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The Role of Human Capital in the Adoption of ConservationTillage: The Case of Aroostook County, Maine, Potato Farmers

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INTRODUCTION

Background

From the colonial times, the public occasionally expressed concern about the effect of soil erosion on the productivity of land and on water quality, but little attention was paid by farmers. Until the 20th century, land was so abundant in the U.S. that farmers had little incentive to husband it. The conservation movement of the late 19^{th} century and early 20^{th} century did not wholly ignore soil erosion, but its main interest was in preservation of forests and management of the public lands. The 1908 White House conference of governors is the highlight of the early conservation movement. It took note of erosion as a problem, primarily in connection with the role of forest and watershed management in reducing sediment damages and in conjunction with irrigation systems and reservoirs.

Until the 1930s, the United States Department of Agriculture (USDA) also showed little interest in soil erosion. Its emergence as a priority issue by the USDA is due to Hugh Hammond Bennet, often referred to as the Father of Soil Conservation in the United States (Crosson 1981). His unflagging efforts, joined with those of like-minded others, moved erosion control to a high place on the national agenda. In 1935, federal legislation was passed establishing the Soil Conservation Service (SCS) of the USDA with Bennet as its first director.

Concern about the productivity and environmental effects of soil erosion has mounted in recent years. Much effort has been put into measurement and damage assessment in the 1970s and 1980s. According to the National Resource Inventory (NRI), in a 1977 survey conducted by the SCS, 1.9 billion tons of soil were eroded by sheet and rill erosion and about 900 million tons, by wind that year in the U.S. Average erosion per acre was 6.8 tons. This is above the 5 tons per acre per year judged by the SCS to be the maximum average erosion level consistent with maintenance of the long-term productivity of the land.

The Yield-Soil Loss Simulator Projection developed by Resource Conservation Assessment (RCA) Service in 1977 indicated that continuation of 1977 rates of erosion in this country over 50 years would reduce crop yield about 8%. Similar results were obtained by Larson et al. (1979). Taken together, these results suggest that continuation of 1977 rates over the next half century may present a major threat to the productivity of the nation's cropland.

The main concern about off-farm effects of soil erosion is water and air pollution. Water pollution results in impaired water quality and turbidity due to increased run-off of agricultural chemicals, with resulting damage to recreational values and aquatic life. By volume, soil is by far the largest pollutant of water (Crosson and Brubaker 1985). In suspension the soil produces turbidity that damages recreational values of the water. Such turbidity must be reduced before the water can be used for domestic, industrial, or other purposes.

Agricultural chemicals, especially fertilizers and herbicides, also impose costs of clean up, damage to aesthetic values and may threaten human and animal health. The principle concerns about fertilizer in the environment have to do with the effect of nitrogen and phosphorus in the water. Nitrates in the water have the potential to convert to nitrites which are toxic in high concentrations. Also, dissolved ammonia in water injures fish. There is also some evidence of damage of the earth's ozone shield because of chemical compounds produced by de-nitrification (White 1973).

There also is concern about eutrophication, a process which involves the nutrient enrichment of lakes and reservoirs. Eutrophication is a natural process, but can be accelerated by the addition of nutrients carried by runoff water and soil eroded from farm land. Eutrophication causes increased growth of aquatic organisms and subsequent decline in the water's dissolved oxygen supply because of the increased demand of oxygen by the decaying organisms. The water becomes incapable of supporting aquatic life.

Erosion also causes accelerated siltation of reservoirs and harbors and rivers resulting in increased flooding. Soil is carried as a suspension in water; when the soil resettles, it clogs waterways, causes increased flooding, shortens the life of reservoirs, and imposes the cost of dredging to keep the harbors clear. Further, dust in the air due to wind erosion can cause damage. Soil carried by wind imposes costs of clean up, damages aesthetic values, and may threaten human health.

The concern about soil erosion in Aroostook County, Maine, is due to estimates of significantly high annual soil loss and the potential consequence to the soil resource base for the agricultural industry and the environmental consequences associated with high rates of soil erosion. The study of Non-Point Agricultural Pollution SNAP estimated that the Aroostook County average annual rate of soil erosion varied between 5.2 and 6.3 tons per acre per year for land in row crops during the years 1979 to 1983 (Hepler et al. 1985). Soil loss in excess of 3 tons per acre per year is considered sufficiently serious to more than offset the natural process of soil formation in most Aroostook county soils, since they are more fragile than some of the midwestern soils. Farmers and public agencies have spent considerable time and money in attempting to control erosion but the problem has not been solved. According to Hepler et al. (1985) there is inadequate moisture to produce a consistent crop quality besides loss of soil and environmental pollution; thus, more conservation treatment is required if the productivity of the soil resource base is to be maintained.

Objective of the Study

Given the continuing potential loss from soil erosion and the significant effort put forth recently to alleviate the problem in Aroostook County, it is important to study ways to improve the success rate of that effort. One way to improve the soil loss problem is for farmers to adopt conservation tillage practices for those areas where there are significant benefits from doing so. So that the agencies involved can focus their efforts in this regard most productively, information on farm and farmer characteristics that play a significant role in the adoption decision should be identified.

A study conducted in Iowa identified important farm and farmer characteristics that influence the adoption of conservation tillage by Iowa farmers (Rahm and Huffman 1984). The objective of this study is to use the methodology proposed by Rahm and Huffman to identify the characteristics important in the adoption decisions of Aroostook County farmers. The Maine and Iowa results also will be compared to identify any differences in the decision-making process in Maine relative to Iowa.

The remainder of this report is organized as follows. First is a brief technical description of conservation tillage practices. Next, the previous work on technology adoption and, in particular, the adoption of soil conservation practices is discussed. Following are descriptions of the study area and of the data used for this study. Then the economic model and empirical estimation procedures are presented, followed by a discussion of the empirical results. The last section contains a summary, the conclusions, and some suggestions for future research.

CONSERVATION TILLAGE

Introduction

National policy seeks through a variety of federal conservation programs to reduce excessive erosion on U.S. agricultural land to levels that maintain the long-term productivity of soil resource and improve water quality. According to the Universal Soil Loss Equation (White 1973), soil loss is a function of soil cover and management practice (C-factor) and supporting conservation practices (P-factor) among other factors. The 1982 National Resource Inventory (NRI) studies indicate that conservation management techniques are not widely used on erosion-prone soils, nor are they concentrated on the most erodible soils (Assessing the NRI, Volume 1). This has led some soil scientists to believe that conservation efforts are generally fruitless nationwide (Hepler 1980). Schultz (1964) argues that in spite of the relatively high agricultural achievement by U.S. farmers, they apparently have little perception of the value of their soil resource and are indifferent to soil losses.

However, there is interest in soil conservation as can be seen by the re-enforced efforts within the research community. Among other things this interest has posed new challenges for refining and understanding soil erosion processes and environmental consequences. One soil conservation technology that has received a lot of attention over the past decade is conservation tillage.

Definition of Conservation Tillage

There is no precise, commonly accepted definition of conservation tillage. The common element of the various definitions is the presence of crop residues on the soil surface to reduce water and wind erosion and to increase soil moisture.

A conservation tillage system, broadly defined, is any tillage system that creates an environment as good as possible for the growing of crops and that optimizes conservation of the soil surface and water resources consistent with sound economic practices. According to Crosson (1981), conservation tillage is synonymous with maximum or optimum retention of residues on soil surface and utilization of soil herbicides to control weeds where tillage is not or cannot be performed. Conservation tillage methods range from no till (an extreme form of conservation tillage) to varying degrees of minimum or reduced tillage.

The no-till method

The no-till method involves placing the crop seed or seed transplant into the soil by a device that opens a trench or a slot through the sod or previous crop residues only sufficiently wide or deep to receive the seed or transplant roots and to provide satisfactory coverage. No other soil manipulation is required. The weeds are controlled by herbicides, crop rotation, and plant competition. The devices commonly used in planting are the fluted coulter or angled disk.

Minimum tillage and reduced tillage methods

Reduced tillage refers to a reduced number of passes over field. This may be due to reasons other than soil conservation; for example, increased costs of fuel. In this case the amount of soil loss prevented can be negligible because the tillage equipment remains unchanged. On the other hand, minimum tillage refers to limited tillage where the total field surface is still worked by tillage equipment that minimizes soil disturbance. The Resource Conservation Glossary (1976:15g-16g) defines minimum tillage as that "amount of tillage required to create the proper soil conditions for seed germination and plant growth."

Costs and benefits of conservation tillage

Less labor per acre may be used with conservation tillage because labor is saved by reducing the number of passes over the field. As Crosson (1981) observed, the labor saved confers no advantage to conservation tillage unless the labor has some other productive use or has value to the farmer as increased leisure. The importance of the difference in labor requirement depends upon how important labor costs are in relation to total costs, exclusive of land costs (assuming that land costs are not affected by the choice of tillage technology). The effect on profit could be substantial particularly if cost margins were small. If all other costs, as well as yield, remained the same the shift in tillage practice could save the farmer money by reducing total costs.

Data on machinery and investment costs are fragmentary for the two classes of technology and specific to type, location, and size of the farm. Most of the data however show that conservation tillage costs are lower (Crosson 1981; and Girt 1978). It has been hypothesized that direct planting into untilled soil requires less power than conventional tillage, so a smaller, less expensive tractor will suffice for conservation tillage.

It is plausible that tractor maintenance costs would also be less with conservation tillage because the farmer makes less frequent use of the tractor than with conventional tillage.This judgement applies to situations in which farmers convert entirely to conservation tillage. Some observers (Crosson 1981; and Girt 1978) believe that many farmers who adopt conservation tillage will want to maintain the capacity to use conventional tillage every few years to reduce the weed problem and deal with soil compaction which can become a problem with conservation tillage.

Other farmers may use both conservation tillage and conventional tillage because they have a variety of soils; some are well adapted to conservation tillage and others are not. For farmers who adopt this strategy, machinery investment costs will probably be greater. There is a less expensive alternative to additional investment in machinery, that is, to hire custom conventional tillage when needed. According to Girt (1978), many farmers view conservation tillage as a complement to conventional tillage rather than as a substitute.

Conservation tillage generally requires less fuel than conventional tillage because of fewer passes over the field and the elimination of plowing and disking. As in cases of labor and machinery investment cost estimates of fuel savings vary (Girt 1978).

There are differing views about whether conservation tillage and conventional tillage require different amount of fertilizers. The view commonly expressed in the literature is that under given soil conditions, conservation tillage often requires more fertilizer than conventional tillage because the cool, more moist soils with conservation tillage slows mineralization, especially where soils are poorly drained.

Conservation tillage relies more on herbicides and less on cultivation to control weeds than conventional tillage. This is particularly marked in no till where higher rates or more costly herbicide combination are usually needed for adequate weed control. Phillips et al. (1980) state that a reduction in tillage generally requires about 50% more herbicides.

There are a number of reasons why any form of conservation tillage may require more herbicides to maintain yields than conventional tillage and why no till definitely does. Under specific conditions a given level of weed control may be achieved either by tillage, or by herbicides, or some combination of both. If control by tillage is reduced, then a compensatory increase in the amount of herbicides applied is necessary to maintain the same level of control. A second reason why conservation tillage is likely to require more herbicides is the efficiency effect. Apart from the substitutional effect, more herbicides must be applied to achieve a given level of weed control because some of the herbicides get tied up by the crop residue. Herbicide efficiency is thus reduced. A third reason why conservation tillage may require more herbicides than conventional tillage is the environmental effect. The surface residue accompanying conservation tillage usually reduces evaporation of soil water so that soils are typically more moist with conservation tillage than with conventional tillage. The increased moisture improve the conditions for germination and growth of weeds.

It is frequently stated in the literature (White 1973; Crosson 1981; and Girt 1978) that conservation tillage requires a greater variety of herbicides than conventional tillage, but it is not clear that greater variety implies greater quantity. There also seems to be a consensus that over time perennial weeds become more important with conservation tillage, especially no till. This is because herbicides do not attack the root system of these weeds as tillage does, thus giving them a competitive advantage relative to annual weeds. It is not clear that the relative shift from annual to perennial weeds requires heavier application of herbicides. It may mean instead that conservation tillage becomes uneconomical relative to conventional tillage in places where perennial weeds are a problem. Some weeds cannot be adequately controlled with any amount of currently available herbicides. In such instances, the economic disadvantage of conservation tillage may be significant. For given kinds and prices of herbicides, the requirement for more of them increases the farm level and social cost of conservation tillage relative to conventional tillage.

Conservation Tillage in Potatoes

Potato culture is particularly tillage intensive and this often leads to organic matter depletion, unprotected soils and increased soil erosion. Frequently the rows are oriented up and down the slope to ensure surface drainage and to prevent the detrimental effects of ponding on the crop. Additional tillage required to hill during the growing season creates ridges. If these ridges are oriented up and down the slope, they can intensify the effect of moving water. Harvesting operations also cause deep soil disturbances, and they are usually done too late in the fall in the northern part of the county to permit the establishment of winter cover crops. All these conditions aggravate soil erosion on potato cropland.

In the mid-1980s, a relatively low demand and low prices for potatoes combined with spiraling levels of farm indebtedness forced many farmers out of business. The remaining farmers, in order to overcome poor market conditions, have increased the intensity of their farming operations to increase revenues from their cropland acreage. Thus, soil conservation has been of low priority in potato production although higher recent prices has alleviated the situation somewhat.

Whereas crops like corn, legumes, and grasses show promise in helping to control erosion because they leave a substantial amount of residue, potatoes and other crops, like soybeans, cotton, and sugar beets, leave little residue and make soil conservation more difficult to practice. However, in rotation with other crops, soil conservation can be achieved in potatoes. Hinkle (1980) observed a 40% decrease in runoff with potato-oats-sod rotation compared with continuous potatoes.

Conservation practices have been applied on Aroostook County potato farms to varied degrees over the past 40 years. The Field Appraisal of Resource Management (FARMS) study (Hepler et al. 1983-85) reports that farmers in Aroostook County have carried out a wide array of conservation management, from very good to very poor, over several decades. These practices address one or more of the factors contributing to the rate at which cropland erodes. However, only 41% of the land has been adequately treated according to the SNAP study.

Conservation tillage was recommended as a viable alternative for controlling soil loss by the U.S. Army Corps of Engineers (New England Division) and the Soil Conservation Service after a 3-year economic feasibility study in 1980. According to the study, there was severe lack of soil conservation practices over the 75% of 180,000 acres of cropland under potato production.

PREVIOUS WORK ON THE ADOPTION OF A NEW TECHNOLOGY

Factors Affecting Technology Adoption

Many recent agricultural studies support the hypothesis that investment in formal education and extension enhances allocative skills. Studies by Fane (1975), Khaldi (1975) and Petzel (1978) show that schooling and extension improve the farmer's response to economic disequilibria and that farmers who have invested in more years of formal schooling are better cost minimizers. While some studies have suggested profitability in explaining rates of adoption (Dixon 1972) others have emphasized risk and uncertainty (Marra and Carlson 1987). Although rainfall, soil type, and topography greatly influence soil loss rates, management decisions can exacerbate or mitigate their effects. Soil management decisions at the farm level have been analyzed by maximizing expected net income over a planning horizon. Dixon (1972) postulates that an individual calculates the net income effect of a proposed new technology over time and compares it to the expected net income without the new technology. Within this framework, other things being equal, individuals may reach different conservation decisions depending on their planning horizon. Dixon (1972) also hypothesized that the level of education of an individual is associated with his or her planning horizon.

The conceptual foundation of agricultural technology adoption can be traced back to Zvi Griliches's (1957) analysis of wide cross-sectional difference in the use of hybrid seed corn in the United States. He treated hybrid corn as a case study in the economics of technological change and demonstrated a union of the theoretical and empirical approaches. Griliches (1957:519) hypothesized that "a substantial proportion of the variation in the rate of acceptance of hybrid corn is explainable by differences in the profitability of the shift to hybrids in different parts of the country." He argued that the proportion of a total population that have adopted a new innovation (i.e., total acreage in each state planted with hybrid seed) at any moment in time should be regarded as points on a single time trend. His analysis involved fitting logistic trend functions to the national hybrid corn data. The dynamic properties of the logistic curve were summarized by three separate parameters representing the date of origin, the slope or rate of acceptance, and the ceiling. The parameters of the logistic curve were obtained by fitting the log linear transform (logit) of the logistic curve. When the procedure was applied to the proportion of total acreage in each of the states in the U.S., it was found that the process of innovation, adoption, and distribution of a particular invention to different markets and its acceptance by entrepreneurs is amenable to economic analysis.

Griliches accounted for a large share of spatial and chronological differences in the use of hybrid corn with the help of economic variables. The economic variables included supply factors, i.e., availability and demand factors, i.e., acceptance of hybrid corn. He further explained the lag in development of adoptable hybrids for particular areas on the basis of varying profitability of entry. He was also able to explain long-run equilibrium use of hybrids and the rate of approach of the equilibrium by differences in the profitability of the shift from open pollinated to hybrid varieties.

Dixon (1980) used similar but slightly longer run and more recent data for most of the states and improved estimating techniques (weighted regressions to correct for heteroscedasticity) to re-estimate Griliches equations and he obtained results supportive of Griliches.

Schultz (1964:67) referring extensively to Griliches work, also asserted that "one approach to the explanation of observed differences in the rate of acceptance of a new innovation is in terms of cultural variables ....and another approach ...is in terms of profitability." He further asserts that "to the extent that the term profitability variables and cultural variables have meaning, it is difficult to accept that they are unrelated or mutually exclusive; if anything they are complements rather than substitutes."

Factors that Influence the Adoption of Soil Conservation Practices

Despite the significance of loss of potential farm revenues associated with erosion, adoption rates of many conservation practices, particularly conservation tillage systems, are very low (White 1973). The decrease of the effect of erosion on farm revenues depends largely on the increased adoption of soil conservation practices. Girt (1978) lists seven factors that affect the adoption of soil conservation:

awareness of the problem;
physical factors;
personal factors;
type and form of information;
availability of solution;
economic factors;
type of farm operation.

The adoption process begins with the recognition of the erosion problem. Farmers who do not believe they have a problem will not take action to alleviate it. In addition to being aware of erosion, farmers must also be aware of the extent to which it affects their net income now and in the future. Many farmers have other problems, such as debt and low income, that they may perceive as more significant. Under these circumstances, action will only be taken if farmers view the problem of soil erosion as a priority and are financially able to make adjustments.

Control of soil erosion to achieve desired conservation goals is related to land characteristics. Soil is not homogeneous and as such, general recommendations without accounting for differences in topography and climatic conditions may result in failure or inappropriate use of conservation measures. Even within a farm, differences in soil characteristics may require a variety of measures. Studies by Timmons and Fischer (1963) in Iowa, Coughenour and Kothari (1962) in Kentucky, and Carlson et al. (1981) in Idaho have indicated a positive relationship between farm size and adoption of soil conservation measures. This may occur because operators of large farms have more flexibility in their decision making, better access to capital, and the opportunity to experiment with new conservation practices on a small portion of their farms. Moreover, high fixed costs for control measures can slow the rate of adoption on smaller farms. Further, Wagner, et al. (1981) suggested that the operators of the large farms are better able to deal with the risk and uncertainty often associated with new agricultural practices. Buttel (1981) found a negative relationship between farm size and adoption. He maintains that operators of large farms are likely to create or ignore erosion problems compared to operators of small farms since large farm machinery is often incompatible with many conservation practices.

Several studies including those by Sampson (1974), Hoover and Waitala (1980) and Lasley and Nolan (1981) have shown that the age of the operator is related to the adoption of conservation practice. It appears that younger farmers perceive conservation practices as being profitable and are therefore more willing to accept the associated financial risk. They are also more likely to reap the long-term benefits of conservation practices.

Denison (1962) postulated that education plays a significant role in productivity regardless of occupation; that is, the more education an individual has the more able he or she will be to allocate inputs efficiently. More highly educated people tend to act more favorably toward controlled land use since they may be better able to perceive the potential impacts and the consequences of uncontrolled use. Also education is an indicator of the farmer's ability to deal with abstract ideas and should facilitate the operator's capability to determine the feasibility of the alternative solutions being proposed.

However, instruments that do not promote voluntary adoption of soil conservation measures will probably be resisted by the farm community. A survey of farmers in Iowa in 1980 by Korshing and Nowak found that economic incentives and educational programs were acceptable to the majority, only 28% indicated economic penalties were acceptable, and 24% viewed legal regulation as an acceptable method of controlling erosion. These instruments must be evaluated against such measures as equity, cost, complexity of administering, and difficulty of targeting before being implemented.The complexity of the adoption process dictates that a variety of program instruments might be used by government to increase adoption rates.

The adoption of soil conservation practices is highly dependent on the type and form of technical and economic information. To make rational decisions on the adoption of conservation practices, farmers need accurate and easily understandable information, such as long- and short-term economics of conservation systems, recommended cultural practices and rates of soil erosion for varying farming practices. According to Wall (1984) most farmers in southwest Ontario were aware of soil erosion problems, less than half indicated that they wanted to adopt new or additional soil management practices. The primary reason for not implementing measures included poor economics, lack of information and lack of time. As Girt (1978:5) noted, "The lack of information and in some instances misinformation are major reasons for farmers not adopting conservation farming practices. Their perceptions of poor economics of conservation tillage is probably due, in part, to the fact that some equate yields to financial returns."

The key to preventing soil degradation is the availability of economically viable production alternatives. Only for some farms are economically and technically feasible solutions currently available. Further research is needed in such areas as pest control, tillage equipment, and cultural practice, such as fertilizer placement, to overcome problems associated with some conservation techniques. Improvements in the area will require continued research efforts.

The actual and perceived economic returns of conservation practices are a major reason for their low adoption rates. Unlike most agricultural technologies, the economic benefits often do not accrue immediately after adoption and are uncertain. This makes it difficult for farmers to make rational decisions on adoption. Future erosion rates, commodity prices, input prices, and technological developments will all influence the profitability of conservation tillage systems and non-conservation systems.

The economic assessment of conservation farming systems should be based on the value of the discounted net income with conservation tillage as opposed to non-conservation systems. The net present value of conservation practice depends on a farmer's planning horizon, personal rate of discount, annual net profit, and the resale value of land. The planning horizon will depend on such factors as the operator's age or intentions to transfer the farm to another family member. In general, the longer the planning horizon, the more favorable will be the economics of conservation practices. An appropriate discount factor depends on such factors as alternative investment opportunities and individual risk attitudes.

The discounted income stream will also depend on annual net profit with conservation tillage as opposed to non-conservation systems. As the productivity of the soil is improved or maintained, conservation systems often result in a higher net profit in the longer term. However, on the discounted basis, profit in the future is of less value to the farmer than profit today.

The resale value of land also affects the discounted income. Some current evidence indicates that farmers are willing to pay little or nothing more for land that has been properly managed. Interviews undertaken by the Conservation Foundation concluded that almost no premium is paid for land on which permanent conservation measures have been applied, or on which the soil has been carefully husbanded (Batie 1984). The lack of premiums for properly managed land reduces the economic incentives of conservation practices and therefore adoption rates. In addition to the net present value of income, the level and source of income also appear to be correlated with the adoption of soil conservation and farming practices. Lasley and Nolan (1981) found that farmers who tend to cooperate with soil conservation organizations have slightly higher incomes than non-cooperators.

Farm debt may influence the adoption of soil conservation measures in two ways. First, to pay off high debts, for example mortgages, operators are forced to plant high-value row crops that leave significant portions of the soil exposed throughout the growing season. Secondly, farmers with high debts find it difficult to finance conservation measures. Blase and Timmons (1961) found that the majority of farmers (60%) surveyed cited debt servicing as a major obstacle to adopting conservation practices in western Iowa.

Access to capital is necessary to finance adoption of some erosion control practices. This differential access to borrowed capital is often cited as a factor affecting adoption rates, especially for those measures requiring large investment. The farmers' land tenure arrangement may also be a significant factor to the adoption of erosion control measures (Ajaga 1980; and Dillman 1978). Earlier studies (Frey and Otte 1952) found that tenancy arrangements are very important in explaining adoption or non-adoption. Owners, unlike tenants, tend to employ more control practices because they are likely to reap long-term economic benefits directly from conservation practices. The relationship between tenancy and soil conservation is partly a function of tenants rarely being compensated for improved land or penalized for land degradation (Cook 1981).

Lee and Stewart (1983) hypothesized that minimum tillage differences among landownership groups can be accounted for by land quality differentials or regional locations. They analyzed the relationship of the explanatory variables and the minimum tillage rates with a linear model in logit, or log-odds, scale. They found that full-owner operators and land owners with small holdings have higher minimum tillage adoption rates on cultivated cropland than do other landownership groups after accounting for land quality and regional location.

Just and Zilberman (1983) investigated the role of risk and uncertainty in technology adoption. The Just-Zilberman model (1983) is an extension of the Baron-Sandmo model of producer behavior under uncertainty, where the expected utility of the farm firm was expressed as a function of total acreage, return from pro-duction, and fixed costs of adoption. Marra and Carlson (1987) empirically tested the Just and Zilberman model using double-cropped soybean data from individual farms in the Southeast. They investigated the role played by farm size, risk attitudes and joint distribution of returns, credit constraints, and fixed costs of adoption of risky technologies. From their analysis, they concluded that farm size/ technology adoption relationship was consistent with risk aversion and a high covariance of returns between the old and the new technology.

Putler and Zilberman (1988) used logit analysis on data from a survey of Tulare County, California, to analyze the pattern of computer technology adoption. Their results indicated that the probability of computer ownership is significantly influenced by the size of the farming operation, the education level of the farmer, the age of the farmer, and the ownership of a non-farming related business.

Rowberry and Anderson (1983) established a crop rotation project to determine the effect of crop rotation on yield and quality of potatoes and to relate the results to the pertinent soil properties. A profitability study of continuous potato versus rotation including potatoes and other cash crops demonstrated that even though continuous potato production had caused a reduction in yield by the end of the 7-year cycle, it remained the most profitable cropping system. However, they indicated that continuing these trials for several years should determine whether or not they are mining the soil. Rowberry and Anderson's project also demonstrated that selected crop programs by themselves did not reduce the soil losses to a tolerant level for a specific slope condition.

Rahm and Huffman (1984) not only formulated a general model for assessing the impact of specific human capital investments on decisions to adopt or not adopt a single production technology, but also empirically specified and estimated the model in an attempt to analyze and evaluate the adoption of reduced tillage by Iowa farmers. They hypothesized that investment in general education, job training, experience, information, and mental and physical health serve to develop and enhance allocative skills and thus reduce adoption error. Their method will be described in more detail later in this report.

Rosenman and Lawrence (1986) using data from the FARMS study in Aroostook County, Maine, developed and estimated a regression model to explain variation in potato yield. Among the explanatory variables used were soil management, experience, number of acres farmed, and potential erosion. They found that "experienced" farmers had lowest potential erosion, while "young" farmers had the highest potential erosion. They also found that, other things constant, increase in potential erosion resulted in an increase in soil management. In addition to the county-wide model, they estimated models for selected subsets of the entire data set. Their results showed that high yields are associated with "experience" and "large" farms. Furthermore their analysis showed that soil management and crop production decisions appear to be dominated by variables not directly related to the properties of the soil. As such conservation behavior may be motivated by various exogenous or endogenous forces including human capital. Hepler et al. (1985) analyzed the relationship between potato yield and quality to estimated soil erosion and the individual factors of the USLE. Their data set was formed of 429, 1980-FARMS plots where potato yield was reported. Gross yield was regressed against conservation districts, potato varieties, and erosion among other factors. The analysis showed significant differences among varieties for gross yield, but no significant difference was found for yield and quality to predicted erosion or the separate factors of the USLE. In addition to the above, the data set was reduced to include only the 334 plots of the principal 8 varieties and soils. Again a significant difference was found among varieties, but no significant relationship was found between quality or yield and the USLE or its individual factors. However, when the data set was modified to include only the potato plots on Caribou soils and 7 potato varieties, statistical analysis demonstrated a significant response for potato yield to erosion. All potato varieties showed a comparable decrease in yield with increasing rate of erosion (Hepler et al. 1985). The same procedures were applied to the 1981 and 1982 FARMS data set and obtained similar results.

DESCRIPTION OF THE STUDY AREA

Environmental Setting

The County has humid continental climate with short, mild summers and long, cold winters. Average monthly temperatures are about 40 F. Daily temperatures in the summer average between 50 F and 70 F, but occasionally rise into the 90s F. In winter, sub-zero temperatures are frequent.The annual average precipitation is about 36 inches, which includes about 100 inches of average annual snowfall. The average frost-free period is 120 days. The average growing season from planting in mid-May to harvesting in early September is 110 days.

Soil Types

According to the Soil Conservation Service's Soil Survey, Aroostook County, Maine, 1964, several main patterns of the soils, called soil associations, exist in Aroostook County. Each association contains a few major soils and a several minor soils in a pattern that is characteristic but not uniform. The soils within one association differ among themselves in some properties, for example, slope, depth, stoniness, and natural drainage. The associations are named for the major soil series in them.

Caribou-Conant association

These are smoothly sloping soils derived chiefly from shale and limestone. They comprise the area known as the limestone valley of Aroostook County. This is the most highly specialized potato-producing area in the state. This soil association consists mainly of broad, gently rolling ridges of glacial till soils on the uplands. Each ridge or hill has a nearly level top and smoothly sloping sides. In general the broad ridges consist of deep, well-drained Caribou soils, which make up more than 50% of the association.The Caribou soils are used mainly for potato production. The Caribou soils grade smoothly to the moderately wet Conant soils in the slight depression of the ridges. The Conant soils are easily farmed because of the gently rolling to slightly undulating relief. The Caribou soils are mostly used for potato growth in rotation that includes peas, small grain, and hay.

Plaisted-Perham-Howland-Daigle association

This association is made of smoothly sloping soils derived from acid rocks. More than half of the acreage of these association consist of well-drained Perham and Plaisted soils. Most of these two soils occur on high ridges. Depressions and low areas consist of the moderately wet Howland soils and the Daigle soils.Some areas have been cleared and are used for growing crops. Peas, small grain, and hay are grown. However, thousands of acres have never been cleared and therefore have been left in forest. Mixed hardwood and softwood trees grow on the soils. Spruce is the most common tree.

Mapleton-Conant association

The association is made of irregular sloping, shallow to moderately deep soils derived from calcareous rocks. Irregular relief is the outstanding characteristic of this soil association. The bedrock under Mapleton is partly weathered, but contains unweathered limestone. About half of the acreage consist of Mapleton. Depressions consist of poorly drained conant soils. About three-fourths of the land is used for potato, peas, small grain, and hay production.

Thorndike-Howland association

This association consists of irregularly sloping soils derived from acid rocks. Irregular broken relief is characteristic of this association. The shaly Thorndike soils are more common on the slopes. Moderately wet depressions consist of Howland soils. These Howland soils are deeper than the other soils of the association and have smooth relief. Approximately 20% of this land is used for crop production. Most of the rest is forested.

Stetson-Allagash-Hadley-Winooski association

The association consists of nearly level to sloping soils of the flood plains and terraces. The soils on the higher terraces have a surface layer of gravelly loam underlain by sand and gravel. The soils are made up of well-drained silt, sand, and gravel. Stetson soils are most common on the higher terraces. The Allagash and Hadley soils are well drained and nearly level. The well-drained Hadley and moderately well drained Winooski soils are on level areas of the level plain a few feet above the streams. Nearly all the acreage is used for crop production.

Easton-Washburn-Monarda-Burnham association

This association consists of nearly level to gently sloping, poorly drained soils. Wet, nearly level, extensive areas covered with dark forests of spruce are typical of this association. Monarda and Burham soils are predominant. Easton and Washburn soils are also extensive. Only a small part of the acreage has been cleared because the soils, unless drained, are too wet for crop production. Also, Monarda and Burnham soils are very stony.

THE DATA

The Surveys

An inventory was taken of the land used for row crops in the St. John's Valley, Aroostook-Resource-Conservation and Development Project area by the St. John's Valley Soil and Water Conservation District Administration, in cooperation with the Central and Southern Aroostook SWCDs. The inventory, Field Appraisal of Resource Management Systems, (FARMS) was done as a complement to the 1977 National Resource Inventory (NRI). During data collection for FARMS, it was estimated that an 8-10% sample would provide reliable data on a county-wide basis. There were approximately 246,000 acres of cropland then; therefore, a 20,000- to 30,000-acre sample was needed.It was decided to sample 24,000 acres composed of 300 randomly selected 80-acre crop field plots. During the years 1980, 1981, and 1982, 100 field plots were inventoried each year. For each sampled plot, soil chemistry properties, crop history, crop management, crop yields, and monthly rainfall information were collected. Farmers were contacted by a soil and water district supervisor to obtain sociological information. Information gathered from the inventory was computerized and analyzed by researchers at the Maine Agricultural Experiment Station.

Follow-up mail surveys were sent to all of the farms identified in the FARMS dataset to track their soil conservation practices and to elicit further farm and farmer information. These surveys were conducted in 1985, 1986, and 1987. Many farms were no longer in business when the mail surveys were conducted, and some that were, did not respond. In all, complete information was compiled for 43 farms, which were used as the basis for the statistical analysis. These farms represent 65% of the potato acreage sampled in the FARMS study.

The basis for choosing these farmers was response to the 1987 potato grower survey because the dependent variable for analysis was elicited from that survey and because this was the only year in which information on extension contact was gathered. Response in 1987 was then used as a criterion to extract information from the 1986 and 1985 potato grower surveys and from the FARMS dataset.

The names selected from the potato grower survey were matched with name codes in the FARMS dataset. The FARMS dataset was set up in such a way that each farmer's name code could appear more than once in any one year (1980, 1981, and 1982) depending on the number of sample plots chosen from a farm. Also, a name code could appear in all the three years, in two years or only in one year depending on when and how often a farm was sampled. To avoid duplication of variables from individual farmers, random number tables were used to pick one code associated with a name code. If a farmer was randomly chosen more than once, only the code from the latest of the three years was kept. Using the codes, data from the potato grower surveys were merged with that from FARMS to create the dataset used in this study. The data to be used in the analysis are described in the tables below. Early 1980s refers to data from the years 1980, 1981, and 1982 collectively, while later 1980s refers to 1985, 1986, and 1987 collectively.

Farm and Farmer Characteristics

Farm Size

Table 1 describes the dataset information on total potato acreage and mean potato acreage harvested for the early 1980s and for acreage planted in 1987. Assuming the acres planted are all harvested, the total and the mean potato acreage of the farms for the sampled group has been decreasing over time.

Table 2 shows the distribution of acres of potatoes harvested for the early 1980s and by acres planted, for 1987. Over the time of study, the potato acreage planted and harvested is concentrated below 400. In the early 1980s about 67% of the farms were growing less than 300 acres of potatoes, but by the mid-1980s, almost 80% of the farms were growing less than 300 acres of potatoes.

Table 1. Total and Mean Potato Acreage per Farm Over Time

Year	Total	Mean	Std. Dev.	N
Early 1980s	20,646	362.21	(444.16)	57
1987	13,368	226.60	(337.20)	54

Table 2. Distribution of Potato Acreage Per Farm

	-------- Early 1980s -------- N=54			-------- 1987 ---------- N=52		
Size	Freq	%	Cum %	Freq	%	Cum %
1–99	6	10.8	10.5	17	28.9	40.7
100–199	17	30.2	40.4	17	28.9	69.5
200–299	15	26.7	66.7	6	10.2	79.7
300–399	3	5.4	71.9	5	8.5	88.1
400–499	6	10.8	82.5	0	0	88.1
500–599	3	3.6	86.1	1	1.7	89.8
600–699	1	1.8	87.9	0	0	89.8
700–799	1	1.8	89.5	1	1.7	91.5
800–899	0	0.0	89.5	1	1.7	93.2
900–999	2	3.6	93.0	0	0	93.2
>1000	4	7.2	100.0	4	6.8	100.0

Conservation programs

Table 3 shows the percentage of farmers (out of the total number of farmers who responded to the Farms Survey) who participated in various conservation programs during the years 1980, 1981, and 1982. There are 38 farmers (67.9%) from the 1987 Potato Grower Survey who have a Conservation Plan (Conservation Contract) filed with A.S.C.S. The Conservation Plans were filed between 1936 and 1987.

ACP = Agricultural Conservation Program
FIP = Forestry Incentive Program
RCWP = Rural Clean Water Program
PL566 = Public Law 566 Non-Point Pollution

Table 3. Participation in Various Conservation Programs in 1980, 1981, and 1982

	1980 N=23	1981 N=16	1982 N=26
Conservation Plan with SCS	69.57	81.25	92.31
ACP	95.65	93.75	80.77
FIP	30.43	6.67	11.54
EMS	4.35	18.75	0.0
RCWP	0.0	0.0	0.0
PL566	0.0	0.0	0.0
OTHER	0.0	0.0	11.54

Cost sharing

From the 1987 survey, farmers indicated the pattern shown in Table 4 for cost sharing of reduced tillage practices from ASCS. Cost sharing consists of a per-acre payment to the farmer for certain soil and water conservation efforts. The program payments and requirements have varied over the time of the study. The amount received ranged from $5-$550 per acre.

Table 4. Cost Sharing Pattern

Year	Freq	%
1981	5	29.4
1982	6	33.3
1983	9	42.9
1984	12	52.2
1985	16	59.3
1986	19	65.6
1987	15	60.0

Farm organization

Table 5 shows the distribution of farm organization, while Table 6 shows farm ownership and management patterns for the years 1980, 1981, and 1982. This information is not available for later 1980s. Most of the farms under study (over 80%) are individually owned. Most of the farmers not only own, but also manage their farm.

Table 5. Distribution of Farm Organization for 1980, 1981, and 1982

	1980 N=23	1981 N=16	1982 N=26
	Freq (%)	Freq (%)	Freq (%)
Individual	19 (82)	13 (81)	21 (81)
Partnership	0 -	2 (13)	3 (12)
Corporation	2 (9)	0 -	2 (7)
Other	2 (9)	1 (6)	0 -

Table 6. Type of Farm Ownership and Management for 1980, 1981, and 1982

	1980 N=23	1981 N=16	1982 N=26
	Freq (%)	Freq (%)	Freq (%)
Owns and operates farm	22 (96)	16 (100)	23 (88)
Operates farm for owner	1 (4)	0 -	2 (8)
Part owner and operates farm	0 -	0 -	1 (4)
Tenant farmer operator	0 -	0 -	0 -
Operates rental land	0	0	0

Table 7. Age Distribution of Farmers (N=58)

Age	Freq	%	Cum %
< 25	1	1.7	1
25-34	12	20.7	22.4
35-44	13	22.4	44.8
45-54	16	27.6	72.4
55-64	15	25.9	98.3
65	1	1.7	100.0

Age

Table 7 shows the farm operators' age group distribution in 1985. Most farmers are evenly distributed between ages 25-64 years old. One-quarter of the respondents were over the age of 55 in 1985.

Experience

The 1985 Potato Grower Survey asked respondents the number of years they have been principal operators of the farms. This is used to gauge their experience. Distribution of years of experience by the farm operator is shown in Table 8. Most farmers are 'experienced'; they have been farming for 20-30 years, although a little over 8% have less than 10 years experience as farm operators.

Table 8. Experience Distribution of Farmers, 1985 (N=48)

Age	Freq	%	Cum %
< 10	5	8.5	8.5
10-19	8	30.9	39.7
20-29	21	36.1	75.9
30-39	11	19.0	94.8
40-49	3	5.2	100.0

Education

Table 9 shows the distribution of years of schooling by farmers. Data were obtained from the 1985 dataset. Most of the farmers have had at least 12 years of formal education. About one-third of them have had some college or technical school training.

Table 9. Distribution of Education Levels of Farmers, 1985 (N=48)

Age	Freq	%	Cum %
< 12	11	18.9	18.9
12	26	49.1	68.0
> 12	17	32.0	100.0

Irrigation

Table 10 shows the percentage of farmers who irrigated in 1980, 1981, and 1982, while Table 11 shows the same information for 1985, 1986, and 1987. The proportion of irrigating farmers is quite low, although the percentage increased significantly in the mid-1980s. Generally, for any of the years under study, the proportion is still below 10%.

Table 10. Percentage of Total Sample Farms Irrigating in 1980, 1981, and 1982

	1980 N=21	1981 N=16	1982 N=10
Frequency	0	0	1
Percent	0	0	2

Table 11. Percentage of Total Sample Farms Irrigating in 1985, 1986, and 1987

	1985 N=54	1986 N=46	1987 N=50
Frequency	4	5	5
Percent	7.4	10.9	10.0

Soil erodability

In order to determine the degree of erodability for each of the farm plots under study, the T value (acceptable tolerable soil loss) was divided by the A value (average annual soil loss) to allow comparison between tolerance for a site and predicted losses. According to the guideline offered by Jones (1989) the ratio of less than 1 is considered high erodability, 1-3 is considered medium erodability, and above 3 is considered low erodability. The percentage represents the proportion of farmers out of the total number for that year whose land falls in that category of erodability. This information for the sampled farmers is shown in Table 12. Only 12% of the sampled farms were judged to have low erodability. Most of the farms (more than 80%) are classified under high or medium erodability.

Table 12. Soil Erodability Categories from the Farms Survey for the Sample Farms

		Soil Erodability		
Year	N	High	Medium	Low
		Freq (%)	Freq (%)	Freq (%)
1980	23	9 (39.13)	13 (56.52)	1 (4.35)
1981	16	4 (25.00)	10 (62.50)	2 (12.50)
1982	26	6 (23.08)	15 (57.69)	5 (19.23)
Early 1980s	65	19 (29.23)	38 (58.46)	8 (12.31)

Table 13 presents a summary of the proportion of the sample farmers practicing conservation tillage in both time periods, categorized by various farm and farmer characteristics. As expected, as farmers' ages increased over time, use of conservation tillage practices decreased. Those with more formal education showed a slight increase in adoption rates, but still below overall averages. Contrary to initial expectations, however, those with larger farms tended to decrease their use of conservation tillage over time. This may have been due to the reduction of the cost-sharing benefits available from SCS over the study period. This also may explain the overall decrease in conservation tillage practices over time by the sample farmers, as indicated in the last column of Table 13.

Table 13. Percent of Farmers Using Conservation Tillage on Potato Acreage by Time Period and Category

Time Period	Farm or Farmer Category (as of 1987)			
	Age ≥54	Education ≥12	Potato Ac. ≥199	All
Early 1980s	23%	9%	40%	24%
1987	18%	14%	26%	19%

AN ECONOMIC MODEL OF TECHNOLOGY ADOPTION

The Decision to Adopt a New Technology

The utility derived from use of a production technology is a function of the characteristics of the farm, the farmer, and the technology, itself. A farmer will adopt a new technology if the utility gained from doing so outweighs the utility derived from using the present technology. From society's standpoint, soil conservation measures should be adopted generally on those farms where the soil productivity is eroding faster than the natural rate of generation. From the farmer's viewpoint, they should be adopted when the utility of the present value of the net returns from doing so is positive. If the farmer's rate of discounting future gains coincides with society's and the farmer takes into account the value of gains to future generations, then the farmer will make the socially optimal adoption decision. Otherwise, the farmer's decision and society's desires will not necessarily agree. In the analysis that follows, we examine the farmer's decision to adopt conservation tillage at the farm level. We also examine this decision in light of the degree to which it conforms to the "efficient" decision from society's point of view by taking account of farm level soil erodability, but do not consider possible differences in individual and societal discount rates or time horizons.

The Adoption Model

The adoption model defines the utility of adoption as a function of farm characteristics that affect the net returns from adoption. That is,

$$U_1 - U_2 = f(R_1, A_1) - f(R_2, A_2),$$

where

U_k = expected utility derived from the utilization of production technology k,

k = 1 for a new technology (conservation tillage) and k=2 for the current technology (conventional tillage),

R_k = vector moments describing the distribution of net returns for technology k,

A_k = vector of attributes other than net returns associated with technology k.

A farmer will adopt the new technology if $U_1 - U_2 > 0$. We hypothesize (following Rahm and Huffman) that the utility derived from each technology is a function of a number of observed farm-specific characteristics, so that the ADOPTION MODEL is specified as:

$$U_1 = f(R_1, A_1) = a_o + \sum_{j=1}^{s} a_j X_{1j} + e_1,$$

$$U_2 = f(R_2, A_2) = a_o + \sum_{j=1}^{s} a_j X_{2j} + e_2,$$

where:

X_j = observed farm, farmer, and technology characteristics expected to affect the utility associated each production technology, and

e_k = additive random error.

Farm-specific characteristics reflect the profitability and riskiness of the investment in a new technology and may reflect firm managers' preferences towards risk and other attributes of the technology. Higher moments and other attributes may be important factors affecting the decision to adopt a new production technology. The decision to adopt will be made considering all other options open to the farmer that may have a positive effect on utility and will be made in the context of a limited amount of management time.

The Qualitative Response Model

The utility of net returns from either technology and the net returns, themselves, are unobservable. What is observable is the adoption decision of an individual farmer and the farm and farmer characteristics associated with each decision. Different individuals faced with identical circumstances and options will often choose differently based on their own preference structure.

$D = 1$ if $U_1 > U_2$,

$D = 0$ if $U_1 <= U_2$,

where:

D = observed binary variable equal to one if the farm has adopted the new technology, zero otherwise.

If the perceived utility of the new technology exceeds the utility associated with the current technology, the farm manager adopts the new technology.

The qualitative response or discrete choice model is characterized by a univariate dichotomous dependent variable or conditional probability model. The dependent variable is limited in that it is endogenous to some underlying unobserved economic relationship and is not continuous over the entire real line.

The probit model

Probit is a maximum likelihood estimation procedure based on the assumption of normality of the residual error u_i and yields a consistent, efficient, and asymptotically normal estimator if this assumption is correct.

Maximum likelihood estimation of the probit model is undertaken by interpreting a linear function of the independent variables as an index, for example, adoption potential index. If a person's adoption potential index exceeds his/her critical value index, that individual will adopt. Some individuals need little encouragement to adopt, so they will have low critical values. Others adopt only under extremely favorable circumstances and will have high critical values. In the probit model these critical values are assumed to be distributed normally among individuals. The likelihood of an individual adopting is given by the probability that his/her personal critical value is below the potential index. The likelihood function for the entire sample is formed by multiplying together all the expressions for the likelihoods for the individuals and taking the integral to find the cumulative normal distribution.

Another way of looking at the adoption potential index is explained by Kmenta in *Elements of Econometrics* (1986). An event E is chosen by the decision maker if its expected utility is "high enough". High enough depends on the individual. Let $I=bX_i$ be a latent index variable that is linear in b, such that the larger the index variable, the greater the probability of event E occurring. Since the probability must fall between zero and one, the monotonic relationship between I_i and $P(E/I_i)$ must assume a general form of a tonic relationship between I_i and $P(E/I_i)$ must assume a general form of a cumulative density function. It is assumed that all individuals weight the factor X_i identically, i.e., the b factor is constant across all individuals. It is also assumed that if all individuals are faced with a particular bX_i, some will choose event E and others will choose not-E because of personal preferences. Each person makes a choice between E and not-E by comparing the value of I_i to some threshold level I^* so that if $I_i > I^*$ then E is chosen.

For each individual the value of I^* is determined by many independent factors and thus can be assumed normally distributed by the central limit theorem, so that:

$$\begin{aligned} P &= P(E/I_i), \\ &= P(I^* <= I_i), \\ &= F(I_i), \\ &= F(bX_i). \end{aligned}$$

F(.) is the value of a standard normal cumulative distribution function.

Based on this theory, the probability of the ith firm adopting the new technology is:

$$\begin{aligned} P_i &= P(D_i = 1), \\ &= P(U_{1i} > U_{2i}), \\ &= P(U_{1i} - U_{2i}) > 0, \\ &= P(c_o + \sum_{j=1}^{s} c_j X_{ij} + \mu_i > 0), \\ &= P(\mu_i > - c_o - \sum_{j=1}^{s} c_j X_{ij}), \\ &= F(c_o + \sum_{j=i}^{s} c_j X_{ij}). \end{aligned}$$

In particular, the probability of adopting conservation tillage by Maine farmer i can be hypothesized as:

$$P_i = P(D_i = 1) = F(c_o + c_1 X_{i1} + c_2 X_{i2} + c_3 X_{i3}), \qquad (1)$$

where X_{i1} = farm size,
X_{i2} = farm size squared, and
X_{i3} = soil erodability.

The parameters of the log-odds version of this model will be estimated, and the predicted probabilities from it will be used to measure adoption efficiency.

The Measure of Adoption Efficiency

The second phase of the analysis utilizes the calculated probabilities from the adoption model to calculate a measure of adoption efficiency. Adoption inefficiency can be thought of as one of two things. If a farm's characteristics (soil erodability, etc.) are such that adoption of conservation tillage should provide positive net returns and the farmer does not adopt, then the farmer has made an "error" from society's point of view. On the other hand, if farm characteristics are such that it is not appropriate to use conservation tillage and the farmer adopts, then another type of inefficiency occurs because resources devoted to conservation would have a higher value elsewhere. The measure of the inefficiency, therefore, on an individual farm i is the absolute value of the difference between the observed decision to adopt (0 or 1) and the predicted probability of adoption from estimation of equation (1). That is,

$|AE_i| = |D_i - P| = \mu_i$,

AE = adoption efficiency,

D_i = observed binary variable (adopt=1 or non adopt = 0), and

P = predicted probability for adoption.

This efficiency measure is assumed to be a function of farmer characteristics, such as age of the operator, farm operator's experience, formal education, and continuing education. The lower the absolute value of the efficiency measure, the more efficient is the adoption decision, so that if a variable's estimated coefficient has a negative sign, then the variable is contributing to adoption efficiency.

$|AE|$ = g (human capital variables),

$$|AE_i| = g_0 + \sum_{j=1}^{t} g_{ij}X_{ij} + e_i \qquad (2)$$

where

X_{i1} = age,

X_{i2} = experience,

X_{i3} = formal education

X_{i4} = continuing education, and

e_i = random error.

VARIABLES USED IN THE ANALYSIS

The Adoption Model

Conservation Tillage

The dependent variable for the adoption model is the probability of adopting "conservation tillage". The definition of conservation tillage as defined by ASCS for cost-sharing purposes, has been changing over the time of study. The definition that will be used for this study is based on the basic-tillage implement used. Using a moldboard plow alone or with any other implement for basic-tillage is considered as "not practicing conservation tillage". Using any other implement for basic tillage constitutes conservation tillage. In 1987 the definition of conservation tillage considered in the follow-up survey is constructed from the implement used for fall tillage after harvesting small grains, peas, or potatoes and the implement used in spring before planting potatoes on the same acreage. A list of fall and spring tillage implements was included in the questionnaire. For the year 1987, if a farmer happened to report moldboard alone or in combination with any other implement for fall or spring tillage, then conservation tillage was assumed not to be practiced in 1987. Otherwise conservation tillage is assumed to be practiced.

Farm-specific characteristics

A number of farm-specific characteristics such as the size of operation, the cropping system, amount of rainfall, length of growing season, and soil erodability affect the distribution of net returns and thus determine the economic feasibility of conservation tillage practice (Rahm and Huffman 1984). For this study measures of farm size and soil erodability will be used, since the other factors listed do not vary substantially within the sample.

The change in mean net farm income resulting from adopting reduced tillage is the product of change in expected per acre net returns and the total potato acreage of the farm. For a given per acre net returns, the total expected net return from adoption is proportional to the size of the enterprise. Farm firms with larger enterprises have a greater absolute incentive to adopt and utilize more efficient tillage technology than the farms with smaller enterprises. Thus, the probability of a farm operator adopting reduced tillage is hypothesized to be positively related to the number of acres planted. All the three potato grower surveys requested the farmers to report both their total farm acreage and their potato acreage. The 1987 total acreage will be used as a measure of size of operation.

The erosion rate at a given site is determined by the particular way in which the levels of numerous physical and management variables are combined at that site. The Universal Soil Loss equation (USLE) is a model designed to predict the long-time average soil losses and runoff from specific field areas in specified cropping and management systems. It computes the soil loss for a given site as a product of six major factors whose most likely value at a particular location can be expressed numerically. The USLE is given as A=RKLSCP, where

A is the computed annual soil loss per unit area,
R is the rainfall and runoff factor,
K is the soil erodability factor,
L is the slope length,
S is the slope steepness,
C is the cover and management factor, and
P is the support practice factor.

A values (in tons per acre per year) for each sampled plot are reported in FARMS dataset. The T values for each sampled plot are also reported in the FARMS dataset. The T value denotes the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely. For cropland soils, the 1972 NRI estimated T values to range between 1 and 5. Cropland is defined as non-erosive if its T value is above 5, moderately erosive if its T value is above 3 but below 5 and highly erosive if its T value is below 3. The T value also reflects soil natural fertility, drainage characteristics and erosion susceptability of the soil; and conveys a sense to which soils are vulnerable to erosion.

If T is divided by A, (T/A) the ratio obtained reflects the potential erosion damage and allows comparison between tolerance for a site and predicted losses (Jones 1989). This ratio will be used as proxy for soil erodability. The larger the T/A ratio, the lower is the erosivity of the soil and the less likely are potential profits from adoption of conservation tillage practices. The probability of adoption of conservation tillage is therefore expected to be negatively related to the T/A value of the soil sample.

The Adoption Efficiency Model

Continuing education

Adoption may occur as a result of dynamic information gathering. Information changes attitudes and behavior. The decision to acquire information is an endogenous element of the system. Potential users must be aware of and familiar with the technology. The more educated or experienced farmer is expected to be more informed of a new technology.

Once a potential user is aware of the technology, he calculates the feasibility of the technology. Perceived feasibility will be based on expected profitability. His expectation will in turn be affected by experience with other new technologies. If a farmer had contact with the Cooperative Extension Service or the Soil Conservation Service in 1987, then following Rahm and

Huffman, it is assumed that s/he engaged in continuing education. Thus, contact with extension service is expected to reduce the adoption inefficiency.

Education

Adoption can be affected by changes in education. General education affects adoption by changing values, attitudes, and decision-making ability. Generally, education is believed to enhance allocative efficiency, improve the ability to deal with abstract ideas, and facilitate the ability to determine the feasibility of the alternative solutions. Rahm and Huffman (1984) hypothesized that investment in formal education enhances allocative skills. Thus, a negative relationship is expected between education and adoption inefficiency.

Experience

Adoption may occur as a result of changes in past experience which leads to changes in future behavior patterns. Experience also adds to the farmer's skills. Lack of previous experience increases the difficulties involved in individualizing the new knowledge. Adoption has been characterized as a result of Bayesian learning process in which the present period opinion is added to the previous period experience (Denison, 1964). The relationship between experience and adoption inefficiency is expected to be negative. The 1985 potato grower survey asks farmers the number of years they have been principal operators of the farm. This response is used as a measure of the farmer's experience as a farm manager.

Age

Age, like education and experience, is associated with management capacity and with attitudes towards the adoption of conservation technologies. Age is often a proxy measure for experience and represents accumulated human capital. Generally, however, above a certain age the relationship between age and technology adoption changes. The period of time over which the adoption benefits can be realized decreases. Several studies including those by Swanson (1974), Lasley and Nolan (1981) and Hoover and Wiitala (1980) have shown that the age of the operator is related to adoption of new technology. It appears that young farmers perceive erosion as a problem and conservation practices as being profitable and are more willing to accept the associated financial risk. Nowak (1980) found that age and education tend to be correlated. Young farmers tend to have more education and more managerial capacity. As age increases, the opportunity cost of making an error decreases, so age can have either a positive or negative effect on adoption inefficiency.

Health

Ill health taxes physical capacity, decreases one's mobility and vitality, decreases productivity, and may cause the withdrawal of individuals from labor force. Respondents were asked to evaluate their health in the 1987 potato grower survey. Responses ranged from very good (1) to very poor (5). Individuals with ill health, therefore, are expected be less likely to adopt conservation compared to the healthy farmers. Thus, a negative relationship is expected between good health and adoption inefficiency.

The minimum, maximum, mean, and standard deviation (std) values for the independent variables are shown in Table 14.

Table 14. Minimum and Maximum Values for Independent Variables

Variable	Maximum	Minimum	Mean	Std
T/A	5.0	0.1	1.98	1.5
ACRES	3,000	36	46.95	608.3
EXTCON	1	0	0.91	0.29
HEALTH	5	1	1.77	0.65
AGE	72	30	50.72	10.66
EDUCATION	21	1	12.93	3.3
EXPERIENCE	51	3	24.63	11.59

The parameters of the two stage model described above are empirically estimated to explain the potato tillage decisions of the farm operator. The sample data include two farm-specific characteristics that can be used to determine the economic feasibility of reduced tillage and five human capital variables which are expected to affect utility and reduce the adoption error.

The Adoption Model Estimates

Although the preliminary information provided by the descriptive statistics assists in identifying adopters and non adopters, the purpose is to analyze the variables simultaneously in order to understand the relationship within the adoption function. The results from the procedure are summarized in the tables below.

Table 15 shows the estimates of regression equation 1, where the probit model is used to regress the probability of the adoption of conservation tillage on total operated acres, total acres squared, and T/A. Column 1 displays the parameter estimates of adopting reduced tillage technology for the 43 sample farmers, while column 2 shows the t-ratios.

The parameter estimates show each variable's contribution in calculating the probability of adoption. The coefficients are based on the simultaneous effect of all variables. All the signs for regression equation 1 agree with expectation. However, the magnitude of the coefficients are low and not significant at 1% or 5% confidence levels. The estimates are non-linear and as such, the critical values are only asymptotically valid.

Table 15. Estimates of Probit Probability Model, Adoption of Conservation Tillage Practices by Maine Farm Operators, 1987

Dependent Variable = Log-Odds of Adopting ConservationTillage		
Independent Variables	Estimates	T-Ratio
INTERCEPT	.83	1.67
ACRES	.0023	1.40
$ACRES^2$	-.98E-6	-1.10
T/A	-.01	-.07
R^2 = .067		

The Adoption Efficiency Model Estimates

Table 16 shows the OLS regression estimates of equation (2) where the adoption efficiency, AE, and ln AE are used as the dependent variables and regressed on the human capital variables (extcon, educ, age, exp and health) from the 43 sample farmers. The education and experience variables are statistically significant at the 5% level. The other coefficients, however, are not. In Table 16, the coefficients clarify the relative contribution of each independent variable to the adoption efficiency. An examination of these coefficients indicate that, other things equal, education and experience are the most important variables that influence the decision to adopt or not adopt. Specifically, the high level of education and the more years of experience significantly reduce the adoption error.

The adoption efficiency model results for Iowa corn/soybean farmers in 1976 are presented in Table 17 for comparison. Rahm and Huffman tried several model specifications and, only those most closely comparable to the present study are presented here. Some of the Rahm and Huffman specifications contain more than one variable representing continuing education: Extension contact, use of media services, and attendance at meetings and conferences at Iowa State University. The variable "continued" is a measure of this last component and, therefore, does not compare exactly with the "EXTCON" variable in this study. However, since in Maine, most potato farmer conferences and meetings are held in the County with joint sponsorship among Cooperative Extension, the Maine Agricultural Experiment Station, and other state and federal agencies, the two measurements of continuing education are more similar than they appear on the surface. In the Iowa study, the variable for Extension contact alone, when it appeared in a specification, was not statistically significant.

Table 16. Estimates of the Human Capital Equation Explaining the Efficiency of Reduced Tillage Adoption Decisions by Maine Farm Operators, 1987.

Independent Variable	Dependent Variables AE (T-RATIO)	LNAE (T-RATIO)
INTERCEPT	0.25	-2.3
	(1.07)	(-2.4)
EXTCON	0.01	0.11
	(.12)	(0.32)
EDUCATION	-0.02	-0.06
	(-2.06)**	(-1.74)**
AGE	-.005	-.005
	(-1.06)	(-.23)
EXPERIENCE	-0.008	-0.02
	(-1.98)**	(-1.13)
HEALTH	0.004	0.12
	(0.07)	(.61)
R^2=	0.18	0.13
N =	43	43

**Significant at the 5% level.

The Maine and Iowa coefficients for the rest of the human capital variables are surprisingly similar in sign and significance. Formal education seems to have played a significant role in increasing adoption efficiency in both cases, even though the time periods and cropping systems studied are quite different. Farmer experience contributed significantly to efficiency in one specification for Maine, but did not seem to significantly effect efficiency in Iowa. The coefficient on farmer's health, although statistically insignificant, did have the expected sign in all cases.

Table 17. Adoption Efficiency Model Results for Iowa Farmers, 1976[a]

Independent Variables	Equation 1	Equation 1
INTERCEPT	-.616	-.550
	(-3.89)**	(-3.49)
CONTINUED[b]	-.221	
	(-2.94)**	
EDUCATION	-.037	-.044
	(-3.11)	(-3.78)**
EXPERIENCE	-.002	-.003
	(-1.08)	(-1.29)
HEALTH	.088	-.90
	(1.40)	(1.43)
R^2=	.03	.02
N =	797	797

Source: Rahm and Huffman, 1987.

[a]Dependent variable for both equations is LN |AE|

[b]"Continued" is a dummy variable that equals 1 if the farmer or spouse attended short courses, conferences, or meetings at Iowa State University; O, otherwise.

**Significant at the 5% level.

SUMMARY AND CONCLUSION

This section summarizes the procedures and findings relative to the objectives of the study. The discussion also outlines the limitations of the study and suggests directions for further research.

Summary

The dataset for the sample of farmers for the study consists of 43 farmers. These are the farmers who responded to the 1987 potato grower survey and for whom site characteristics are available from the FARMS survey. Since the dependent variable for the adoption model was elicited from the 1987 potato grower survey, response to the 1987 was a limiting factor to the number of farmers who could be included in the data set. Information on these 43 farmers was obtained from the 1986, 1985, and FARMS datasets by matching identification codes. The final dataset was obtained by merging variables of interest from all four datasets. The variables included in the final dataset were the education level of each farmer, whether or not they have had any contact with the extension or soil conservation service in 1987, their age, self assessment of health, their experience as farm managers, the size of their farm, and a calculated erosion potential for the farm. These variables were used as regressors in a probit model of the probability of adoption and a linear model of adoption efficiency.

Conclusions

In order to formulate specific policy recommendations, it is necessary to obtain an understanding of the adoption process among farmers. Analyses such as the one presented in this study are but one of the many tools in the process of identifying feasible policy choices. The results discussed here, based on the human capital theory of adoption, do provide a reasonable explanation of some contributory factors that would offer a guided direction for policy implementation.

According to the results, an individual's education and experience are relatively important in the process of adopting new technology. This finding is consistent with many other studies done elsewhere. The results support the notion that those with greater allocation skills (as proxied by education and experience) have tended to make an "efficient decision" regarding conservation tillage. It may be the case that these farmers have a greater ability to seek out and assimilate information from multiple sources in making their decisions. Those for whom Extension and Soil Conservation Service efforts might have a higher payoff are the newer and less well educated farmers. These results tend to support a concentrated effort among these two groups if the efficiency of conservation tillage adoption decisions is to be improved among Maine potato farmers.

Suggestions for Future Research

The results and limitations of this study raise significant questions for future research. The present research pertains to a particular group of farmers, Maine potato farmers. The human capital and land characteristics adoption theory alone does not account completely for the decision to adopt or not adopt conservation tillage among this group of farmers. The major factor is profitability, which is not measured directly here. The challenge is to further refine the model or develop alternative models of adoption relative to appropriate theoretical considerations which could explain more completely the individual decision to adopt or not adopt new agricultural technologies.

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