sensitive to deletion or omission of observations. While multicollinearity is not a violation of the classical linear model, it is still an undesirable. To correct this, either additional data must be obtained, nonsample information must be incorporated into the model, or suspect variables should be dropped.

dependence between OWN and the intercept in the regression equation[19]. For this reason, OWN was dropped from the original model.

To determine whether the reduced model was significantly different from the full model, an F-test was conducted to test the hypothesis that the coefficient of the variable dropped from the full equation was equal to zero.

$$H_o = OWN = 0$$

The calculated F-value was less than the critical value of $F_{(1,120)}$ at the 0.05% confidence level. The hypothesis that there was no statistically significant difference between the full and reduced models could not be rejected. The omitted variable (OWN) did not significantly affect the regression equation.

The signs of the coefficients of the other variables in the reduced model was unchanged from the original model. The magnitudes of the coefficients also differed little. No fragility of the estimates was indicated, again confirming the F-test hypothesis that the reduced equation was not significantly different from the full model.

The Reduced Model

After dropping the OWN variable, the reduced regression equation was estimated (see Table 9) and again tested for heteroskedasticity using the Breusch-

[19] Griffiths et al, 1993, p.437.

Pagan test. The calculated B-P value was less than the chi-squared critical value at the 0.05% level; the hypothesis of homoskedastic errors was not rejected. The reduced model apparently was also free from heteroskedasticity.

Unfortunately, many of the irrigators surveyed either chose not to or were unable to answer the PWRCST question. This left an actual sample size of 54 observations for the regression equation including the PWRCST variable. The result from this regression are presented in Table 9.

Variables with Significant T-Values

In testing the null hypothesis that the parameters are equal to zero, the null hypothesis is rejected and the parameters are significantly different from zero if the computed t-value is greater than the critical t-value. The computed t-values are given by SAS in the 't for Ho' column (see Table 9). The critical t-value for 60 D.F. at the 0.10% level is 1.671; at 0.05% it is 2.00; at 0.01% it is 2.66.

In this regression equation, six variables are significant at the 0.01% level. The remaining 12 do not test as statistically significant within the confidence levels outlined above. We cannot reject the null hypothesis that the parameters are equal to zero. This can mean either that the null hypothesis is true and that these 12 variables are not significantly different from zero, or that the data are insufficient to reject the null hypothesis even though it may be false.

TABLE 9

Regression Results

Statistics for the Reduced Model

Variable	Estimate of Coefficient	Standard Error	t for Ho: Parameter=0	Prob > |t|
INTERCEP	-2.361274	1.62237898	-1.455	0.1542
CROP	-0.558141	0.16177516**	-3.450	0.0014
AGE	0.083998	0.10278935	0.817	0.4192
ED	0.067169	0.15194823	0.442	0.6611
INC	-0.133932	0.06441280**	-2.079	0.0448
SIZE	0.000099	0.00021656	0.458	0.6494
LABON	-0.036626	0.07846842	-0.467	0.6435
LABOFF	0.115044	0.05199949**	2.212	0.0334
WAGES	0.103244	0.04830039**	2.138	0.0394
PWRCST	0.005933	0.13035869	0.046	0.9640
CHILD	-0.373177	0.18018745**	-2.071	0.0456
KNOWLAW	0.027953	0.09648219	0.290	0.7737
KNOWCERT	0.169240	0.16788430	1.008	0.3201
RISK	-0.257375	0.29408209	-0.875	0.3873
GENEFF	-0.046441	0.10874305	-0.427	0.6719
H2OCAP	-0.005881	0.14953749	-0.039	0.9688
SOIL	0.539107	0.26811785**	2.011	0.0519
EXPECT	-0.383102	0.31697268	-1.209	0.2347
pATT	-0.997055	1.23558809	-0.807	0.4250

R^2 = 0.5175 Adj. R^2 = 0.2763 n = 54

** = .01%

Interpretation of the Significant Variables

The following is an examination of signs of the coefficients and the interpretation of the variables in the reduced model. The six statistically significant variables are examined first; non-significant variables are examined last.

The variable for crop type (CROP) is statistically significant at the 0.01% confidence level. The sign on the coefficient for CROP is negative and is consistent with the hypothesis that mint is a commonly-overirrigated crop within the Willamette Valley. The negative sign on the coefficient suggests that growing mint is negatively related to the relative irrigation efficiency index, indicating a lower level of efficiency for mint growers. Lower levels are those with index numbers less than one, with the denominator (amount applied) exceeding the numerator (amount required by the crop) and indicating overirrigation.

The inclusion of the PWRCST variable reduced the number of observations available for this regression. The number of mint growers in this reduced observation set is 14, which is less than the number of dependent variables in the regression equation. For this reason, an F-test of the appropriateness of combining the data on the two crops into one equation cannot be performed.

The coefficient of the income (INC) variable is different than the positive one that was initially hypothesized. The inverse relationship between INC and the irrigation efficiency index is highly significant, but perhaps the least explicable of the results from this regression. The literature seems united on the positive sign of both the INC and the SIZE variable, which are highly correlated in this model. Yet the sign of the INC coefficient is negative and is significant at a 0.01% level. As INC increases, water use efficiency decreases.

INC is an "indicator(s) of the ability to make an investment"[20] in soil conservation, and it could be that while the ability to invest exists, the choice is simply not made, at least for investments in water conservation. Water could be seen by the irrigator as a more renewable resource than soil, with the result that less efforts are seen as necessary for its conservation. Also, the irrigator as a profit-maximizer might choose to adopt only the most profitable practices, and water conservation might be viewed as a long-run environmental rather than a profitable short-run goal.

Constrained maximization theory also provides a potential answer. The shadow value[21] of a constraint (some input) is a measure of how the objective function (profit, in this study) reacts to a slight relaxation of the constraint. If the constraint is not optimally binding, then relaxing that constraint will not affect the

[20] Lovejoy and Napier, 1986. p.34.

[21] The shadow value is the rate of change of the maximum (or minimum) value of the objective function with respect to changes in the value of the constraint. (Silberberg, 1990).

optimal value. In other words, if we examine the shadow value of our capital constraint and find it equal to zero at the optimum, then a relaxation of this constraint (an increase in farm income) has no effect on farm profits. Capital was not a binding constraint for that particular farm.

The coefficient of the LABOFF variable is positive. The hypothesized relationship was an indeterminate one due to uncertainty regarding which of two effects would be paramount. The impact of labor off-farm can be viewed as negatively related to irrigation efficiency because if a principal is working off-farm, she has less hours available for on-farm labor. This may impact irrigation efficiency in various ways, including a delay in the changing of irrigation sets due to off-farm absence. Alternatively, the off-farm labor of a principal increases the income available to the farm, which is shown in the literature to have a positive relationship to the adoption of conservation practices.

The coefficient of the WAGES variable is also consistent with the hypothesis of a positive relationship with irrigation efficiency. Increases in the use of available labor seem to increase irrigation efficiency.

The sign of the CHILD coefficient is contrary to that initially hypothesized. Instead of the expected positive relationship with irrigation efficiency, the CHILD variable is inversely related. The CHILD variable is used here as a proxy for the irrigator's discount rate. The hypothesis is that the irrigator's intent to transfer the operation to a child is indicative of a lower discount rate and longer planning horizon. This implies the hypothesized positive relationship with the dependent variable.

Soil type (SOIL) is statistically significant at the 0.01% level. The sign of the coefficient on SOIL is consistent with the hypothesized positive relationship. Those soil types with high average water-holding capacity (i.e., the clay-soil end of the spectrum) require less frequent irrigation because these soils hold more water. Sandy soils with low water-holding capacity hold less water and force more frequent and less efficient irrigations[22]. Because the results exhibit this pattern, they support the hypothesis that irrigators are aware of the water-holding properties of their respective soil types, and that they irrigate their fields accordingly.

Variables Lacking Statistical Significance

Twelve of the variables from the model did not test significantly different from zero at the 0.01%, 0.05% or 0.10% significance levels. These variables are AGE, ED, SIZE, LABON, PWRCST, KNOWLAW, KNOWCERT, RISK, GENEFF, H2OCAP, EXPECT, and pATT. The insignificance of these variables implies that they did not influence the relative efficiency of the irrigation water use. That is, the efficiency of the irrigators was unaffected by their personal

---

[22] More frequent irrigation increases water losses from evaporation, surface runoff and percolation, and decreases irrigation efficiency.

characteristics, by farm size, by their knowledge of water law or their own water right, by the amount of hours worked on-farm by either the principal operator or a spouse/partner, or by the amount paid for electric power.

Further Reduction of the Model

Due to the greatly reduced number of observations available with the inclusion of the PWRCST variable (54 of a possible 93), the decision was made to re-estimate the equation without this variable and thus with a larger set of observations. The results of this regression are presented in Table 10.

In order to determine whether the regression equation was the same for mint and vegetables, an F-test was used to test the hypothesis that the coefficients of the variables were the same for both crops. This had not been possible in the previous model as the number of observations for mint growers had been less than the number of independent variables in the equation.

$$H_o : \beta_i^{I} = \beta_i^{II} \quad where \quad i = 1, 2, \ldots 16$$

The calculated F-value of 0.7274 was less than the critical value of $F_{(20,120)}$ at the 0.05% confidence level. This meant that combining the two crops into one equation did not significantly affect the results.

TABLE 10

Regression Results

Statistics for the Reduced Model

Variable	Estimate of Coefficient	Standard Error	t for Ho: Parameter=0	Prob > |t|
INTERCEP	-2.051243	1.36227581	-1.506	0.1370
CROP	-0.493734	0.12988543**	-3.801	0.0003
AGE	0.011546	0.08048172	0.143	0.8864
ED	0.026909	0.16431648	0.164	0.8704
INC	-0.025169	0.04958241	-0.508	0.6134
SIZE	0.000026450	0.00016383	0.161	0.8722
LABON	0.006732	0.05097200	0.132	0.8953
LABOFF	0.040539	0.04070324	0.996	0.3230
WAGES	0.015117	0.03138627	0.482	0.6317
CHILD	-0.071487	0.12082423	-0.592	0.5561
KNOWLAW	0.013628	0.05081403	0.268	0.7894
KNOWCERT	0.114306	0.12139654	0.942	0.3499
RISK	-0.131661	0.22441405	-0.587	0.5594
GENEFF	0.005153	0.08913193	0.058	0.9541
H2OCAP	-0.043077	0.11745632	-0.367	0.7150
SOIL	0.454100	0.23763671*	1.911	0.0604
EXPECT	-0.327222	0.18589220*	-1.760	0.0831
pATT	-0.170963	1.63088052	-0.105	0.9168

R^2 = 0.3066 Adj. R^2 = 0.1252 n = 82

** = .01%
* = .10%

Variables with Significant T-Values

The null hypothesis that the parameters are equal to zero is tested in the same way as it was done previously for the regression equation that included PWRCST. Again, the null hypothesis is rejected and the parameters are significantly different from zero if the computed t-value is greater than the critical t-value. The critical t-value for 100 D.F. at the 0.10% level is 1.66; at 0.05% it is 1.984; at 0.01% it is 2.626.

In this regression equation only one variable is significant at the 0.01% confidence level, and two are significant at the 0.10% confidence level. The remaining 14 variables from this reduced model do not test as statistically significant. Again, we cannot reject the null hypothesis that the parameters are equal to zero. This can mean either that the null hypothesis is true and that these 14 variables are not significantly different from zero, or that the data are insufficient to reject the null hypothesis even though it may be false. In light of the results obtained in the regression equation including PWRCST, it is likely that the latter is the correct interpretation. The PWRCST variable, though not statistically significant itself, may have triggered the significance of INC, LABOFF, WAGES and CHILD in the first regression.

The group from whom observations were drawn for the first regression were a self-selected subsample. They represented the 54 irrigators who knew their power costs for the '93 season. The other characteristics that set them apart from the others who were unable to supply power cost information are unknown.

Only two of the significant variables remained consistent between the two reduced models, CROP and SOIL. For this subsample INC, LABOFF, WAGES and CHILD were more important than they were for the rest of the group.

Interpretation of the Significant Variables

The following is an examination of signs of the coefficients and the interpretation of the variables in this non-PWRCST model. The statistically significant variables are examined first; non-significant variables are examined last.

The variable for crop type (CROP) is statistically significant at the 0.01% confidence level. The sign on the coefficient for CROP is negative and is again consistent with the hypothesis that mint is a commonly-overirrigated crop within the Willamette Valley. The magnitude of the coefficient itself differs little between the two reduced models. Earlier in this chapter an F-test was performed which indicated that combining the data on the two crops into one equation did not significantly affect the results. The significance of the CROP variable implies that the intercept value of the equation changes with the crop, but that the remaining slope variables are the same for both crops.

Soil type (SOIL) is statistically significant, but at the 0.10% level. The sign of the coefficient on SOIL is again consistent with the hypothesized positive relationship. The magnitude of the SOIL coefficient also differs little between the two reduced models.

The only newly-significant variable is one that accounts for pre-season expectations regarding the irrigation source (EXPECT). EXPECT is statistically significant at the 0.10% level. The relationship of EXPECT to the index of relative irrigation efficiency is negative. The relationship was previously hypothesized to be indeterminate depending upon both the water source and the soil type present in the field. The correct interpretation seems to be that an irrigator who is expecting her water source to dry up or produce less later in the summer will irrigate her field heavily early on and hope that the water-holding capacity of the soil is such that the water will be retained in the soil.

Only ten irrigators had expectations for the 1993 season which included a reduced or dried-up water source later in the summer. It seems likely that the behavior of these irrigators would mirror the behavior of irrigators on the dry side of the Cascades in eastern Oregon. Accordingly, an examination of the significant variables, some farm-level characteristics, and the efficiency index of these ten irrigators is presented in Table 11.

A comparison of the mean values for this subgroup of ten irrigators to the mean values for the entire sample leads one to conclude that the subgroup are much like the rest of the sample. The percentages of irrigators using handlines and drawing their irrigation water from wells are close to 60% for both the subgroup and the sample. The percentage of irrigators growing vegetables is close to 80% for both the subgroup and the sample. The means of the soil type SOIL and the efficiency index (EFF) for the subgroup is slightly lower than the

TABLE 11

Characteristics of Irrigators Expecting Depleted Water Sources

Irrigator	Crop	Soil Type	Source	Type of Irrigation System	Relative Efficiency Index: EFF
1	Mint	Silt loam	Well	Handline	0.55328
2	Veg	Clay	Stream	Handline	0.76193
3	Mint	Clay	Well	Solid Set	0.69142
4	Veg	Clay	Well	Handline	0.91199
5	Veg	Clay	Well	Handline	0.60070
6	Veg	Silt loam	Stream	Side Roll	2.89730
7	Veg	Clay	Well	Handline	0.63737
8	Veg	Silt loam	Pond	Side Roll	0.83306
9	Veg	Silt loam	Stream	Handline	1.01170
10	Veg	Sandy loam	Well	Solid Set	1.37466

corresponding means for the sample. The mean of the soil type for the subgroup is an average water-holding capacity of 142 mm/m (Fine Sandy Loam from Table 2) and the mean of the EFF index is 1.027. The corresponding means for the sample are an average water-holding capacity of 151 mm/m (Clay Loam) and an efficiency index of 1.179.

Variables Lacking Statistical Significance

Fourteen of the variables from the model did not test as significantly different from zero at the 0.01%, 0.05% or 0.10% significance levels. These variables are AGE, ED, INC, SIZE, LABON, LABOFF, WAGES, CHILD, KNOWLAW, KNOWCERT, RISK, GENEFF, H2OCAP, and pATT. The insignificance of these variables implies that they did not influence the relative efficiency of the irrigation water use. That is, the efficiency of the irrigators was unaffected by their personal characteristics, by farm income or size, by their knowledge of water law or their own water right, by the amount of hours worked on- or off-farm by either the principal operator or a spouse/partner, or by the amount of farm wages paid. The irrigator simply applied the amount of water that she perceived as necessary with regard for little except crop type, soil type, and her expectations regarding the reliability of her water source over the summer.

A Comparison of the Amount of Water Applied and Legally Allowed

Most of the irrigators in our study (94.7%) drew their irrigation water from wells or streams. The remainder drew from a pond. The amount of water legally available each year to an irrigator is referred to as the "duty" of the water. For irrigators in the Willamette Valley who draw from a well or a stream, the legal duty of water is 2.5 acre-feet per acre or 30 inches. Total irrigation applied in this data is represented by the variable SEASIRR, which represents irrigation applied in inches. The frequency and the cumulative percent of the irrigator's measures of SEASIRR are listed in Appendix F. The mean and variance of both SEASIRR and ET appear in Table 12.

The mean measure of the SEASIRR variable is 17 inches applied during the year. Most of the irrigators in the study (87.1%) applied less than the 30 inch per year maximum amount; only 12.9% of the irrigators in the study exceeded the maximum irrigation amount allowed. This result suggests the amount available through their water right is not a constraining input for the majority of the irrigators in this study.

TABLE 12

Mean and Variance of SEASIRR and ET Variables

	Mean	Variance
SEASIRR	17.4132677	145.98041
ET	18.4506440	55.64583

Relative Irrigation Efficiency Index

The relative irrigation efficiency index is also reproduced in Appendix F, along with the total ET requirements for each irrigator's crops. The relative efficiency index itself ranged in value from 0.31 to 3.6. It was greater than one for more than half the sample (49 of 93 observations), with a mean value of 1.179. Recall that an index reading of one or greater indicates that irrigation season ET requirements exceeded the amount of water applied to the crop both through irrigation and rainfall. In a nutshell, more than half of our irrigators appeared to underirrigate their crops during the 1993 irrigation season. Intuitively, this underirrigation seems an unusual practice for a profit-maximizing irrigator. Several circumstances influence this conclusion, however.

First, our ET measure was calculated using the modified Penman method, which tends to be an inflated measure of ET relative to other measures available[23]. Second, the index doesn't account for antecedent moisture that pre-existed the start of the irrigation season. This is moisture available for the plants to use in their early emergent state. The early 1993 season in particular saw unseasonably heavy rain, rain that continued well into July. In this particular season the antecedent moisture was much higher than average. Thus, the water applied during the dates of the irrigation season was not the only water available to the crop. Antecedent water could have supported the crop through its

---

[23] Conversation with Marshall English, 1994.

emergent period. A crop that appeared underirrigated by our index may actually have had ample water, even with "low" levels of irrigation. Thus our measure of irrigation efficiency is relative, not absolute.

Non-Significant but Intriguing

Although the education variable (ED) is not significant in the full 18 variable regression equation (including PWRCST), it is significant at the 0.01% confidence level in the predictive equation used to determine the value of attitudes (pATT). The results for this equation appear in Table 13. The positive sign of the coefficient implies that higher levels of education have a positive effect on farmers' attitudes toward the environment, as represented by the responses to questions for ATTOR and ATTNAT.

The expected sign of the ED coefficient matches the positive relationship that was hypothesized, but the variable ED does not test as significant in determining the relative efficiency of irrigation. The sign of pATT, the predicted value of ATT, is not the positive sign that was expected, but this variable also does not test as significant in explaining efficiency.

Nonetheless, two interesting aspects of these variables present themselves. The impact of ED on the predicted value of attitudes seems to be strongly significant at the 0.01% level (Table 13). This tends to indicate that while ED is a strong component of predicted irrigator attitudes (Pearson correlation coefficient of .985), neither it nor pATT are significant contributors to relative

TABLE 13

Estimation of the pATT Variable

Variable	Parameter Estimate	Standard Error	t for Ho: Parameter=0	Prob > |T|
INTERCEP	-0.670077	0.36344192	-1.844	0.0703
AGE	-0.065523	0.07411665	-0.884	0.3803
ED	0.122809	0.02400272**	5.116	0.0001
EXP	0.112514	0.10006349	1.124	0.2655
KNOWLAW	0.065397	0.04209272	1.554	0.1257

R^2 = 0.3496 Adj R^2 = 0.3048 n = 62

efficiency of irrigation. Additionally, the correlation coefficient between ED and ATTOR is 0.37 and between ED and ATTNAT is 0.30.

Another interesting result is the relatively strong correlation between ATTOR and ATTNAT, two of the component variables forming ATT. Again, these are questions measuring the pro-business or pro-environment attitude of the irrigators in this study. ATTOR is from a study by the Oregon Business Council (1993), and ATTNAT is from a sociological study by Dunlap and van Liere (1992). While no pair of variables in the model have a higher Pearson correlation coefficient than 0.60 (WAGES and SIZE), ATTOR and ATTNAT have one of the next highest correlation coefficients at 0.436 (see Appendix D). Since the two variables are attempting to measure essentially the same thing, this relatively high correlation coefficient indicates that they are to some degree succeeding.

The results for the ATTOR and ATTNAT variables for this study were compared with the results of the original studies that were conducted by the Oregon Business Council and by Dunlap and van Liere. These results and the comparison are outlined in Appendix E. In that comparison it is interesting to note that for the ATTOR variable, 33% of the irrigators in this study sided with the pro-environment majority in the Oregon Business Council survey, compared with 75% of the original study. For the ATTNAT variable, 18% of the irrigators from this study agreed with the pro-environment majority in the national study, compared with 30% of the original study.

The mean values of ATTOR and ATTNAT are listed in Table 14. In both cases the variable is specified on a scale of zero to one. As the value of the variable approaches one it indicates a relatively pro-environment attitude on the part of the irrigator. For the ATTOR variable, 33% of our sample chose the pro-environment response to the question. For the ATTNAT variable, approximately

TABLE 14

Mean of ATTOR and ATTNAT Variables

Variable	Mean
ATTOR	.333333
ATTNAT	0.579029

58% of the irrigators in our study had attitudes that were more pro-environment than the attitude indicated by the mean value of ATTNAT. Despite these pro-environment sentiments, irrigator behavior seems unaffected by their attitudes.

Summary

Except for the removal of one variable due to the presence of multicollinearity, the initial modeling was without incident. The results themselves were less clear-cut. In the 18 variable model including PWRCST, six variables proved to be significant at the 0.01% confidence level. These variables were CROP, INC, LABOFF, WAGES, CHILD and SOIL. Unfortunately, the subsample of irrigators who were able to answer the PWRCST question was only 54 of the possible 93 observations available. Due to this small pool of available observations, the model was run again with PWRCST removed.

In the regression without PWRCST, only three variables proved to be statistically significant influences on farmers' attitudes toward irrigation efficiency. These variables, CROP, SOIL and EXPECT, suggest that a farmer's irrigation efficiency is unaffected by personal characteristics. According to these results, the irrigator simply applied the water that she deemed necessary, a decision based solely on the needs of the crop, the holding capacity of the soil, and her expectations regarding the reliability of her water source.

Only two of the significant variables remained consistent between the two reduced models, CROP and SOIL. For the PWRCST model subsample INC, LABOFF, WAGES and CHILD were more important than they were for the rest of the group. While these results are not conclusive, they do raise some interesting points. These points are analyzed in Chapter Seven.

CHAPTER SEVEN
SUMMARY AND CONCLUSIONS

With a growing Oregon population making increasing demands on limited water resources, some water will eventually be reallocated to urban and recreational uses at the expense of agriculture. One of the least painful methods of finding water to reallocate may be through the adoption of more efficient irrigation practices. Water conserved by increasing irrigation efficiency might potentially placate urban interests without penalizing rural water users.

Because water is a public resource, the state will have a role in this reallocation process. But as the state learned with SB 24 (an Oregon attempt to encourage water conservation among irrigators), conservation legislation does not work if irrigators have little incentive to participate in the program. To help design more effective conservation programs, ones that irrigators embrace, it is necessary to know what motivates an irrigator to adopt efficient irrigation practices. This thesis was an attempt to do just that, to identify the demographic, attitudinal and farm-level characteristics common to efficient irrigators.

Of the characteristics theorized to influence irrigation efficiency, seven proved to be statistically significant in one or the other of the two models used: crop type, net income, off-farm labor, farm wages, expectations of transferring the farm to a child, soil type, and expectations regarding the reliability of the water source. Only crop and soil type were consistently significant in both models.

Having such a large number of theorized variables rejected by the data led to a number of questions regarding the study itself. These are analyzed below. More interesting are the implications of the significant variables. The implications are subsequently discussed.

Literature Review: Important Characteristics

A multidisciplinary literature review was conducted to determine the appropriate variables for this analysis and to pinpoint the characteristics most likely to influence irrigation efficiency. No studies were uncovered which addressed the determinants of irrigation efficiency. A search of the environmental sociology literature and water and soil conservation literature, however, revealed several characteristics likely to be linked to conservation. These characteristics became the predictor variables for this study.

The fact that so many of the variables used in the study proved to be statistically non-significant suggests that either the previous studies were mistaken or that something else is afoot. We suspect the latter.

Why? Because this is a multidisciplinary study, it brings together a number of user characteristics that have not been previously analyzed together. Indeed, the literature did not contain previous work linking all the disciplines and characteristics that were covered in this study. It is likely, therefore, that no one had directly compared the relative importance of sociological factors like attitudes with the nuts and bolts of something like soil type, a factor generally reserved to conservation literature. In short, no one had ever examined the relative importance of one factor versus another within a similar context.

According to the results of this study, the difference in importance among the variables is huge. No literature could be found which directly addressed the determinants of irrigation efficiency. While the available conservation literature suggests that attitude, age, education, risk and other characteristic variables should impact a farmer's irrigation efficiency, this study indicates that the effect of these variables pales in significance when compared to crop type and soil type, and, for a subsample of irrigators who knew their power costs, net income, wages, off-farm labor, and an intention to transfer the farm to a child. The other variables are not necessarily invalid, they are just not significant in comparison to a farmer's overwhelming concern with raising a crop and turning a profit.

Survey Method

It is doubtful the survey instrument itself was responsible for the lack of expected results from this study. Indeed, the survey followed all the standard practices and accounted for possible sample bias. This may not be true, however, for the timing of the survey, but this doesn't change the significance of the predictor variables themselves. The survey, conducted in March 1994, asked farmers to answer technical questions based on the 1993 growing season. Because 1993 was an abnormally rainy and cool season in most of Oregon, crops required less irrigation due to higher levels of antecedent moisture in the soil. This may have made the irrigators appear to be more efficient because less irrigation was required. Indeed, more than half of the irrigators sampled applied less water than the 1993 ET data indicated was required by the crop. The only way to refute this result is to repeat the study in a "normal" year, or to repeat it by using a measurement of seasonal irrigation that includes actual antecedent moisture along with rainfall and irrigation.

If the timing of the survey and the method of measurement combine to lessen the amount of water needed and to make the irrigators appear more efficient, then they are surprisingly inefficient today. The survey data reveals that close to 50 percent of the sample are overirrigating their crops according to our efficiency index. The index is a ratio of the ET requirements of the crop to the sum of rainfall and irrigation applied to the crop over the length of the irrigation season. For this reason the index can be used as an rough indicator of overall efficiency. If our measure is skewed towards making irrigators appear more efficient than they actually are, and 50% of the irrigators sampled still seem to be irrigating inefficiently, then it is possible that more than half of the irrigators surveyed are systematically overirrigating their crops.

Significant Variables

The influence on relative irrigation efficiency of both the crop under irrigation and the type of soil seem to be important. These variables were consistently significant in both the model including PWRCST and the model without the PWRCST variable. The negative relationship of mint to relative irrigation efficiency tends to support anecdotal evidence of systematic overirrigation of mint crops by irrigators in the central Willamette Valley. The positive relationship of soil type to the efficiency index reflects the water-holding capacities of different soils. Soils with a higher water-holding capacity (clay soils) can be watered less frequently and hence more efficiently than those soils with a lower water-holding capacity (sandy soils). The results indicate that irrigators seem to be aware of the water-holding capacities of their soil type, and that they irrigate accordingly. In the case of mint irrigators, they do not seem to be as aware of the water needs of their crop.

In the model including PWRCST, four additional variables were shown to have statistically significant influences on irrigation efficiency. Net income and an expected transfer of the farm to a child were negatively related to irrigation efficiency. Neither relationship was as hypothesized. Conversely, off-farm labor and farm wages both had the hypothesized positive relationship to irrigation efficiency.

The group of irrigators from which the observations for the PWRCST model were drawn were a self-selected subsample. They represented the 54 irrigators who returned usable surveys and knew their power costs for the '93 season. It is difficult to assess the characteristics which set them apart from the 39 others who were unable to supply power cost information. However, for this subsample, INC, LABOFF, WAGES and CHILD were more important than they were for the rest of the group. This suggests that irrigation efficiency within this sample subset is more determined by financial and profit considerations than across the entire sample.

There is a great deal of uncertainty surrounding farming. This increases the level of risk for the farmer. As discussed in Chapter Three, irrigation can be used as a risk-reducing input, an occurrence which could lead to overuse of the input, even in a profit-maximizing situation. The results of the PWRCST model suggest that those farmers coming closest to the point of maximizing income are those coming closest to guessing correctly the necessary amount of irrigation. As the increase in net income is negatively related to irrigation efficiency, it could be that water is being used as a risk-reducing input by profit-maximizing farmers.

The non-PWRCST model provides an additional statistically significant variable. The relationship between an irrigator's preseason expectations for her water source (EXPECT) and the relative irrigation efficiency index was hypothesized as indeterminate, depending on the soil type involved. The results of this study indicate that the relationship is negative; an irrigator with expectations of a diminished water source might overirrigate early in the season if the soil is capable of retaining water. She would hope to use the soil itself as a form of storage for her irrigation water.

The results indicate that the efficiency of the irrigator was unaffected by her personal characteristics or attitudes, by farm size, by her knowledge of water law or her own water right, or by the hours worked on-farm by either the principal irrigator or her spouse/partner. The irrigator simply applied what she perceived as the necessary level of water; she was influenced primarily by the crop type, the water-holding capacity of the soil, and her expectations regarding the reliability of the water source.

The Influence of Attitudes

While the influence of attitudes on irrigation efficiency was the initial focus of this study, the results indicate that attitudes were not a statistically significant influence on water use decisions by irrigators. The divergence between an individual's attitudes and her behavior is not an uncommon finding in social science research; our results seem to support this. Two questions that were included in the survey attempt to elicit the pro-business or pro-environment sentiments of irrigators (ATTOR and ATTNAT). The ATTOR question was taken from a study of Oregonians by the Oregon Business Council (1993); ATTNAT comes from a national sociological study by Dunlap and van Liere (see Olsen *et al*, 1992). The results of this study reveal that 33% (the Business Council question) and 58% (the Dunlap and van Liere question) of the irrigators sampled had attitudes that were more pro-environment than the average irrigator in our study. Attitudes, however, were not a significant influence on irrigation efficiency.

Despite professed pro-environment attitudes and the fact that most of the irrigators surveyed were using less than the legally allowed amount of water[24], their progressive attitudes weren't matched by their pumping actions. Many irrigators were over-applying water by our index of relative irrigation efficiency. Because most of those surveyed were drawing their irrigation from groundwater, the opportunity costs of not pumping must be considered. An irrigator who does not pump as much as possible from the common property resource of the underground water supply faces the possibility that some other irrigator will. The Willamette Valley has high levels of rainfall to recharge groundwater during the winter months, and groundwater shortages for irrigation are generally not a problem. However, the bulk of the growing season occurs during the driest

[24] Willamette Valley irrigators drawing their water from either wells or streams are legally allowed up to 2.5 acre-feet per acre per year. Of the irrigators surveyed, 95% were irrigating from one of these sources, and 87% were using less than the legally allowed amount of irrigation water.

months of the year, when there is little or no rain. If an irrigator does not extract as much groundwater as possible from the common property resource, she runs the risk that others may reduce the groundwater to a level below her ability to pump.

Recommendations for Future Research

As mentioned in Chapter Six, ten irrigators identified themselves as having unreliable water sources that dried up over the summer. Their expectation regarding their water source should be similar to that held by many irrigators in arid eastern Oregon. As a subgroup, their answers are especially interesting because they may be reflecting many of the concerns regarding uncertain water supplies shared by irrigators east of the Cascades. More importantly, among this subgroup 70% are overirrigating by the relative efficiency index used here. If the same holds true in that dry but increasingly populous area of the state, a water crisis seems imminent - the information gained from a study of this type could prove immediately beneficial.

In light of these results, this study could be a test run for a similar study situated in eastern Oregon. That study should focus on the variables identified as significant by this work, in addition to any additional variables specific to the different location of the study.

Just as importantly, such a study should explore where irrigators get their information. Approximately 37% of the irrigators in this sample responded that they chose their sprinkler system because it was the "best system for the specific crop and soil". This response begs the question "the best system according to whom"? Ideally the university community would like to believe that this information is coming from the agricultural extension service, but that may not be the case. The effectiveness of extension at disseminating information may be an important variable to include in a future study. By the same logic, many farmers see their farm supply salespeople more than their extension agent, yet the influence of agribusiness -- with multi-million dollar marketing budgets -- is also unknown. These two additional factors could prove to be significant variables in a future study. Involving agribusiness would have additional benefits. With extensive outreach to the farming community east of the Cascades, agribusiness could help provide the mailing lists, backing, and entre such a study would require.

Policy Recommendations

While most of the irrigators in the study are using less than the maximum amount of water allowed (30 inches a year), more than half are overirrigating by our measure of relative irrigation efficiency. If inefficient irrigation exists, the potential also would exist for benefits to the state, the public, and the irrigators through conserving water under legislation similar to SB 24. The question is how to go about doing it.

The results of the study indicate that the irrigator simply applied the water that she deemed necessary; this decision is based primarily on the needs of the crop, the water-holding capacity of the soil, and her expectations regarding the reliability of the water source. Attitudes did not have a significant influence on the efficiency of irrigation. Any proposal or program initiated by the state with the intent of encouraging irrigation conservation must make economic sense to the user rather than attempting to appeal to pro-conservation attitudes.

Educational programs are sometimes proposed as logical places to start when attempting to influence changes in behavior. The negative relationship between mint and sandy soil-types and irrigation efficiency demonstrated in this study even pinpoints a group on which to focus extension efforts at conservation education. Extension must remember, however, that any proposed educational program should focus on economic gains to the irrigator rather than on efficient irrigation being the "right thing" to do.

But in the final analysis, even the most targeted educational program won't change the underlying concern for profit uncovered by this study. As long as irrigators are motivated by practical concerns for their crops and their profit, their actions will not be significantly influenced by attempts to change their attitudes.

As long as the benefits from current irrigation practices exceed the costs incurred by the irrigators, the irrigators have no financial incentive to change.

This study draws on the theory of the irrigator as a profit-maximizer, a theory which is not tested, but which is not out-of-step with the results. If we assume this to be the case, profit is maximized when the revenue gained through using an input is equal to the cost of using the input. Once the price of using an input exceeds the increase in revenue resulting from its use, the input will no longer be used in the same quantities. Common sense as well as economics dictates that if the price of water increases, either through an increase in pumping costs or a resource-use tax, less water will be used.

Is an increase in the price of water to Willamette Valley irrigators a necessary or desirable step? There is generally no shortage of groundwater sources for irrigation in the central Willamette Valley because heavy winter rains recharge the aquifers that most irrigators draw from. Of the irrigators surveyed, the majority were using less than the legally allowed amount of water. While urban pressures seem likely to eventually change this situation, currently there seems to be no need for a water price increase in this area of Oregon. In the arid regions of eastern and central Oregon, however, where demands on the water sources exceed the regenerative capacities of the climate, perhaps the need for an increase in the price of water is a real one.

Water is still relatively cheap when compared to the capital necessary to modernize outdated and inefficient irrigation equipment or to pay the extra labor needed to run large irrigation systems. The overriding conclusion of this study is that the most significant influence on irrigation efficiency is not attitudinal but financial. Until inefficient irrigation practices become a losing proposition, other efforts to increase irrigation efficiency may come up dry.

BIBLIOGRAPHY

Ardila, Sergio, Robert Innes "Risk, Risk Aversion, and On-Farm Soil Depletion", Journal of Environmental Economics and Management, 25(1993):S27-S45.

Beus, Curtis E., Riley E. Dunlap "Measuring Adherence to Alternative vs. Conventional Agricultural Paradigms: A Proposed Scale", Rural Sociology, 56(1991):432-460.

Bosch, Darrell J., Vernon R. Eidman "Valuing Information When Risk Preferences Are Nonneutral: An Application to Irrigation Scheduling", American Journal of Agricultural Economics, 69(1987):658-668.

Buckwell, Allan "Economic Signals, Farmer's Response and Environmental Change", Journal of Rural Studies, 5(1989):149-160.

Cadillac Desert: The American West And Its Disappearing Water. Marc Reisner, Penguin Books, New York, NY, 1986.

Carlson, John E., "Attitudes Toward Water Use Practices Among South Eastern Idaho Farmers: A Study On Adoption Of Irrigation Scheduling" Idaho Water Resource Research Institute, University of Idaho, Moscow, 1975.

Carlson, John E., Maurice McLeod, William R. Lassey, Don A. Dillman, "The Farmer, Absentee Landowners and Erosion: Factors Influencing The Use of Control Practices" Idaho Water Resources Research Institute, University of Idaho, Moscow, 1977.

Carr, Susan, Joyce Tait, "Differences in the Attitudes of Farmers and Conservationists and their Implications", Journal of Environmental Management, 32(1991):281-294.

Caswell, Margriet F., David Zilberman, "The Choices of Irrigation Technologies in California", American Journal of Agricultural Economics, 67(1985):224-234.

______, "The Effects of Well Depth and Land Quality on the Choice of Irrigation Technology", American Journal of Agricultural Economics, 68(1986):798-812.

Colby, Bonnie G., "Enhancing Instream Flow Benefits in an Era of Water Marketing", Water Resources Research, 26(1990):1113-1120.

Conservation And Efficient Water Use. Oregon Water Management Program, State Water Resources Policy, 1990.

Crossing The Next Meridian: Land, Water, and the Future of the West. Charles F. Wilkinson, Island Press, Washington D.C. 1992.

Dinar, Ariel, Dan Yaron, "Influence of Quality and Scarcity of Inputs on the Adoption of Modern Irrigation Technologies", Western Journal of Agricultural Economics, 15(1990):224-233.

DuMars, Charles T., A. Dan Tarlock, "Symposium Introduction: New Challenges to State Water Allocation Sovereignty", Natural Resource Journal, 29(1989):331-346.

Economics of irrigation, The. Ian Carruthers, Colin Clark, Liverpool University Press, Liverpool, U.K. 1981.

Economics Of Production, The. Bruce R. Beattie, C. Robert Taylor, John Wiley & Sons, New York, NY 1985.

Energy and water management in western irrigated agriculture. Norman K. Whittlesey, Westview Press, Boulder, CO 1986.

English, M., A. Taylor and P. John, "Evaluating sprinkler system performance", NZ Agricultural Science :32-38.

Ervin, Christine A., David E. Ervin "Factors Affecting The Use of Soil Conservation Practices: Hypotheses, Evidence and Policy Implications", Land Economics, 58(1982):277-292.

Evapotranspiration and Irrigation Water Requirements: ASCE No. 70. M.E. Jensen, R.D.Burman, R.G. Allen, Eds., American Society of Civil Engineers, New York, NY 1990.

Final Report Initial Planning And Development: Incentives For Improved Water Use Efficiency, Larry C. Kerpelman, ABT Associates, Cambridge, MA 1975.

Fundamental Methods Of Mathematical Economics. Alpha C. Chiang, McGraw Hill, New York, NY 1984.

Harbison, John S., "Waist Deep In The Big Muddy: Property Rights, Public Values, and Instream Waters", Land And Water Law Review, 26(1991):535-570.

Hooks, Gregory M., Ted L. Napier, Michael V. Carter "Correlates of Adoption Behaviors: The Case of Farm Technologies", Rural Sociology, 48(1983):308-323.

Huffman, Wallace E., "Allocative Efficiency: The Role Of Human Capital", Quarterly Journal of Economics, 91(1977):59-79.

Instream Flow Protection in the West. L.J. MacDonnell, T.A. Rice, and S.J. Shupe eds, Natural Resource Law Center, Boulder 1989.

Irrigated Crops And Their Management. Roger Bailey, Farming Press, Ipswich, U.K. 1990.

Irrigation: design and practice. Bruce Withers, Stanley Vipond, Cornell University Press, Ithaca, NY 1980.

Jones, Robert Emmet, Riley E. Dunlap "The Social Bases of Environmental Concern: Have They Changed Over Time?", Rural Sociology, 57(1992):28-47.

Kaufman, Joseph Q., "An Analysis Of Developing Instream Water Rights In Oregon", Willamette Law Review, 28(1992):285-332.

Kramer, Randall A., William T. McSweeney, Robert W. Stavros, "Soil Conservation with Uncertain Revenue and Input Supplies" American Journal of Agricultural Economics, 65(1983):694-702.

Kreutzwiser, R.D., L.J. Pietraszko, "Wetland Values and Protection Strategies: a Study of Landowner Attitudes in Southern Ontario", Journal of Environmental Management, 22(1986):13-23.

Learning and Practicing Econometrics. William E. Griffiths, R. Carter Hill, and George G. Judge, John Wiley and Sons, New York, NY, 1993.

Lee, Linda K. "Impact of Landownership Factors on Soil Conservation" American Journal of Agricultural Economics, 62(1980):1070-1076.

Livingston, Marie L., Thomas A. Miller, "A Framework for Analyzing the Impact of Western Instream Water Rights on Choice Domains: Transferability, Externalities and Consumptive Use", Land Economics, 62(1986):269-277.

Lynne, Gary D., J.S. Shonkwiler, Leandro R. Rola, "Attitudes and Farmer Conservation Behavior" American Journal of Agricultural Economics, 70(1988):12-19.

Mail And Telephone Surveys: The Total Design Method. Don A. Dillman, John Wiley and Sons, New York, NY, 1978.

Management of Farm Irrigation Systems. G.J. Hoffman, T.A. Howell, K.H. Solomon, ASAE, St. Joseph, MO, 1990.

Marsh, C. Paul, A. Lee Coleman "The Relation Of Farmer Characteristics To The Adoption Of Recommended Farm Practices", Rural Sociology

McConnell, Kenneth E. "An Economic Model of Soil Conservation" American Journal of Agricultural Economics, 65(1983):83-89.

McDowell, Clive, Ross Sparks "Multivariate Modelling and Prediction of Farmers' Conservation Behaviour Towards Natural Ecosystems", Journal of Environmental Management, 28(1989):185-210.

Merriman, Ed, "Ag avoids bath in water bills course", Capitol Press, August 13, 1993.

Microeconomic Theory: A Mathematical Approach. James M. Henderson, Richard E. Quandt, McGraw Hill, New York, NY 1980.

Microeconomic Theory: Basic Principles and Extensions. Walter Nicholson, Dryden Press, New York, NY 1992.

Microeconomics with Calculus. Brian R. Binger, Elizabeth Hoffman, Scott, Foresman and Company, Glenview, IL 1988.

Negri, Donald H., Douglas H. Brooks, "Determinants of Irrigation Technology Choice", Western Journal of Agricultural Economics, 15(1990):213-223.

Nowak, P.J. 1984, "Adoption and diffusion of soil and water conservation practices" in Conserving Soil: Insights from Socioeconomic Research. Stephen B. Lovejoy, Ted L. Napier, Eds., Soil Conservation Society of America, Ankeny, IA, 1986.

Oregon Crop Water Use and Irrigation Requirements. Extension Miscellaneous 8530, June 1992.

Oregon Law Institute, "Water Law", Program Materials from Oregon Law Institute program on water law in Bend, OR, September, 1983.

Oregon Values & Beliefs: Summary. Oregon Business Council, May 1993.
Pampel, Fred Jr., J.C. van Es "Environmental Quality and Issues of Adoption Research", Rural Sociology, 42(1977):57-71.

Oregon Water Management Program: Conservation and Efficient Water Use. Oregon Department of Water Resources, December, 1990.

Rahm, Michael R., Wallace E. Huffman, "The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables", American Journal of Agricultural Economics, 66(1984):405-413.

Root, Anne L., "Improving Instream Flow Protection in the West: An Evaluation of Strategies with an Analysis of Oregon's Program", Oregon State University Ph.D Thesis, 1993.

Seitz, Wesley D., Earl R. Swanson "Economics of Soil Conservation from the Farmer's Perspective" American Journal of Agricultural Economics, 62(1980):1084-1088.

Shupe, Steven J., Gary D. Weatherford, Elizabeth Checchio, "Western Water Rights: The Era of Reallocation", Natural Resources Journal 29(1989)413-434.

The Sociology of Agriculture. Frederick H. Buttel, Olaf F. Larson, Gilbert W. Gillespie Jr., Greenwood Press, New York 1990.

Stern, Paul C., Thomas Dietz, Linda Kalof "Value Orientations, Gender and Environmental Concern", Environment and Behavior, May 1993.

Stevens, Joe B., "Satisfaction with Environmental Change: An Empirical Analysis of Attitudes toward Air Quality by Recent Interstate Migrants", Journal of Environmental Economics and Management, 11(1984):264-281.

Survey of Oregon's Water Laws. Chapin D. Clark, University of Oregon, 1974. Reprinted and updated by Oregon Law Institute, WRRI, Oregon State University, 1983.

Taylor, Barbara Jane, "Perceived Profitability In Farmer's Adoption Of Soil Conservation Tillage", Washington State University M.A. Thesis, 1982.

Troubled Waters: New Policies for Managing Water in the American West. Mohamed T. El-Ashry, Diana C. Gibbons, World Resources Institute, Study 6, October 1986.

van Es, J.C., "The Adoption/Diffusion Tradition Applied to Resource Conservation: Inappropriate Use of Existing Knowledge", The Rural Sociologist, 3:(1983):76-82.

Viewing the World Ecologically. Marvin E. Olsen, Dora G. Lodwick, Riley E. Dunlap, Westview Press, Boulder, CO 1992.

Water Conservation: Using Conserved Water In Oregon. Water Resources Department, 1989.

Water Production Functions for Irrigated Agriculture. Roger W. Hexem, Earl O. Heady, Iowa State University Press, Ames, IA 1978.

Water Rights: Oregon's Water Rights System. State of Oregon, Water Resources Department, 1993.

Water Saving Techniques for Plant Growth. H.J.W. Verplancke, E.B.A. De Strooper, and M.F.L. De Boodt, eds, NATO ASI Series, Kluwer Academic Publishers, Boston, MA 1992.

Wilkinson, Charles F., "Aldo Leopold and Western Water Law: Thinking Perpendicular to the Prior Appropriation Doctrine", Land and Water Law Review, 24(1989):1-38.

Williams, Stephen M., Rosaleen McCrorie "Analysis of Ecological Attitudes in Town and Country", Journal of Environmental Management, 31(1990):157-169.

APPENDICES

APPENDIX A

Table 15

Definitions of Independent Variables

CROP	Dummy variable of one if the irrigator answered the survey with a mint field as their representative field; zero if they chose a vegetable field. (Q.#5)
AGE	Age of principal irrigator: 1=30 years or younger; 2=31 to 45 years; 3=46 to 60 years; 4=over 60 years. (Q.#48)
ED	Highest level of education completed by principal irrigator. (Q.#49)
EXP	Log of total years of experience in working with irrigation by the principal irrigator. (Q.#35)
INC	Net farm income as defined by the Schedule F farm income tax form. (Q.#50)
OWN	Whether or not the irrigator indicated that the farm is owned by their family. (Q.#45)
SIZE	Total acres of irrigated and non-irrigated crops. (Q.#2)
LABON	Total hours of on-farm labor by principal irrigator, spouse/partner and other adult, divided by SIZE for a per-acre measurement, and then logged. (Q.#43)
LABOFF	Total hours of off-farm labor by principal irrigator, spouse/partner and other adult, divided by SIZE for a per-acre measurement, and then logged. (Q.#43)
WAGES	Approximate total cash wages and bonuses, before taxes, paid to all agricultural workers on farm during 1993 season, divided by SIZE for a per-acre measurement, and then logged. (Q.#44)
PWRCST	Approximate cost of electricity for irrigating field during 1993 season, exclusive of demand charges or annual fees. (Q.#34)

Table 15 continued

CHILD	Does the irrigator plan to transfer the farm operation to a child: yes, no or don't know. (Q.#47c)
KNOWLAW	Four true/false questions were asked; irrigators knowledge of water law was based on their number of correct answers. Dummy variable of one for each right answer (a=T, b=T, c=F, d=F) and zero for each wrong answer. (Q.#40)
KNOWCERT	Did respondent know the maximum rate of diversion of their water right in either cubic feet per second (cfs) or gallons per minute (gpm). Dummy variable of one for either of the two possible answers, zero for no response. (Q.#38)
RISK	Two questions based on those used in a Washington State University thesis (Taylor, 1982) to determine a particular irrigator's attitude towards risk. Responses on scale of one to five. (Q.#42e and f).
GENEFF	Composite of whether or not irrigator uses three general conservation practices: changing sprinkler nozzles every one or two years, using a timer, and offsetting. (Q.#20, 24, and 25)
H2OCAP	Was irrigator aware of the water holding capacity of the soil in the field selected? Dummy variable of one for response, zero for no response. (Q.#8)
SOIL	Log of the mean water-holding capacity of the soil type for the field selected: low to high water-holding capacity as rated on scale of soils from coarse sand to peat. (Q.#7)
EXPECT	Dummy variable of one for either of two expectation choices (response 1 or 2) involving seasonal water shortages. (Q.#39a)
ATT	Summation of the three attitudinal questions below: ATTNAT, ATTOR and ATTGEN.

Table 15 continued

ATTOR	Oregon attitudes benchmark question from a summary of a survey commissioned by the Oregon Business Council (1993). Value of zero indicating pro-business response (response 1); one indicating pro-environment response (response 2). (Q.#41)
ATTNAT	National attitudes benchmark question from study by Dunlap and Van Liere (Olsen *et al*, 1992) who constructed a New Environmental Paradigm (NEP) scale. Scale of one to five with one indicating pro-business answer; five indicating pro-environment. (Q.#42a)
ATTGEN	Composite of four other attitudinal questions concerning attitudes toward water rights, water left instream, overirrigation and competition between rural and urban water use. Scale of one to five for each question, with one indicating pro-business answer; five indicating pro-environment answer. (Q.# 42b, c, d, and h)

APPENDIX B

Table 16

Mean and Variance of Variables

Variable	Mean	Variance
EFF (Relative Efficiency Index)	1.1791640	0.3726822
CROP (% Mint)	0.2258065	0.1767181
AGE (Category)	2.7634409	0.6390837
ED (Category)	5.0537634	4.7470781
EXP (Years)	28.7849462	142.82281
INC (Category)	2.7471264	1.5632184
OWN (% Yes)	0.9784946	0.0212716
SIZE (Total acres)	500.7365591	334990.46
LABON (Hours on-farm)	3908.09	5059235.97
LABOFF (Hours off-farm)	540.3064516	1539858.95
WAGES (Gross wages)	121516.85	38292356321
CHILD (% intending transfer)	0.4086022	0.2442730
KNOWLAW (% correct answers out of four)	2.6666667	1.4202899
KNOWCERT (% able to answer)	0.5591398	0.2491819
RISK (Lower number indicates risk-averse)	7.5141177	3.0194740
GENEFF (Conservation procedures)	1.5591398	0.4448340
H2OCAP (One if number known)	0.4301075	0.2477793
SOIL (Water-holding capacity)	151.4444444	957.4406991
EXPECT (% expected source to dry up)	0.1075269	0.0970079
pATT (Predicted attitudes)	0.2964007	0.0464645

APPENDIX C

Table 17

Sample Characteristics

Frequency of Nozzle Replacement	Percent
Every three years or less	29.4
Every three and a half to five years	26.2
Every five to ten years	13.1
Every twelve and a half years	3.3
Every fifteen years	3.3
Every twenty years	1.6
Never	23.0

Missing Response = 32

Type of Irrigation System	Percent
Handline	55.9
Side Roll	34.4
Solid Set	9.7

Source of Irrigation Water	Percent
Pond	4.3
Well	66.7
Stream	29.0

Use of Timer	Percent
No timer on system	7.5
Timer on system	92.5

Table 17 continued

Practice Offset?	Percent
No	49.5
Yes	50.5

Years of Operator Irrigation Experience	Percent
Ten years or less	6.6
Eleven to fifteen years	8.7
Sixteen to twenty years	19.4
Twenty-one to twenty-five years	10.8
Twenty-six to thirty years	17.2
Thirty-one to forty years	21.6
Forty-one to fifty years	14.1
Over fifty years	2.2

Reason for System Choice	Percent
System already in place	15.1
Least costly system available	18.3
Least labor-intensive system available	20.4
Most water efficient system available	4.3
Best system for specific crop and soil	36.6
Other	5.4

APPENDIX D

Table 18
Pearson Correlation Coefficients

	EFF	CROP	AGE	ED	EXP
EFF	1.000	-0.36626	0.00321	0.09099	0.03904
CROP	-0.36626	1.000	0.03130	-0.02527	-0.01619
AGE	0.00321	0.03130	1.000	-0.14239	0.55551
ED	0.09099	-0.02527	-0.14239	1.000	-0.22789
EXP	0.03904	-0.01619	0.55551	-0.22789	1.000
INC	-0.11152	-0.01490	0.06561	-0.29602	0.32943
OWN	0.01776	0.08006	0.04912	-0.20156	0.24676
SIZE	-0.14654	0.03471	-0.20265	-0.12707	0.11049
LABON	0.02842	-0.17694	-0.07785	-0.05393	0.06207
LABOFF	0.11706	-0.03530	-0.02973	0.22409	-0.02273
WAGES	-0.14686	0.10442	-0.19414	0.16996	0.07821
PWRCST	-0.27212	0.31555	-0.08652	-0.26719	0.02490
CHILD	-0.02769	-0.03038	0.24730	-0.38400	0.27819
KNOWLAW	-0.01632	-0.02170	-0.08367	-0.02233	-0.01654
KNOWCERT	0.18679	-0.19382	0.06268	0.06201	0.13516
RISK	-0.04169	-0.05689	-0.32580	0.33119	-0.12192
GENEFF	0.14011	-0.22260	-0.15695	-0.08823	0.01661
H2OCAP	0.09391	-0.15751	-0.09663	0.03858	0.16006
SOIL	0.10548	0.02268	-0.13371	-0.07052	0.01175
EXPECT	-0.08679	-0.10444	-0.07135	0.21563	-0.11929
pATT	0.10210	-0.02869	-0.19549	0.98549	-0.13879
ATTOR	0.04838	-0.05455	-0.01912	0.37191	-0.07356
ATTNAT	0.01270	0.02546	-0.03684	0.30257	-0.02599

Table 18 continued

	INC	OWN	SIZE	LABON	LABOFF
EFF	-0.11152	0.01776	-0.14654	-0.02842	0.11706
CROP	-0.01490	0.08006	0.03471	-0.17694	-0.03530
AGE	0.06561	0.04912	-0.20265	-0.07785	-0.02973
ED	-0.29602	-0.20156	-0.12707	-0.05393	0.22409
EXP	0.32943	0.24676	0.11049	0.06207	-0.02273
INC	1.000	0.06481	0.40266	0.19120	0.01356
OWN	0.06481	1.000	0.06560	0.08900	0.06250
SIZE	0.40266	0.06560	1.000	0.19130	-0.17568
LABON	0.19120	0.08900	0.19130	1.000	0.08664
LABOFF	0.01356	0.06250	-0.17568	0.08664	1.000
WAGES	0.34741	0.06780	0.60129	0.14936	0.03039
PWRCST	0.29680	-0.01170	0.30164	0.37519	-0.08487
CHILD	0.13997	0.12323	0.07586	0.24418	-0.00623
KNOWLAW	-0.00261	0.14592	0.28367	0.06015	-0.07001
KNOWCERT	-0.07181	0.01766	-0.00502	0.03519	-0.13076
RISK	0.12586	0.08748	0.29637	0.03967	0.09901
GENEFF	-0.00531	0.12496	0.11906	0.09473	0.01976
H20CAP	0.07704	-0.02093	0.09121	0.17585	0.06197
SOIL	-0.00778	-0.07866	0.06153	-0.08088	-0.11139
EXPECT	-0.12962	0.05146	-0.05305	-0.04336	0.20010
pATT	-0.25711	-0.16146	-0.10210	-0.03794	0.22593
ATTOR	-0.18961	-0.05241	-0.18452	-0.20140	0.09992
ATTNAT	-0.04564	-0.01281	-0.23941	0.05314	0.22314

Table 18 continued

	WAGES	PWRCST	CHILD	KNWLAW	KNWCERT
EFF	-.14686	-0.27212	-.02769	-0.01632	.18679
CROP	.10442	0.31555	-.03038	-0.02170	-.19382
AGE	-.19414	-0.08652	.24730	-0.08367	.06268
ED	.16996	-0.26719	-.38400	-0.02233	.06201
EXP	.07821	0.02490	.27819	-0.01654	.13516
INC	.34741	0.29680	.13997	-0.00261	-.07181
OWN	.06780	-0.01170	.12323	0.14592	.01766
SIZE	.60129	0.30164	.07586	0.28367	-.00502
LABON	.14936	0.37519	.24418	0.06015	.03519
LABOFF	.03039	-0.08487	-.00623	-0.07001	-.13076
WAGES	1.000	0.25413	-.05776	0.30873	-.17532
PWRCST	0.25413	1.000	0.20635	-0.01011	0.00653
CHILD	.03347	0.20635	1.000	0.15993	.03316
KNOWLAW	.30873	-0.01011	.15993	1.000	.17053
KNOWCERT	-.17532	0.00653	.03316	0.17053	1.000
RISK	.33943	0.06675	-.12856	0.17777	-.09813
GENEFF	.03530	0.14795	.02482	0.11396	.06284
H20CAP	.01266	0.08442	.07316	0.17101	.37771
SOIL	.08197	0.10596	.16092	-0.02378	.06742
EXPECT	-.03677	-0.14213	-.14730	-0.07809	-.18117
pATT	.19859	-0.25763	-.37843	-0.04421	.07587
ATTOR	-.00207	-0.26048	-.30934	-0.07056	-.06126
ATTNAT	-.01691	-0.08048	-.03632	-0.05604	-.05886

Table 18 continued

	RISK	GENEFF	H2OCAP	SOIL
EFF	-0.04169	0.14011	0.09391	0.10548
CROP	-0.05689	-0.22260	-0.15751	0.02268
AGE	-0.32580	-0.15695	-0.09663	-0.13371
ED	0.33119	-0.08823	0.03858	-0.07052
EXP	-0.12192	0.01661	0.16006	0.01175
INC	0.12586	-0.00531	0.07704	-0.00778
OWN	0.08748	0.12496	-0.02093	-0.07866
SIZE	0.29637	0.11906	0.09121	0.06153
LABON	0.03967	0.09473	0.17585	-0.08088
LABOFF	0.09901	0.01976	0.06197	-0.11139
WAGES	0.33943	0.03530	0.01266	0.08197
PWRCST	0.06675	0.14795	0.08442	0.10596
CHILD	-0.12856	0.02482	0.07316	0.16092
KNOWLAW	0.17777	0.11396	0.17101	-0.02378
KNOWCERT	-0.09813	0.06284	0.37771	0.06742
RISK	1.000	0.08489	0.09434	0.04713
GENEFF	0.08489	1.000	0.15173	0.01940
H20CAP	0.09434	0.15173	1.000	0.04275
SOIL	0.04713	0.01940	0.04275	1.000
EXPECT	0.14463	-0.03094	-0.16133	0.10405
pATT	0.33778	-0.07004	0.07834	-0.04954
ATTOR	0.20440	-0.04585	-0.01536	-0.09064
ATTNAT	0.13362	-0.19094	0.09738	-0.04023

Table 18 continued

	EXPECT	pATT	ATTOR	ATTNAT
EFF	-0.08679	0.10210	0.04838	0.01270
CROP	-0.10444	-0.02869	-0.05455	0.02546
AGE	-0.07135	-0.19549	-0.01912	-0.03684
ED	0.21563	0.98549	0.37191	0.30257
EXP	-0.11929	-0.13879	-0.07356	-0.02599
INC	-0.12962	-0.25711	-0.18961	-0.04564
OWN	0.05146	-0.16146	-0.05241	-0.01281
SIZE	-0.05305	-0.10210	-0.18452	-0.23941
LABON	-0.04336	-0.03794	-0.20140	0.05314
LABOFF	0.20010	0.22593	0.09992	0.22314
WAGES	-0.03677	0.19859	-0.00207	-0.01691
PWRCST	-0.14213	-0.25763	-0.26048	-0.08048
CHILD	-0.14730	-0.37843	-0.30934	-0.03632
KNOWLAW	-0.07809	-0.04421	-0.07056	-0.05604
KNOWCERT	-0.18117	0.07587	-0.06126	-0.05886
RISK	0.14463	0.33778	0.20440	0.13362
GENEFF	-0.03094	-0.07004	-0.04585	-0.19094
H20CAP	-0.16133	0.07834	-0.01536	0.09738
SOIL	0.10405	-0.04954	-0.09064	-0.04023
EXPECT	1.000	0.20872	0.04909	0.11577
pATT	0.20872	1.000	0.36612	0.30453
ATTOR	0.04909	0.36612	1.000	0.43689
ATTNAT	0.11577	0.30453	0.43689	1.000

APPENDIX E

Two measures of attitudes (ATTNAT and ATTOR) used were taken from other studies to compare the results from our study with these earlier findings. The ATTOR question was taken from a 1993 Oregon Values and Beliefs study by the Oregon Business Council, and the ATTNAT question was from a sociological study by Dunlap and van Liere (1992).

The participants in both this study and the Business Council study were asked to chose one of the answers below to the question "Which is more important to economic growth in Oregon?"

1 Relax environmental regulation to make it easier for companies to do business
2 Maintain a quality environment to attract people and companies to Oregon

Table 19

Contrast of Results for ATTOR Variable

RESPONSE	PRESENT STUDY (%)	COUNCIL STUDY (%)
RELAX	57.0	16.0
MAINTAIN	33.0	75.0
NO RESPONSE	10.0	
DON'T KNOW		9.0

The results from the Business Council survey and the results from our study are contrasted above. The two studies showed widely different responses to the same question. With an alpha of.025 and d.f. of 90, the calculated chi-sqared exceeds the critical chi-squared. This means a rejection of the null hypothesis that there is no difference between the two survey populations. This is not suprising, as participants in the Business Council survey were from a wider demographic selection than those individuals surveyed in our study. It reached 1,361 Oregonians from the metro area, western, southern and eastern Oregon. Our survey obviously was directed at a smaller and much less diverse group.

Some of the irrigators in our survey seemed to take issue with the "attract people and companies to Oregon" portion of the Business Council question. There were some surveys in which the respondent answered the question, but crossed out the offending portion of the response. It could be that this irritation with a portion of one of the responses had something to do with the response differences between the two studies. Either choice of responses would result in more people coming to Oregon. This is a touchy point for many Oregonians.

The ATTNAT question asked a people chosen at random from across the country to read the statement, "Economic growth should be given priority over environmental protection", and to place their personal beliefs along a 5-point scale.

Table 20

Contrast of Results for ATTNAT Variable

RESPONSE	PRESENT STUDY (%)	SOCIOLOGY STUDY (%)
Agree Strongly	13.7	8.0
Agree	27.4	18.0
Neither[1]	28.4	23.0
Disagree	17.9	30.0
Disagree Strongly	12.6	21.0

[1] Listed as Undecided in environmental sociology study

The results from the Dunlap and van Liere survey and the results from our study are contrasted above. With an alpha of .025 and d.f. of 90, the calculated chi-squared does not exceed the critical chi-squared. This means a failure to reject the null hypothesis that there is no difference between the two survey populations.

The percentage response numbers from this study seem to match those from the Dunlap and van Liere-based sociology survey more closely than they do those from the Business Council survey. This could mean that the lack of implied population increases in the Dunlap-van Liere question led to less biased responses. No part of this second question seemed to offend people as much as the section of the first question indicated above. It could be that this kept the responses between this study and ours more closely aligned.

APPENDIX F

Table 21

Relative Irrigation Efficiency ratios for irrigators in study

EFF	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.3121360937	1	1.1	1	1.1
0.3499534603	1	1.1	2	2.2
0.3527419051	1	1.1	3	3.2
0.4513604207	1	1.1	4	4.3
0.5532788792	1	1.1	5	5.4
0.5593008068	1	1.1	6	6.5
0.5604274547	1	1.1	7	7.5
0.5654514032	1	1.1	8	8.6
0.6004304715	1	1.1	9	9.7
0.6007019864	1	1.1	10	10.8
0.6188179913	1	1.1	11	11.8
0.6253848313	1	1.1	12	12.9
0.6324415888	1	1.1	13	14.0
0.6373737618	1	1.1	14	15.1
0.6587888707	1	1.1	15	16.1
0.6703585657	1	1.1	16	17.2
0.6742903274	1	1.1	17	18.3
0.6914182319	1	1.1	18	19.4
0.692382689	1	1.1	19	20.4
0.6956215878	1	1.1	20	21.5
0.7165707182	1	1.1	21	22.6
0.7562717308	1	1.1	22	23.7
0.7619326919	1	1.1	23	24.7
0.7699566003	1	1.1	24	25.8
0.7719859895	1	1.1	25	26.9
0.7798582729	1	1.1	26	28.0
0.7916077866	1	1.1	27	29.0
0.8161745472	1	1.1	28	30.1
0.8204062028	1	1.1	29	31.2
0.833064368	1	1.1	30	32.3
0.8674381288	1	1.1	31	33.3
0.868800315	1	1.1	32	34.4
0.8780906453	1	1.1	33	35.5
0.879591557	1	1.1	34	36.6

Table 21 continued

Relative Irrigation Efficiency ratios for irrigators in study

EFF	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.8903832556	1	1.1	35	37.6
0.8926474047	1	1.1	36	38.7
0.9016079569	1	1.1	37	39.8
0.9055840054	1	1.1	38	40.9
0.9119886742	1	1.1	39	41.9
0.9169117813	1	1.1	40	43.0
0.937095537	1	1.1	41	44.1
0.9396765822	1	1.1	42	45.2
0.9550576555	1	1.1	43	46.2
0.959166757	1	1.1	44	47.3
0.9633187203	1	1.1	45	48.4
0.9653173136	1	1.1	46	49.5
0.9850251878	1	1.1	47	50.5
0.9963283582	1	1.1	48	51.6
1.0044686979	1	1.1	49	52.7
1.0116991504	1	1.1	50	53.8
1.0246212361	1	1.1	51	54.8
1.036179129	1	1.1	52	55.9
1.0888730757	1	1.1	53	57.0
1.101182404	1	1.1	54	58.1
1.1575944487	1	1.1	55	59.1
1.1682460052	1	1.1	56	60.2
1.180385052	1	1.1	57	61.3
1.1824652261	1	1.1	58	62.4
1.2179369327	1	1.1	59	63.4
1.276336422	1	1.1	60	64.5
1.2911642362	1	1.1	61	65.6
1.3077355316	1	1.1	62	66.7
1.3122423089	1	1.1	63	67.7
1.3455345681	1	1.1	64	68.8
1.3620986359	1	1.1	65	69.9
1.3746603827	1	1.1	66	71.0
1.3775827252	1	1.1	67	72.0
1.4194606104	1	1.1	68	73.1
1.4409469823	1	1.1	69	74.2
1.4682926016	1	1.1	70	75.3

Table 21 continued

Relative Irrigation Efficiency ratios for irrigators in study

EFF	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1.4746860962	1	1.1	71	76.3
1.5236176669	1	1.1	72	77.4
1.5791386861	1	1.1	73	78.5
1.5874878557	1	1.1	74	79.6
1.6203802723	1	1.1	75	80.6
1.6645258753	1	1.1	76	81.7
1.6691518899	1	1.1	77	82.8
1.6995024876	1	1.1	78	83.9
1.7254101354	1	1.1	79	84.9
1.7368497459	1	1.1	80	86.0
1.791231599	1	1.1	81	87.1
1.799305413	1	1.1	82	88.2
1.8700770848	1	1.1	83	89.2
1.9462108922	1	1.1	84	90.3
1.9546260223	1	1.1	85	91.4
2.0084433222	1	1.1	86	92.5
2.0577036745	1	1.1	87	93.5
2.1850228699	1	1.1	88	94.6
2.4065256151	1	1.1	89	95.7
2.5481900248	1	1.1	90	96.8
2.8972990777	1	1.1	91	97.8
3.2203617325	1	1.1	92	98.9
3.6122778891	1	1.1	93	100.0

Table 22

Total Irrigation applied during season by irrigators in study

SEASIRR	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1.32	1	1.1	1	1.1
1.56	1	1.1	2	2.2
2.996	1	1.1	3	3.2
3.9	1	1.1	4	4.3
5.208	1	1.1	5	5.4
5.236	1	1.1	6	6.5
5.302	1	1.1	7	7.5
5.321	1	1.1	8	8.6
5.453	1	1.1	9	9.7
5.61	1	1.1	10	10.8
6.0685	1	1.1	11	11.8
6.16	1	1.1	12	12.9
6.188	1	1.1	13	14.0
6.556	1	1.1	14	15.1
7.224	1	1.1	15	16.1
7.308	1	1.1	16	17.2
7.312	1	1.1	17	18.3
7.4676	1	1.1	18	19.4
8.296	1	1.1	19	20.4
8.393	1	1.1	20	21.5
8.448	1	1.1	21	22.6
8.584	1	1.1	22	23.7
9.49	1	1.1	23	24.7
9.504	1	1.1	24	25.8
9.576	1	1.1	25	26.9
9.698	1	1.1	26	28.0
9.882	1	1.1	27	29.0
10.08	1	1.1	28	30.1
10.098	1	1.1	29	31.2
10.176	1	1.1	30	32.3
10.37	1	1.1	31	33.3
10.64	1	1.1	32	34.4
10.668	1	1.1	33	35.5
10.692	1	1.1	34	36.6
10.752	1	1.1	35	37.6
10.758	1	1.1	36	38.7

Table 22 continued

Total Irrigation applied during season by irrigators in study

SEASIRR	Frequency	Percent	Cumulative Frequency	Cumulative Percent
11.055	1	1.1	37	39.8
11.946	1	1.1	38	40.9
12.5696	1	1.1	39	41.9
12.672	1	1.1	40	43.0
12.72	1	1.1	41	44.1
12.936	1	1.1	42	45.2
13.2	1	1.1	43	46.2
14.144	1	1.1	44	47.3
14.168	1	1.1	45	48.4
14.3352	1	1.1	46	49.5
14.344	1	1.1	47	50.5
14.392	1	1.1	48	51.6
14.454	1	1.1	49	52.7
14.5985	1	1.1	50	53.8
15.204	1	1.1	51	54.8
15.6	1	1.1	52	55.9
15.764	1	1.1	53	57.0
16.74	1	1.1	54	58.1
16.852	1	1.1	55	59.1
16.854	1	1.1	56	60.2
16.932	1	1.1	57	61.3
17.028	1	1.1	58	62.4
17.82	1	1.1	59	63.4
18.579	1	1.1	60	64.5
18.684	1	1.1	61	65.6
19.206	1	1.1	62	66.7
19.422	1	1.1	63	67.7
19.624	1	1.1	64	68.8
20.152	1	1.1	65	69.9
20.2745	1	1.1	66	71.0
21.056	1	1.1	67	72.0
21.472	1	1.1	68	73.1
21.609	1	1.1	69	74.2
22.344	1	1.1	70	75.3
22.572	1	1.1	71	76.3
23.22	1	1.1	72	77.4

Table 22 continued

Total Irrigation applied during season by irrigators in study

SEASIRR	Frequency	Percent	Cumulative Frequency	Cumulative Percent
23.584	1	1.1	73	78.5
23.772	1	1.1	74	79.6
23.972	1	1.1	75	80.6
26.316	1	1.1	76	81.7
26.964	1	1.1	77	82.8
27.885	1	1.1	78	83.9
27.945	1	1.1	79	84.9
29.121	1	1.1	80	86.0
29.184	1	1.1	81	87.1
31.552	1	1.1	82	88.2
31.584	1	1.1	83	89.2
31.925	1	1.1	84	90.3
32.032	1	1.1	85	91.4
35.022	1	1.1	86	92.5
38.584	1	1.1	87	93.5
41.272	1	1.1	88	94.6
44.118	1	1.1	89	95.7
48.6	1	1.1	90	96.8
49.224	1	1.1	91	97.8
57.46	1	1.1	92	98.9
62.48	1	1.1	93	100.0

Table 23

Total crop water requirements during season for fields in study

ET	Frequency	Percent	Cumulative Frequency	Cumulative Percent
3.35916	1	1.1	1	1.1
4.35116	1	1.1	2	2.2
4.3981	1	1.1	3	3.2
6.2875	1	1.1	4	4.3
6.46536	1	1.1	5	5.4
8.275	1	1.1	6	6.5
9.0381	1	1.1	7	7.5
9.40026	1	1.1	8	8.6
10.55236	1	1.1	9	9.7
10.62786	1	1.1	10	10.8
10.6744	1	1.1	11	11.8
10.75036	1	1.1	12	12.9
10.8274	1	1.1	13	14.0
11.14556	1	1.1	14	15.1
11.79036	2	2.2	16	17.2
11.9566	1	1.1	17	18.3
12.00646	1	1.1	18	19.4
12.0756	1	1.1	19	20.4
12.14646	1	1.1	20	21.5
12.62654	1	1.1	21	22.6
12.835	1	1.1	22	23.7
12.9808	2	2.2	24	25.8
13.14486	1	1.1	25	26.9
13.25296	1	1.1	26	28.0
13.3508	1	1.1	27	29.0
13.45946	1	1.1	28	30.1
13.53196	1	1.1	29	31.2
13.57279	1	1.1	30	32.3
13.7416	1	1.1	31	33.3
13.911	1	1.1	32	34.4
14.19654	1	1.1	33	35.5
14.6744	1	1.1	34	36.6
14.71486	1	1.1	35	37.6
14.98636	1	1.1	36	38.7
15.13236	1	1.1	37	39.8
15.54436	1	1.1	38	40.9

Table 23 continued

Total crop water requirements during season for fields in study

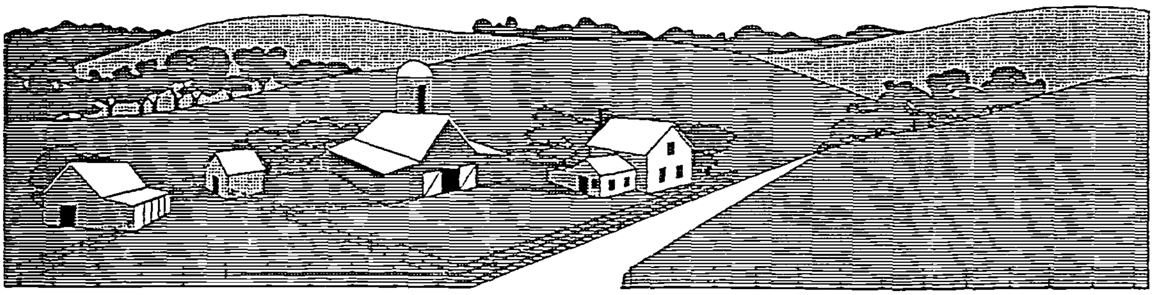
ET	Frequency	Percent	Cumulative Frequency	Cumulative Percent
15.54636	1	1.1	39	41.9
15.55936	1	1.1	40	43.0
16.30736	1	1.1	41	44.1
16.826	1	1.1	42	45.2
16.9916	1	1.1	43	46.2
17.30736	1	1.1	44	47.3
17.34779	1	1.1	45	48.4
17.60336	1	1.1	46	49.5
17.69279	1	1.1	47	50.5
17.907	1	1.1	48	51.6
18.30056	1	1.1	49	52.7
18.45815	1	1.1	50	53.8
18.46986	1	1.1	51	54.8
18.82736	1	1.1	52	55.9
19.51586	1	1.1	53	57.0
19.98956	1	1.1	54	58.1
20.0002	1	1.1	55	59.1
20.0615	1	1.1	56	60.2
20.2461	1	1.1	57	61.3
20.5414	1	1.1	58	62.4
20.88775	1	1.1	59	63.4
21.486	1	1.1	60	64.5
21.5352	1	1.1	61	65.6
21.559	1	1.1	62	66.7
21.60376	1	1.1	63	67.7
21.66416	1	1.1	64	68.8
22.0402	1	1.1	65	69.9
22.23886	1	1.1	66	71.0
22.48518	1	1.1	67	72.0
22.521	1	1.1	68	73.1
22.58206	1	1.1	69	74.2
22.70768	1	1.1	70	75.3
22.78216	1	1.1	71	76.3
22.79726	1	1.1	72	77.4
22.82718	1	1.1	73	78.5
23.21266	1	1.1	74	79.6

Table 23 continued

Total crop water requirements during season for fields in study

ET	Frequency	Percent	Cumulative Frequency	Cumulative Percent
23.6219	1	1.1	75	80.6
24.35229	1	1.1	76	81.7
26.29325	1	1.1	77	82.8
26.45105	1	1.1	78	83.9
26.95018	1	1.1	79	84.9
27.0379	2	2.2	81	87.1
27.16085	1	1.1	82	88.2
27.3779	1	1.1	83	89.2
28.9672	1	1.1	84	90.3
29.02183	1	1.1	85	91.4
29.78595	1	1.1	86	92.5
30.2498	1	1.1	87	93.5
31.32667	1	1.1	88	94.6
31.4795	1	1.1	89	95.7
33.19252	1	1.1	90	96.8
33.82875	1	1.1	91	97.8
36.26952	1	1.1	92	98.9
40.51945	1	1.1	93	100.0

APPENDIX G



IRRIGATION SCHEDULING QUESTIONNAIRE

1. First, did you use a sprinkler system for irrigating mint and/or vegetables in the 1993 season? *(Circle one number)*

    1 YES, IRRIGATED MINT ONLY
    2 YES, IRRIGATED VEGETABLES ONLY
    3 YES, IRRIGATED BOTH MINT AND VEGETABLES
    4 NO, DID NOT IRRIGATE MINT OR VEGETABLES

    → If you did not irrigate either mint or vegetables, this questionnaire is not for you. Please return it now in the enclosed postage-paid envelope.

2. Please give the number of acres for each of the following in the 1993 season.

    a. Total acres of mint irrigated . . . . . . ________

    b. Total acres of vegetables irrigated. . . . ________

    c. Total acres of all other crops irrigated . ________

    d. Total acres of crops NOT irrigated . . . . ________

3. And, how many irrigation pumps, in total, did you use in the 1993 season?

    _________NUMBER OF IRRIGATION PUMPS

We'd like to ask more detailed information about your irrigation systems for mint and/or vegetables.

4. Did you use a handline, side roll or solid set irrigation system for mint or vegetables?

    1 YES
    2 NO

    → If you did not use handline, side roll or solid set systems this questionnaire is not for you. Please return it now in the enclosed postage-paid envelope.

(PLEASE TURN THE PAGE)

5. To answer the rest of the irrigation questions we'd like you to choose your largest mint OR vegetable field on which you used either a handline, side roll or solid set irrigation system in 1993. Please circle the number of the field you select and complete the remaining questions on irrigation for that field only. *(Circle one number)*

   1 MY LARGEST IRRIGATED MINT FIELD
   2 MY LARGEST IRRIGATED VEGETABLE FIELD

6. How many acres are there in the field you just selected?

   _________ACRES

7. What is the <u>dominant</u> soil type for this field? *(Circle one number)*

   01 COARSE SAND
   02 FINE SAND
   03 LOAMY SAND
   04 SANDY LOAM
   05 FINE SANDY LOAM
   06 VERY FINE SANDY LOAM
   07 CLAY OR CLAY LOAM
   08 SILT LOAM
   09 PEAT OR MUCK
   10 OTHER (Specify________________________________)

8. What is the available water capacity of the soil in this field, that is, about how many inches of water per foot of soil?

   ___________INCHES PER FOOT

9. How many pumps did you have in the 1993 season for the field you selected?

   ____________NUMBER OF PUMPS

10. What is the source of water for the MAIN pump used on this field? *(Circle one number)*

    1 LAKE
    2 POND
    3 WELL
    4 SPRING
    5 STREAM

(PLEASE GO ON TO THE NEXT PAGE)

11. Is there a <u>working</u> flow meter on this pump? *(Circle one number)*

    1 NO
    2 YES

12. What is the horsepower rating on this pump?

    _________HP

13. And, what is the pump pressure?

    ________PSI

14. Thinking about the MAIN line for this field (the one you selected in Question 5) please give the diameter of the pipe and length.

    a. Mainline diameter . . _______ INCHES

    b. Mainline length . . . _______ FEET

15. What is the elevation difference between the highest point and lowest point on the main line -- about how many feet? Your best estimate is fine.

    _________ELEVATION DIFFERENCE IN FEET

16. Do you pump directly into the main line without any bends or turns? *(Circle one number)*

    1 YES, PUMP DIRECTLY
    2 NO

17. And, which irrigation system do you use to irrigate this particular field? *(Circle one number)*

    1 HANDLINE
    2 SIDE ROLL
    3 SOLID SET

18. What is the diameter of <u>most</u> of your sprinkler nozzles? *(Circle one number)*

    1 1/8 INCH
    2 9/64 INCH
    3 5/32 INCH
    4 11/64 INCH
    5 3/16 INCH
    6 13/64 INCH
    7 OTHER (Specify________)

(PLEASE TURN THE PAGE)

19. About how many gallons per minute (GPM) do you get from the sprinkler heads? *(Circle one number)*

1 LESS THAN 3 GPM
2 3.1 TO 4.0 GPM
3 4.1 TO 5.0 GPM
4 5.1 TO 6.0 GPM
5 OVER 6.0 GPM

20. How often do you replace the sprinkler nozzles? *(Circle one number)*

1 EVERY YEAR
2 EVERY OTHER YEAR
3 OTHER (Specify_______________)

21. About how far apart are the sprinkler heads?

________FEET APART

22. Please give the number of laterals running in this field at any one time and give their average length.

a. Number of laterals . ________

b. Average length . . . ________ FEET

23. About how far apart are the laterals?

_________FEET APART

24. Do you offset when you change the set? *(Circle one number)*

1 YES
2 NO

25. Is there a working timer on this sprinkler system? *(Circle one number)*

1 YES
2 NO

26. Which one of the following best describes why you chose the sprinkler system that you use on this field? *(Circle one number)*

1 ALREADY IN PLACE WHEN LAND PURCHASED
2 LEAST COSTLY SYSTEM AVAILABLE
3 LEAST LABOR-INTENSIVE SYSTEM AVAILABLE
4 MOST WATER EFFICIENT SYSTEM AVAILABLE
5 BEST SYSTEM FOR SPECIFIC CROP AND SOIL
6 OTHER (Specify________________________________)

(PLEASE GO ON TO THE NEXT PAGE)

27. There are a number of things that might influence a decision to install a more efficient system to conserve water. Please indicate whether or not each of the following would influence you in favor of installing such a system. *(Circle one number for each)*

	Influence you in favor? YES, WOULD	NO, WOULD NOT
a. Availability of technical assistance for irrigation system design	1	2
b. Availability of financial assistance for irrigation system design	1	2
c. Ability to lease or sell excess water to other irrigators without losing my water rights	1	2
d. Ability to lease or sell excess water for instream uses without losing my water rights	1	2
e. Demonstrated ability of the system to increase yield and/or revenue.	1	2
f. Demonstrated ability of the system to decrease production costs.	1	2

The next section addresses the timing of irrigation. Please remember we are still talking about the field you selected in Question 5.

28. What were the approximate dates of your first and last irrigations during the 1993 season for this field?

a. First irrigation ______/______ MONTH DAY

b. Last irrigation ______/______ MONTH DAY

29. For each month of the 1993 season, please indicate the average number of days between each irrigation on this field.

	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.
AVE. DAYS BETWEEN SETS							

30. About how many hours does it take to change the set on this field?

__________HOURS TO CHANGE SET

(PLEASE TURN THE PAGE)

31. For the months below indicate the average number of hours you irrigated during each set.

	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.
AVERAGE HOURS PER SET							

32. About how many days, if any, were you able to interrupt irrigating this field in the 1993 season because of rainfall?

_________ DAYS INTERRUPTED FOR RAINFALL

33. And, about how many days did you interrupt irrigating to harvest the crop from this field?

_________ DAYS INTERRUPTED FOR HARVEST

34. Excluding any demand charge or annual fee, how much did it cost to irrigate this field during the 1993 season?

$__________ POWER COST

35. How many years, altogether, have you had experience working directly with irrigation?

________YEARS OF IRRIGATION EXPERIENCE

36. Do you have a certificate for the water right for this field, is the application pending, or has the application not yet been made? *(Circle one number)*

1 APPLICATION NOT YET MADE
2 APPLICATION PENDING
3 HAVE CERTIFICATE

→ 36a. What is the year of the certificate? Just your best estimate if you are not sure.

______________YEAR

(PLEASE GO ON TO THE NEXT PAGE)

37. What is the maximum rate of diversion that is allowed by your water right in either cubic feet per second or gallons per minute?

_______CUBIC FEET PER SECOND

OR

_______GALLONS PER MINUTE

38. What is the maximum amount of diversion that is allowed by your water right during the season? Please give the acre-feet per acre and the number of acres.

a. Acre-feet per acre _________

b. Number of acres . . _________

39. We'd like to know what you might have been thinking last spring prior to the growing season. Did you think 1993 would be wetter than most summers, drier than most summers or about the same? *(Circle one number)*

1 WETTER THAN MOST SUMMERS
2 ABOUT THE SAME AS MOST SUMMERS
3 DRIER THAN MOST SUMMERS

→ 39a. Which one of the following best describes any worries you might have had early in 1993 about this field's main water source.

1 I THOUGHT THE WATER SOURCE WOULD PRODUCE LESS WATER LATER IN THE SUMMER

2 I THOUGHT THE WATER SOURCE WOULD DRY UP LATER IN THE SUMMER

3 I WASN'T WORRIED ABOUT THE WATER SOURCE

4 OTHER (Specify__________________________)

(PLEASE TURN THE PAGE)

That completes the questions about the field you picked in Question 5. The next few questions are about water rights and Oregon law.

40. Below is a list of statements about water law in Oregon. Please read each one and indicate if you think it is true or false. *(Circle one number for each)*

	TRUE	FALSE	NOT SURE
a. All water in Oregon is publicly owned . .	1	2	3
b. The state has authority to enter private property to inspect irrigation systems.	1	2	3
c. A water right has to be used every year or it will be lost.	1	2	3
d. An irrigator who conserves water on one field can use it to irrigate other fields not on the water right certificate. . .	1	2	3

41. Which of the following statements best reflects your personal response to the question: "Which is more important to economic growth in Oregon?". *(Circle one number)*

1 RELAX ENVIRONMENTAL REGULATION TO MAKE IT EASIER FOR COMPANIES TO DO BUSINESS
2 MAINTAIN A QUALITY ENVIRONMENT TO ATTRACT PEOPLE AND COMPANIES TO OREGON

42. Below is a list of statements that have been made recently about the use of water in Oregon. Please read each one and indicate if you agree strongly (AS), agree (A), neither agree nor disagree (N), disagree (D) or disagree strongly (DS). *(Circle one number for each statement)*

	(AS)	(A)	(N)	(D)	(DS)
a. Economic growth should be given priority over environmental protection	1	2	3	4	5
b. A person should be able to do whatever they want to do with their water right.	1	2	3	4	5
c. Water left instream is wasted water . . .	1	2	3	4	5
d. Many of my neighbors occasionally over-irrigate their fields.	1	2	3	4	5
e. I am reluctant to adopt new irrigation practices until I see my neighbors use them successfully	1	2	3	4	5
f. I am willing to take risks in order to be successful	1	2	3	4	5
g. Water shortages do not affect irrigators in my farming community	1	2	3	4	5
h. There is enough water for both rural and urban users in my community	1	2	3	4	5

(PLEASE GO ON TO THE NEXT PAGE)

Finally, a few more general questions about you and your household...

43. In the table below, please give the approximate number of weeks per year and the number of hours per week, if any, you and other adult members of your household worked on and off the farm in 1993.

	On-Farm		Off-Farm	
	WEEKS PER YR	HOURS PER WK	WEEKS PER YR	HOURS PER WK
a. Yourself . . .	______	______	______	______
b. Spouse/partner	______	______	______	______
c. Other adult. .	______	______	______	______

44. What was the approximate total cash wages and bonuses, before taxes, that you paid to all agricultural workers on your farm during the 1993 season.

$__________TOTAL WAGES/BONUSES

45. How many years has the farm been owned by your family?

________YEARS IN FAMILY

46. And, how many years have you personally been operating the farm?

________YEARS OPERATING

47. Do you have any children? *(Circle one number)*

1 NO
2 YES

→ 47a. How many children do you have?

_________NUMBER OF CHILDREN

47b. How many children, if any, 15 years of age or older are living at home?

_______NUMBER 15 AND OLDER AT HOME

47c. Do any of your children plan to operate the farm one day? *(Circle one number)*

1 YES
2 NO
3 DON'T KNOW

(PLEASE TURN THE PAGE)

48. What is your age category? *(Circle one number)*

1 30 YEARS OR YOUNGER
2 31 TO 45 YEARS
3 46 TO 60 YEARS
4 OVER 60 YEARS

49. What is highest level of education you have completed? *(Circle one number)*

1 8th GRADE OR LESS
2 SOME HIGH SCHOOL
3 HIGH SCHOOL GRADUATE OR GED
4 SOME TECHNICAL SCHOOL OR TWO YEAR COLLEGE
5 TECHNICAL SCHOOL OR TWO YEAR COLLEGE GRADUATE
6 SOME FOUR YEAR COLLEGE OR UNIVERSITY
7 FOUR YEAR COLLEGE DEGREE (BACHELOR'S)
8 SOME GRADUATE SCHOOL
9 GRADUATE OR PROFESSIONAL DEGREE

50. What was your approximate Schedule F farm income for 1993? *(Circle one number)*

1 $25,000 OR LESS
2 $25,001 TO $50,000
3 $50,001 TO $100,000
4 OVER $100,000

51. Is there any additional information that you think we should know that we did not cover in the survey?

(THANK YOU VERY MUCH FOR YOUR COOPERATION WITH THIS EXTENSIVE SURVEY)