

REDUCTION OF YIELD VARIANCE THROUGH
CROP INSURANCE

by

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ABSTRACT

The variance of a producer's yield provides uncertainty and may be considered the risk a producer faces. Crop insurance may provide protection against yield variability. If yields are necessarily low, an insured producer may receive an indemnity payment. Currently, crop insurance is based on each individual's yield. If the individual's yield falls below a specified level, the individual will receive an indemnity. An alternative crop insurance program bases indemnities on an area yield. If the yield of the predetermined area falls below a specific level, all insured producers will receive an indemnity. This thesis examines the yield variability reduction received by purchasing various forms of area yield and individual yield crop insurance and the actuarially fair premium costs associated with them.

When a producer purchases insurance two decisions are made. First, the producer selects a trigger level which determines the critical yield which generates an indemnity payment. Second, the producer may be able to select a coverage level which is the amount of acreage covered by the contract. Each contract examined allows different levels for the trigger and coverage levels. The variance reduction provided from each contract is the variance of the yield without insurance less the variance of the yield with an insurance contract.

The results indicate most producers receive some variance reduction from the area yield contracts. And, producers who have yields which are closely correlated with the area yield receive more variance reduction from the area yield insurance than from the individual yield insurance contracts. However, the area yield contracts which provide on average more yield variance reduction than the individual yield contracts, also have much higher actuarially fair premium costs. The area yield insurance contracts should be considered as an alternative to individual yield insurance, but the premium costs must be evaluated also.

CHAPTER 1

INTRODUCTION

The debate over farm programs that preceded passage of the 1990 United States Food, Agricultural, Conservation and Trade Act (the 1990 Farm Bill) took place in the context of a government wide drive to reduce the federal budget deficit. During the course of that debate, serious attention was given by both the House and Senate agricultural committees to the cost of the federal crop insurance program, which was estimated to have cost the federal treasury between \$700 million and \$800 million per year for operations expenses and the payment of indemnities to farms experiencing losses.

The subsidies, in and of themselves, constituted a problem for the program. The fact that ad hoc disaster relief bills had commonly been passed to deal with damage to crops and livestock from natural phenomenon during the 1980's also called into question the validity of the program. Under the 1980 Federal Crop Insurance Act, the program had been deliberately expanded with respect to the range of crops covered and the geographic regions in which insurance would be available to obviate the need for ad hoc disaster relief to the farm sector. Most farmers, however, chose not to participate in the program (participation rates were on average just over 20 percent during that period) and, instead, elected either to use other methods for managing income risk

or to continue to rely on the political system to provide free (to the individual farm) protection through ad hoc disaster relief bills.

The Congressional House and Senate agricultural committees and the administration decided not to change the existing federal crop insurance program in the 1990 farm bill but did agree to review the program in subsequent Congressional sessions and to allow the FCIC to test new products on a pilot basis. Major innovations in the structure of the federal crop insurance program are now being examined by the Federal Crop Insurance Corporation (FCIC), which administers the federal crop insurance program, in response to initiatives from both the Clinton Administration and the Congress. In particular, the FCIC is introducing an area yield crop insurance program, called the Group Risk Plan (GRP). For the 1993-94 crop year, GRP contracts are offered in over 100 wheat or soybean producing counties on a pilot project basis.

Area yield insurance contracts provide the purchasing farm with an indemnity when average yields across all farms in the area fall below a critical yield. Typically, it is assumed, the individual farm's yield will have only a small impact on area yields and therefore area yield crop insurance contracts do not provide incentives for moral hazard or adverse selection. However, as Miranda has argued, area yield insurance does provide farms whose individual yields are

closely correlated with area yields with considerable protection against yield and, therefore, income variation. The exact form of the area yield contract may have a substantial impact on the amount by which the variance of a farm's yields and income can be reduced. This thesis therefore examines the effects of alternative area yield contracts on the variance of farm output and income net of insurance premiums. The results from alternative individual yield contracts are then compared with the area yield contracts. Two samples are examined. The first sample consists of 123 dryland wheat producers in Chouteau county, Montana. The second sample consists of 29 dryland wheat producers in Sheridan county, Montana.

It is shown that the restricted contract similar to the current FCIC pilot area yield contract provides the least variance reduction for most producers in both counties. The simpler "almost ideal" area yield contract which restricts the coverage level to equal one, would permit the average farm in each sample to reduce the variance of its yields by a substantially larger amount than the pilot area yield contract. The small number of farms made worse off under an "almost ideal" area yield contract would experience increases in yield variability of less than 5 percent. And, for those producers who have individual yields which closely correlate with the area yield, the "almost ideal" contract provides more

CHAPTER 2

HISTORY AND INSTITUTIONS OF CROP INSURANCE

History

The idea of insuring crops against unforeseen adverse events has existed for almost a century. Prior to 1899, private companies offered insurance to provide compensation from crop losses caused by hail and fire damage. By 1919, the hail insurance industry had grown into a large business collecting premiums in excess of \$30,000,000. Producers in North Dakota, South Dakota, Montana, and Nebraska could receive coverage from nearly 60 private insurers or through their mutuals or State departments (Valgren, 1922).

Multiple-peril crop insurance was introduced in 1899 when the Realty Revenue Guaranty Company of Minneapolis purchased an insurance holder's wheat crop for five dollars per acre (Hoffman, 1925). For unknown reasons this offer only lasted one year. Again in 1917, three private insurance companies attempted to provide general crop insurance for North Dakota, South Dakota, and Montana. Severe drought and poor management put an end to these endeavors, also after only the first year (Valgren, 1922).

By 1922, the U.S. government started treating crop insurance as a national issue. A Senate committee investigated (1) the kinds and costs of available insurance; (2) the protection insurance offered; (3) the desirability of

extending the scope of the current insurance; and (4) the availability of statistics to properly issue additional crop insurance (U.S. Congress, 1923). The committee agreed future insurance should be national in scope and more accurate data was necessary, but took no further action.

In 1936 crop insurance resurfaced as a national concern. President Roosevelt appointed a new committee to make recommendations for legislation of government-sponsored crop insurance. The committee's findings developed into the Federal Crop Insurance Act of 1938. The act created the Federal Crop Insurance Corporation (FCIC) within the Department of Agriculture to implement an insurance program for wheat. Producers could insure between 50 and 75 percent of their recorded or appraised average yields against unavoidable loss. Local committees of the Agriculture Adjustment Administration administered the program. For farms with annual data, premiums were based on the indemnities that would have been paid to the farm if it had been insured for prior years.

Initially, federal crop insurance's success seemed unlikely. Drought, inadequate farm-level data, and inexperienced estimators led to a loss ratio of 1.52 in 1939, and indemnities exceeded premiums by 2.6 million bushels (Clendenin, 1942). That poor performance prompted several changes in the calculation of yields and premiums. Representative farms or key-farms were used to appraise yields

and losses for individual farms. Participation in the modified program continually grew from 1939 to 1941. However, premiums still did not cover total indemnities (FCIC Annual Report, 1943). The Agricultural Appropriations Bill for 1943-1944 prohibited any new crop insurance policies from being written due to large underwriting losses and low participation levels (Agricultural Finance Review, 1943).

In late 1944, federal multiple peril crop insurance was reexamined. The new amendments to the 1938 act allowed insurance to again cover wheat and cotton producers. The program was expanded to protect flax, and corn and tobacco received an experimental offering. Also, increasing amounts of protection as crops matured became an option for producers.

In 1946, additions to the 1944 amendments made federal crop insurance more appealing. Three-year contracts for wheat addressed adverse-selection problems. The use of county data eliminated the need for individual yield histories. Partial coverage allowed lower protection levels requiring less indemnities (Agricultural Finance Review, 1946). These modifications resulted in premiums outweighing indemnities for the first time ever, in 1947. Ironically, new legislation in 1947 reduced federal crop insurance to an experimental program. The scope of the new program was greatly reduced, but greater latitude to offer experimental forms of insurance was granted.

During the nineteen fifties the crop insurance program appeared to stabilize. Premiums often covered indemnities, and the average loss ratio for the early fifties was 0.97 (FCIC Annual Report, 1955). In 1956, participation in the program for several high risk counties in Colorado, New Mexico, and Texas was denied. During the late nineteen fifties premiums more than covered indemnities, and surpluses accumulated although participation remained below the expectations of Congress.

Participation became the main concern during the nineteen sixties. Premiums did not keep pace with indemnities. Severe losses occurred in the late years. New management reviewed the program in order to determine the cause of the financial setbacks. They found coverage increases and rate reductions created several problems (FCIC Annual Report, 1969). Many adjustments were made in the seventies which resulted in coverage levels decreasing, rates increasing and many programs with low participation being canceled.

The Agriculture and Consumer Protection Act of 1973, and the Rice Production Act of 1975 created county wide disaster payment programs. Exceptionally low county yields could trigger a disaster relief payment. Payments for prevented planting and for abnormally-low yields provided income support for many producers. Producers encouraged the programs because they received protection against yield risk without having to

pay premiums. Over the period 1974-1980, disaster payments totaled 3.392 billion dollars.

The Federal Crop Insurance Act of 1980 again expanded the scope and objectives of the crop insurance programs. The goal of the act was to replace disaster relief with actuarially sound insurance opportunities. The program was made available in all counties with substantial agriculture. Private insurance companies marketed the insurance, and the federal government provided premium subsidies and offset administrative costs. These changes did not induce a significant increase in participation. From 1985 to 1990 the rate of participation averaged 27% of all insurable acres (U.S. General Accounting Office, 1992). In addition, the actuarial soundness of the program often came into question. The government paid out indemnities of \$6.1 billion between 1980 and 1990, accounting for 80% of total indemnities (U.S. General Accounting Office, 1992).

The 1990 United States Food, Agricultural, Conservation and Trade Act (the 1990 Farm Bill) did little to change the crop insurance program defined in the crop insurance act of 1980. Although major concerns about the 1980 program arose, the 1990 act virtually duplicated the existing program. Congress however did call for more study and new programs for pilot testing.

One pilot program currently under investigation, the Group Risk Plan (GRP), bases indemnities on area not

individual yield. The idea of area yield insurance was first introduced in 1948 by Harold Halcrow who outlined the possible benefits of the program. The idea remained virtually ignored until the early nineties, when Miranda proposed the approach as a possible solution to many crop insurance problems. The current pilot project started in 1993, provides insurance to producers of wheat and soybeans in over 100 selected counties. In the spring of 1994, versions of the GRP will be offered in more than 1200 counties to protect barley, corn, cotton, peanuts and grain sorghum.

Institutions

Individual Yield Crop Insurance

Multiple peril crop insurance which in various forms provided almost all of the yield protection since the inception of crop insurance is based on individual producer yields. In its current form MPCI offers producers choices with respect to yield coverage and price.

Farmers choose among one of three yield coverage levels (50, 65, or 75%). If the producer's actual yield falls below the elected coverage level on the insurable yield, an indemnity will be paid on the shortfall. The insurable yield is defined as a ten year average of verified yields; i.e. it is based on the actual production history (APH) of the farm. If a sufficient verified yield history does not exist, then a

yield based on the county Agricultural Stabilization and Conservation Service yield is substituted.

Second, the producer selects a guaranteed price level from the three alternatives. These price levels are calculated from forecasted expected prices. The producer's indemnity equals the product of the elected guaranteed price and the yield shortfall. Premium rates are factors of the elected yield, price guarantees and the assessment of loss-risk in the geographical area. The per acre premium equals the product of the price election, the yield coverage, the calculated insurable yield and the premium rate. Premiums are subsidized by 30% for 50 and 65 percent yield guarantees. The 75 percent yield guarantee is subsidized by the same dollar amount as the 65 percent yield guarantee. Farmers within a region who have the same insurable yield and make the same insurance election pay the same premium.

Several problems arise with this method of insurance which lead to loss ratios greater than one. First, farmers are not homogeneous even if their insurable yields are the same. The heterogeneity is reflected in differences in the yield probability distribution around the insurable yield. As a result, some farmers are more likely to collect indemnities than others and those farmers most likely to collect are more likely to purchase insurance. This adverse selection increases crop insurance program losses.

Second, after a producer is insured, the producer may take moral hazard actions which increase the probability of losses, and thus the collection of indemnities. The insurer doesn't have this information when setting premiums, thus premiums don't reflect the true risk. If moral hazard exists, the loss ratio will increase.

Third, administrative costs of the individual based program are large. Each farm must be evaluated and adjusted for premiums and possible losses. Also, the premium subsidies granted by the government have greatly increased the total government outlay. Adding the subsidy cost to the indemnities paid increases the loss ratio to 1.57.

Area Yield Crop Insurance

The current pilot test GRP attempts to alleviate some of the individual yield insurance problems. This program bases premiums and indemnities on aggregate yield of a geographical area. As with individual yield insurance, the producer makes two selections. First, a trigger level is chosen, which determines the amount of area yield necessary to induce indemnities, the critical yield. The producer may select up to 90% of the area yield. Thus, if the area yield falls below 90% of normal all insured producers who selected this trigger yield will receive indemnities. Second, the producer decides on a coverage level. This determines the amount of the producers acreage covered. Under the current GRP program up

to 150% of a producer's acreage may be covered. The indemnity equals the difference between the critical yield and the actual area yield times the coverage level.

This method of insuring may greatly reduce adverse selection, moral hazard, and the high administrative costs associated with individual yield insurance. The use of area yield data to set premiums and indemnities should produce an actuarially sound program for each participant. Thus, adverse selection would be mitigated, although adverse selection could occur if premium rates are improperly set. In addition, the area yield data process would eliminate the problem of moral hazard. This area yield program would require less loss adjustment and administration, resulting in large savings.

Although area yield insurance may mitigate several problems in the current program, several problems do exist under an area yield plan. First, although a producer purchases area yield insurance, in the event of an individual loss an indemnity payment may not be issued. If isolated, unavoidable damage occurs which does not decrease the area yield below the critical level, the isolated damage will not be compensated. This reduces the value of the program.

Second, nationwide implementation of an area yield program may face political opposition. Producers with insurance who do not suffer a loss will still receive an indemnity if area yield falls below the selected critical level. This may make the program politically unpopular even

if over time the plan covers indemnities with premiums. Also, if producers cover more than 100% of their acreage, the resulting indemnities may appear more like welfare payments than insurance.

Both methods of insuring crops cause different problems. The FCIC pilot program and other area yield programs may demonstrate the problems with the area yield plan. Then the decision of which method best meets the objectives of crop insurance can be made.

In this chapter, a brief history of crop insurance in the U.S. has been presented. The following chapter provides a review of the literature concerning the current individual yield insurance program, the problems associated with individual yield insurance, and a possible alternative, area yield insurance.

CHAPTER 3

REVIEW OF THE LITERATURE

From its inception in 1938, the FCIC has provided crop insurance coverage to the individual farm against farm losses from multiple perils. This insurance provides risk protection based on individual yield histories. Adverse selection and moral hazard create many problems for this insurance program. Area yield crop insurance, based on the area yield, has been posed as a possible solution to the problems with the current program. The following chapter reviews the literature concerning the theory and empirical studies of the individual yield program, and the area yield program.

Individual Yield Crop Insurance

The current form of crop insurance provides yield protection based on individual farm losses. The producer selects a coverage level of 50%, 60% or 75% of insurable yield, creating a critical yield. Then one of three indemnity prices is chosen. The indemnity received equals the shortfall between the actual yield and the critical yield, multiplied by the indemnity price. Premium rates are based on individual historical yields and the loss history of the county in which the individual farms.

A rational insurance policy makes both producers and the insurance provider better off. Producers will only purchase

insurance if the expected utility of profits with insurance is greater than without insurance (Nelson and Loehman, 1987). Risk sharing between the insurance provider and producers allows each producer to stabilize income. Producers purchase insurance because risk is reduced and utility is increased.

The competitive market has been unable to construct a rational crop insurance policy (Gardner and Kramer, 1986). The federal government has become the sole multiple peril crop insurance provider. However, the federal government has paid out large sums to cover administration costs and the often large differences between premiums and indemnities. Low participation levels lead to the subsidization of 25% of the premium cost (Hazell, Pomareda, and Valdes, 1986). With brief exceptions in the 1940's and 1950's, the loss ratio has averaged more than one over the life of the program. During the 1980's, the ratio grew to average over two (Miranda, 1991).

The failure of the competitive market to provide individual all risk insurance programs stems from asymmetric information. The insured possessing greater and more accurate information than the insurer causes two important problems, adverse selection and moral hazard. The magnitude of these failures account for a large proportion of the loss ratio (Just and Calvin, 1993).

Adverse selection occurs when the insurer can not determine the inherent riskiness of individual producers. The

insurer uses information about the average producer to set premiums. This leads producers who expect their losses to exceed premiums to purchase insurance. Those who believe the premiums will exceed their loss may not purchase insurance. Producers can better judge the actuarial fairness of the premiums than insurers and buy accordingly, leading to a loss ratio greater than one. The pool of insurance buyers becomes more adversely selective as insurance providers attempt to handle the poor loss ratio by increasing premiums.

Moral hazard, also a function of asymmetric information, also creates severe problems for the individual yield insurance program. Moral hazard occurs after a producer purchases insurance. Once insured, the producer practices behavior which increases the chance of loss the insurer cannot observe (Nelson and Loehman, 1987; Chambers, 1989). The premium again does not reflect the true risk.

An insurance policy which eliminates the possibility of adverse selection and moral hazard may still be an inefficient tool to manage risk. A producer may be reluctant to lock up savings in an illiquid insurance policy unless substantial gains are to be had through increased efficiency in risk bearing. Bardsley et al (1984) conducted a study of Australian wheat producers engaged in risky production. They examined the relative efficiency of insurance as opposed to other financial measures for managing risk. They concluded that, in the absence of administrative cost, some benefit from

insurance existed. But if administrative costs were allowed to rise above zero, the insurance made only a minor contribution to risk management. They concluded the funds could, and probably would, be put to better use by the individual producers.

Although adverse selection and moral hazard pose actuarial problems, and in some cases the efficiency of crop insurance may be in question, thousands of U.S. agricultural producers purchase subsidized multiple peril crop insurance annually. Several empirical studies have examined the demand for U.S. crop insurance. According to Gardner and Kramer (1986), the demand for crop insurance depends on the following factors; (1) the producer's utility function for income, (2) current income of the producer, (3) the producer's subjective frequency distribution for future income, (4) the change in the frequency distribution of future income generated by the contract, and (5) the premium or price of the contract. Their empirical study indicates that an increase in the rate of return received by producers of 0.10 percent due to the purchase of insurance would increase participation in the current insurance program by 1.85 percentage points.

The demand for crop insurance may also depend on the risk attitudes of producers. To measure risk aversion we turn to the willingness to purchase insurance. A producer is said to be risk neutral if expected or average income is the only measure of risk. Under a nonsubsidized actuarially fair

program, indemnities would equal premiums. The inclusion of administration and overhead for the program would lead to premiums exceeding indemnities. Based solely on this, a risk neutral producer will never purchase such insurance since over time average income cannot be increased by such a program. Thus, if all producers exhibited risk neutrality no demand for insurance would exist. Empirical tests reveal a downward sloping demand curve for crop insurance which may be explained by various risk aversion categories found among producers (Gardner and Kramer, 1986).

Fraser (1992) reports that the willingness to pay for crop insurance is a function of the level of coverage, the levels of price and yield uncertainty, and the risk attitude of the producer. Producers selecting the 50% coverage level and who also experience relatively high yield variability will be increasingly willing to pay a higher price for insurance as their risk aversion increases.

Although general risk attitude information may be useful, specific information about risk attitudes leads to the most appropriate policy decisions. Averages may be misleading. Standard assumptions about risk aversion are not sufficient to conclude the outcome of input decisions like crop insurance (Leathers and Quiggin, 1991). Detailed knowledge about the distribution of risk attitudes among producers must be included to create successful policy.

An empirical study conducted by Barry Goodwin (1993) explores the factors influencing the elasticity of demand for crop insurance. He assumes producers maximize their expected utility of profits. This maximization yields a demand for crop insurance which is a function of risk attitudes and production and marketing activities. Demand estimates produce statistically significant parameters corresponding to elasticities. Goodwin's results indicate counties with low loss-risk levels create more elastic demands for crop insurance. This suggests an increase in premium rates would increase the occurrence of adverse selection increasing the loss ratio.

Smith and Baquet (1993) studied the demand for crop insurance of 510 Montana wheat producers. Their study is the first to examine a farm's insurance decision as a two stage process. In the first stage, farmers choose whether to participate in the crop insurance program. In the second stage, if the farmer has decided to participate, the coverage level is determined. Smith and Baquet conclude, the participation decision appears to be driven by the farmer's subjective concern about yield variability, not the actual yield variability. Whether the farmer carries debt, receives disaster payments, and the education level of the farmer all affect the participation decision of the farmer. While premium rates do not significantly affect the participation decision of producers, the premium rate does affect the

coverage level chosen. Coverage levels fall as premium rates rise.

The problems of adverse selection and moral hazard in the current insurance program have also been empirically examined. Just, Calvin and Quiggin (1993) view adverse selection as a function of asymmetric information and the subsidy structure of the program. Asymmetric information, as explained above, causes adverse selection because all the characteristics that affect the probability and size of indemnities cannot be reflected in premiums. In this case, producers whose expected indemnities are larger than their premiums will more likely participate.

The subsidy system may inadvertently cause adverse selection. The subsidies cover thirty percent of premiums for the fifty percent and sixty five percent yield levels but only the equal dollar amount as the sixty five percent coverage for the seventy five percent level. Thus, producers whose yields never fall below sixty five percent cannot purchase effective insurance at the same rate of subsidy as a producer whose yields are more variable.

Just, Calvin, and Quiggin's empirical results indicate producers who insure receive greater benefits of risk reduction than producers who currently do not insure. Also, returns to insurance for producers who insure are considerably higher than for those who do not insure. This seems to suggest adverse selection does exist in the current program.

They also report that, although asymmetric information does worsen the adverse selection problem, the impact is smaller than expected. They suggest subsidies are necessary to induce participation of any producers.

Producers participating in moral hazard practice less self protection than noninsured producers to increase the probability of receiving an indemnity. Often, moral hazard takes the form of a lack of input effort. Goodwin and Kastens (1993) found insured producers spent \$2.77 less per crop acre for fertilizer and agricultural chemicals.

An empirical study by Just and Calvin (1993) reveals input levels do decrease for insured producers implying moral hazard does exist in the current program. They estimate wheat production in the U.S. decreases by 10.4%, 170.85 million bushels, annually due to moral hazard. This creates \$238.78 million in indemnities, accounting for 79.9% of indemnity payments. Coble, Knight, Pope, and Williams report a smaller effect claiming moral hazard increased the expected indemnity by about two bushels per acre.

Producers may also increase the use of inputs which increase the probability of receiving an indemnity. Horowitz and Lichtenberg (1993) concluded corn producers purchasing insurance apply 19% more nitrogen than those who have no insurance. This may occur because the marginal product of nitrogen is low or even negative at low rainfall levels. Those who insure also apply about 21% more pesticides than

noninsured producers. Pesticides in many circumstances may be risk increasing. These results suggest that both fertilizer and pesticides at certain levels may be risk increasing.

The moral hazard problem may also be increased because of the use of private insurance companies to offer crop insurance. The FCIC reinsures the companies against extraordinary losses. The private companies handle the loss adjustment, but do not bear the full cost of paying indemnities. The private companies do not have as much incentive to uncover behavior associated with moral hazard than if they incurred the total loss (Just and Calvin, 1993).

Several new crop insurance contracts have been offered to help eliminate the problems of adverse selection and moral hazard. Nelson and Loehman (1987) suggest options which may improve the current program. First, they examine a contract which solves the contract optimization with optimal input use as a constraint. Second, they suggest setting up contracts for several types of risk attitudes and letting producers select a contract. Third, they suggested that repeat contracts spanning several years with premium adjustment could be offered. Incorporating these aspects could improve the actuarial status of the current individual yield crop insurance program, but probably at the cost of lower participation.

Area Yield Crop Insurance

Harold Halcrow, the original proponent of area yield crop insurance states crop insurance should measure yield variation and distribute the cost of the variation across insurance buyers. Successful insurance should cover major losses due to adverse events and charge appropriate premiums. Appropriate premiums are set to encourage high participation levels, but cover indemnities and administration costs over time.

In an attempt to create successful crop insurance, Halcrow (1949) suggested basing crop insurance indemnities on area yields. The basic assumption requires the area to reflect the physical crop conditions faced by any producer in the area. Under area yield insurance, the normal yield of the area is a mean area yield if conditions are normal, estimated perhaps as a moving average adjusted for trend. The producer contracts for a percentage of normal area yield so that if actual area yield falls below that percentage of normal area yield an indemnity will be received. Historical detrended yields of the area determine the premiums. The risk protection provided by area yield insurance depends on the degree of correlation between the area yield and the crop conditions faced by the individual and relative variation in yields among individuals.

Halcrow's area yield crop insurance proposal has recently been reexamined by Miranda. Miranda (1991) proposed that producers first choose a critical yield which is a percentage

of the area yield. Then, producers select a coverage level. Whenever the area yield fell below the critical yield an indemnity equal to the shortfall of area yield subtracted from the critical yield multiplied by the elected price level on the farm's covered acres would be paid.

Miranda divided the individual producer's yield into two components, systematic and nonsystematic yield. The systematic component of the producer's yield is directly correlated with the area yield while the nonsystematic reflects the characteristics of the individual producer. By selecting the optimal trigger and coverage levels, all producers could reduce the systematic risk faced by the same proportion. The producer's nonsystematic risk remains.

In his empirical study Miranda first required the coverage level to be fixed at 100 percent of insurable acreage. Next, producers could optimize both with respect to the trigger and coverage levels. Both area yield proposals were compared with individual yield insurance. Miranda found small or large producers with yields highly correlated with the area yield enjoy more variance reduction from the optimal area yield proposal. Those with highly variable yields selected individual insurance. Miranda suggested the area yield design would decrease adverse selection and moral hazard. He also acknowledged although the program would be actuarially sound, it might be politically unpopular and increase the level and variability of indemnities.

Other empirical studies investigating area yield crop insurance contradict some of Miranda's findings. Carriker, Williams, Barnaby, and Black (1991) compared an individual MPCl contract, the two area yield proposals, and farm yield and area yield disaster assistance plans. They compared reduction in yield equivalent variability and gross income variability. The individual yield contract decreased both types of variability most effectively. The optimal area yield proposal proved to be the second most effective means of reducing both measures of risk. The disaster plans minimally improved variability.

Although their findings show individual yield insurance provides superior risk protection, problems of adverse selection and moral hazard still remain. Carriker et al propose area yield insurance based on percentage measures and dollars of liability. This procedure would eliminate the need for price forecasting and would mitigate the individual yield problems.

A second comparative study by Williams, Carriker, Barnaby, and Harper examined the viability of area yield crop insurance. Stochastic dominance procedures were applied to the six programs; (1) government commodity supports, (2) individual MPCl, (3) area MPCl, (4) linked deficiency payments to crop insurance, (5) individual disaster assistance, (6) area disaster assistance. Williams et. al. found that disaster assistance was preferred to all forms of insurance,

a result that is understandable since disaster assistance requires no payment from the producer. The study also concluded that as risk aversion increases, individual insurance becomes more desirable. However, a subsidy of 20% leads the moderately risk averse to prefer the area MPC. Williams et. al. concluded that the problems of adverse selection and moral hazard warrant the investigation of subsidized area yield insurance as a possible solution.

The current individual yield insurance contracts can provide risk reduction. However, actuarially fair premiums probably cannot be set for these contracts because of adverse selection and moral hazard. Area yield insurance, which does not suffer the effects of those problems, has been proposed to replace individual yield insurance. Although actuarially fair premiums can be used under an area yield contract, the most effective area yield contract may not be obvious. The next chapter examines how to evaluate the risk reduction obtained from area yield contracts and individual yield contracts.

CHAPTER 4

THEORY

Adverse selection and moral hazard create several problems for the current individual yield crop insurance program. Area yield crop insurance may provide risk protection and decrease the effects of adverse selection and moral hazard. This chapter describes the theoretical model presented by Miranda to evaluate the effectiveness of area yield crop insurance to provide risk protection and decrease the current program's problems. The procedure to study the effects of an individual crop insurance contract on risk reduction is also presented.

Area Yield Insurance

Consider a producer in a given area who faces random yields due to uncertain natural phenomena. The producer's yield, y_i , can be orthogonally projected onto the area average yield, y , to obtain the following identity:

$$(1) \quad y_i = \mu_i + \beta_i(y - \mu) + e_i.$$

Here, it is assumed that

$$(2) \quad \beta_i = \text{Cov}(y_i, y) / \sigma_y^2$$

$$(3) \quad E(e_i) = 0; \text{Var}(e_i) = \sigma_{e_i}^2; \text{Cov}(y, e_i) = 0;$$

$$(4) \quad E(y_i) = \mu_i; \text{Var}(y_i) = \sigma_{y_i}^2;$$

$$(5) \quad E(y) = \mu; \text{Var}(y) = \sigma_y^2.$$

Equation (1) expresses individual yield variation as a systematic component, $\beta_i (y - \mu)$, which correlates perfectly with the area yield, and a nonsystematic component e_i , which is uncorrelated with the area yield. The coefficient β_i measures the sensitivity of the individual yield to the systematic factors which influence the area yield. If β_i equals one, the individual yield systematic component exactly corresponds with the area yield. If β_i is greater (less) than one then systematic factors affect the individual producer more (less) than the area average. β_i is also equivalent to

$$(6) \quad \beta_i = \rho_i \cdot \frac{\sigma_{y_i}}{\sigma_y}$$

where ρ_i is the coefficient of correlation between each producer's yield and the area yield.

A producer purchases area yield insurance at a premium rate, r , denominated in bushels per acre. An indemnity, n , equals any positive shortfall between the producer's chosen trigger yield level, y_c , and the average area yield,

$$(7) \quad n = \text{Max}(y_c - y, 0).$$

The trigger yield represents a percentage of the area yield $y_c = \alpha y$, where α equals the trigger level.

If the premium equals the expected value of the indemnity, the program will be actuarially fair. Requiring actuarially fair contracts permits the insurance contract to be evaluated in terms of variation of net yields. The individual net yield when purchasing insurance equals

$$(8) \quad y_i^{\text{net}} = y_i + n - r.$$

The variance of the net yield which here is assumed to measure yield risk becomes

$$(9) \quad \text{Var}(y_i^{\text{net}}) = \sigma_{y_i}^2 + \sigma_n^2 + 2\text{Cov}(y_i, n)$$

As Miranda notes, each contract can be evaluated solely in terms of the variance of net yield if producers are mean variance maximizers. Thus, purchasing the actuarially fair area yield insurance reduces the individual producer's yield variance by

$$(10) \quad \begin{aligned} D_i &= \text{Var}(y_i) - \text{Var}(y_i^{\text{net}}) \\ &= -\sigma_n^2 - 2\text{Cov}(y_i, n). \end{aligned}$$

If the nonsystematic component of yield e , and the area yield y , are conditionally independent, it follows that e_i and n are uncorrelated. Combining this assumption with equation (1), it follows that

$$(11) \quad \text{Cov}(y_i, n) = \beta_i \text{Cov}(y, n).$$

Miranda defines a critical beta as

$$(12) \quad \beta_c = -\sigma_n^2 / 2 \text{Cov}(y, n).$$

Note that β_c changes for every trigger level because each trigger yield level contains a different α which creates a different indemnity n . Using equations (10), (11), and (12) the risk reduction from area yield insurance can be rewritten as

$$(13) \quad D_i = \sigma_n^2 [\beta_i / \beta_c - 1].$$

Risk reduction will be positive as long as $\beta_i > \beta_c$. The maximum value for β_c is 0.5 and, as Miranda showed, the acreage weighted average of the β_i 's within an area is always one. Thus most producers experience reductions in yield risk under the area yield program. Those whose β_i 's correlate most

closely with the area yield will enjoy the most risk reduction.

Under weak regularity conditions, the critical beta β_c is increasing in α and it can be shown that β_c lies in the range $0 \leq \beta_c \leq 0.5$. As α approaches infinity, β_c converges to the value of 0.5. Once the limit value has been reached for β_c , risk cannot be further reduced. The reason for this result can be seen by using equation (12). When β_c equals 0.5, the ratio between the variance of the indemnities and the covariance of the indemnities and area yield is -1. Thus area yield and indemnities have become perfectly negatively correlated. A one unit increase in area yield results in a one unit decrease in indemnities.

Until now, it has been assumed that producers insure exactly one hundred percent of their acreage. However, once a trigger level has been selected, the producer may also choose to select a coverage level, ϕ_i , which differs from 1, that is, the farm can cover more or less than one hundred percent of planted acres. For any given trigger level, the producer's net yield becomes

$$(14) \quad y_i^{\text{net}} = y_i + \phi_i n - \phi_i r.$$

In Equation (14) the premium rate is also multiplied by the coverage level to ensure that the area yield contract remains actuarially fair.

The variance reduction associated with this area yield program is

$$(15) \quad \begin{aligned} D_i &= \text{Var}(y_i) - \text{Var}(y_i^{\text{net}}) \\ &= -\phi_i^2 \sigma_n^2 - 2\phi_i \text{Cov}(y_i, n). \end{aligned}$$

Substituting in (11), risk reduction can be expressed

$$(16) \quad D_i = \sigma_n^2 [\phi_i (\beta_i / \beta_c) - \phi_i^2].$$

Given the selection of any trigger level and coverage level, equation (16) can be used to determine the amount of risk reduction produced by the contract. This equation can be used to determine the risk reduction for any area yield insurance contract.

Given the selection of a trigger level, which yields a specific α and β_c , the locally optimal coverage level, ϕ_i^* , that maximizes risk reduction can be found by differentiating equation (16) with respect to ϕ_i : that is,

$$(17) \quad \phi_i^* = \beta_i / 2\beta_c.$$

If the producer is free to select any positive coverage level, yield risk reduction occurs for any producer with a positive β_i . Equation (17) suggests most producers will select a

coverage level greater than one. The selection of an optimal trigger level creates a β_c no greater than 0.5. As noted above, the acreage weighted average of the β_i 's always equals one. Thus as Miranda showed, if all the farms, which would be unlikely, selected a trigger level associated with a β_c of 0.5, at least half would also choose a coverage level, ϕ_i , equal to or greater than one. This area yield program results in an optimal insurance contract often covering more than 100 percent of the farm's planted acreage.

Individual Yield Insurance

Currently, the FCIC program uses individual yield insurance contracts. Under these contracts the producer insures a percentage of individual average yield, not area yield. To determine the reduction in the variance of net yields under individual yield contracts, first the indemnities must be calculated. Letting $\bar{y}_i$ denote average individual yield, then

$$(18) \quad n = \text{Max}(\alpha(\bar{y}_i) - y, 0).$$

Here, α is interpreted as the proportion of individual acreage insured. The indemnity equals the percent of average yield insured multiplied by the average yield minus the individual

bushels per acre in the given year. The total yield for the individual yield contract becomes

$$(19) \quad \hat{y}_i = y_i + n - r.$$

where r equals the actuarially fair premium associated with the contract.

To obtain the net yield risk reduction for an individual yield contract the variance of yield with the insurance contract is subtracted from the variance of total yield with the specific contract

$$(20) \quad D_i = \text{Var}(y_i) - \text{Var}(\hat{y}_i).$$

In this chapter a method to determine the reduction in yield risk due to the purchase of area yield insurance associated with 100% coverage and a chosen trigger level or given the optimal trigger level selecting a coverage level was developed. Also, the method to calculate the reduction in yield risk associated with an individual insurance contract was examined. The data necessary to empirically test versions of the area yield programs would be comprehensive individual yield in an area. The total annual acreage planted and the yield for each producer would be necessary. The next chapter discusses the specific data sets and their characteristics.

CHAPTER 5

DATA

To empirically test the effectiveness of different area yield programs individual yield data was gathered. Chouteau County and Sheridan County, Montana were considered areas. Over the ten year period 1981-1990, 123 separately insured dryland winter wheat producers made up the Chouteau County "area". These insured producers were assumed to comprise the entire area. The Sheridan County "area" consisted of 29 dryland winter wheat producers operating during 1983-1992. The Federal Crop Insurance Corporation collected the yield information when making net settlements. The data contains only those producers who purchased insurance for each of the ten years. Thus the sample is not random. However, since 1983, about 85% of all dryland wheat acreage has been insured in Montana. The bias created by using only insurance purchasing producers may not be too severe.

The variables compiled by the FCIC include the farm number, the section of acreage, a year number, the year, the total acreage planted, bushels per acre received, and an individual yield average not weighted by acres.

There existed several duplications in the original data containing producers with ten years of data for each county. This occurred because of two procedures in the FCIC data collection process. First, more than one person may be

present on a crop insurance policy. When the FCIC reports, the total yield of any acreage is reported for each person on the policy leading to replicated yield data. Second, many sections may be held by one producer. Such a producer may report acreage of a section as a proportion of the total acreage planted. But, the producer reports the total yield of all sections for each section. The duplications were eliminated from each data set.

Inspection of plots of the Chouteau county individual yields revealed no time trend. When individual yields and the "county" average yield were regressed on time, none of the 124 estimated coefficients on time were significantly different than zero.

The plots for the Sheridan County data raised the question if a time trend existed for some producers. When the individual yields and the "county" average were again regressed against time, five of the individual producers had estimates of a time coefficient which were significantly different than zero. All of the 29 individuals remained in the data set.

The above discussion describes the two "area" data sets and their characteristics. Chapter 6 examines the empirical tests and results of the effectiveness to reduce yield risk and the cost of several crop insurance programs.

CHAPTER 6

METHODOLOGY AND EMPIRICAL RESULTS

The objective in this chapter is to calculate and compare reductions in yield variability for individual farms, as measured by the change in the variance of yield, of three area yield and two individual yield crop insurance contracts. The first sample consists of individual annual yields for 123 separately insured dryland wheat operations in Chouteau county, Montana over the ten year period 1981-1990. The second sample consists of individual annual yield data on 29 separately insured dryland wheat operations in Sheridan county, Montana over the ten year period 1983-1992. A producer's yield can be expressed as the addition of two components, the systematic component and the nonsystematic component. The systematic component correlates with the area yield while the nonsystematic component is uncorrelated with the area yield. Each producer has a specific β_i which is the coefficient on the systematic component of yield. The β_i 's show the amount by which a producer's yield changes given a marginal change in the area yield. This β coefficient measures the sensitivity of the producer's yield to the systematic factors that affect the area yield. As Miranda demonstrated, the acreage weighted average of all the individual β_i 's must equal one. The individual β_i 's were found by using equation (6). Figure 1 presents the distribution of

the estimated β_i 's for each producer of the 123 producers in Chouteau county. Figure 2 presents the distribution of the estimated β_i 's for each of the 29 producers in Sheridan county. Each farm is heterogeneous thus they are treated individually.

The distribution of the estimated β_i 's for Chouteau county possesses a bell shape centered around one. The range for the estimated values of the β_i 's is 0.24-1.93. The positive β_i 's indicate that each producer in Chouteau county using an area yield program, could select a coverage level which would decrease yield variance. About 54% of the producers have β_i 's that are less than one. This result implies that smaller farms tend to have smaller β_i 's since the acreage weighted average of the β_i 's must always equal 1.

The distribution of the β_i 's for the 29 producers in Sheridan county is presented in Figure 2. The distribution for Sheridan is also bell shaped, but the range of the β_i 's, 0.64-1.38, is more compact than in Chouteau county. For producers in Sheridan county, yields appear to be more correlated with the area average than in Chouteau county, that is, producers in Sheridan appears to be more homogenous. As in Chouteau county, smaller farms tend to have smaller betas as 58.6% of all Sheridan producers have β_i 's less than 1.

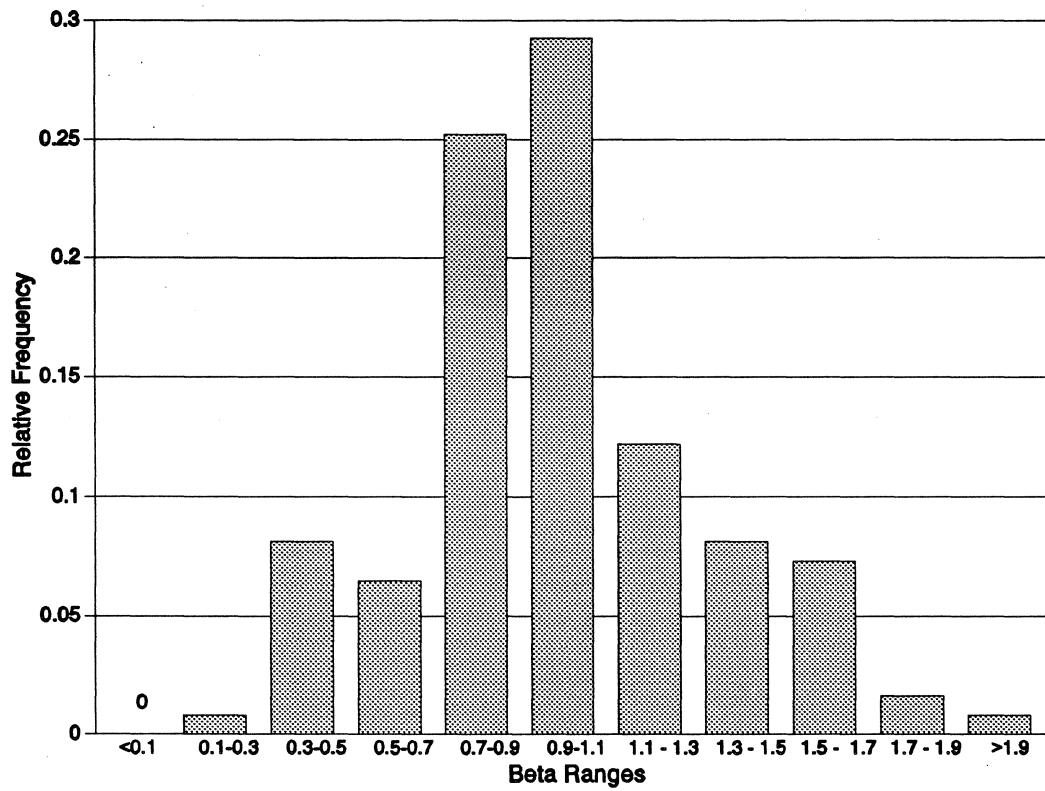
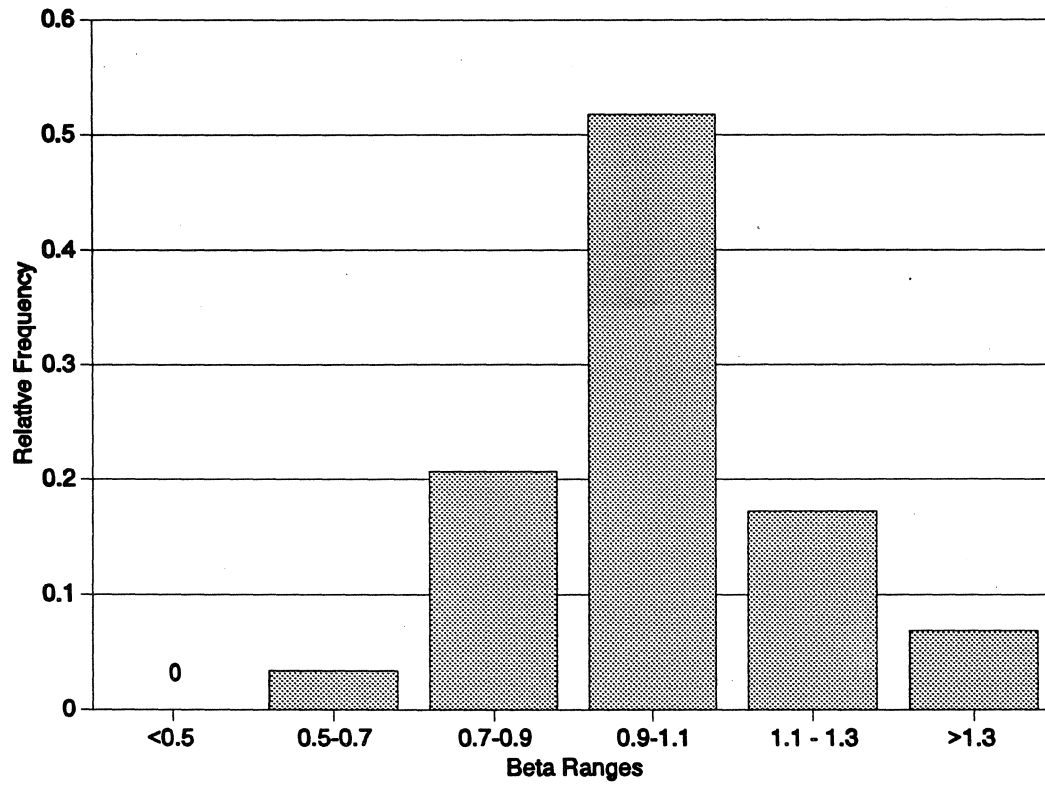
FIGURE 1**Frequency Distribution of Chouteau County Betas**

FIGURE 2

Frequency Distribution of Sheridan County Betas



Reduction In Yield Variance From Area Yield Contracts

The reduction in net yield variance shows the amount by which each contract reduces the producer's yield variance. The estimated risk reduction obtained from a contract equals the variance of the yield with no insurance minus the variance of the yield with an insurance contract.

Five different insurance contracts are considered and compared. The five insurance contracts are described in Table 1. Three are area yield contracts and two are individual yield contracts. The area yield contracts permit various values for the trigger level and the coverage level. The restricted contract, AYC1, limits the farm's trigger level, α_i , to be less than or equal to 0.9 and its coverage level, ϕ_i , to be 1.5 or less. These restrictions are similar to those currently imposed under the FCIC pilot program. However, the premiums under the restricted contract are calculated differently than under the pilot program. The "almost ideal" contract, AYC2, allows any non-negative value for the trigger level, but restricts the coverage level for all producers to equal to one. The "ideal" contract, AYC3, allows any non-negative value for both the trigger level and the coverage level.

The individual yield contracts are based on each producer's yield. The producer insures the exact amount of acreage prescribed by the contract.

TABLE 1

Five Area and Individual Yield ContractsArea Yield Contracts

- AYC1: The restricted area yield contract under which $\alpha_i \leq 0.9$ and $\phi_i \leq 1.5$.
- AYC2: The "almost ideal" contract under which α_i may take on any non-negative value but $\phi_i = 1$.
- AYC3: The ideal contract under which both α_i and ϕ_i may take on any non-negative value.

Individual Yield Contracts

- IYC1: The farm is constrained to insure at 75 percent of its average yield ($\alpha_i = 0.75$).
- IYC2: The farm is constrained to insure at 90 percent of its average yield ($\alpha_i = 0.90$).

As with the most generous yield selection under the current multiple peril crop insurance program, individual yield contract 1, IYC1, constrains each farm to insure 75 percent of its average yield. This implies a trigger level of 0.75. Under IYC2 each farm insures 90 percent of its average yield implying a trigger level of 0.9.

To obtain the reduction in yield variance for each area yield contract, estimates of n were obtained using equation (7), and estimates of β_c is calculated using equation (12) for all values of α ranging from zero to three in increments of 0.05. The limit values of β_c were obtained for a trigger level, α , equal to 1.35 in Chouteau county and a trigger level, α , equal to 1.95 in Sheridan county. In each county, no producer could achieve any additional risk reduction by increasing α beyond these limit values because for these values of α , β_c converges to its upper limit 0.5.

Next, equation (13) was used to determine the risk reduction for each producer, given that the coverage level, ϕ_i , was set equal to one and α was chosen so the critical yield with corresponding β_c and σ_n^2 maximized the risk reduction. This process identified the "almost ideal" contract (AYC2).

Next, to identify the ideal contract (AYC3) equation (17) was used to determine the optimal value for ϕ_i^* , given α was set equal to its optimal value under the "almost ideal" contract. This procedure may not always generate the absolute

optimal value for ϕ . This sequential optimization procedure ignores any multiplicative term between α and ϕ . However, the multiplicative term may be very small and not greatly impact the value of ϕ . To verify that this procedure resulted in a globally optimal contract, a search was carried out over all feasible values of α and ϕ for a sub-sample of five individual farms. The search identified the same contract as the two-step procedure. Equation (16) was then used to calculate the risk reduction from the "ideal" contract for each producer.

The restricted area yield contract (AYC1) limits $\alpha \leq 0.9$ and $\phi \leq 1.5$. A farm whose "ideal" contract consisted of an $\alpha < 0.9$ and a $\phi < 1.5$ would still use this contract under the restricted contract. Farms with an optimal $\alpha < 0.9$ and an optimal $\phi > 1.5$ under the "ideal" contract were constrained to set ϕ equal to 1.5. Farms with an optimal $\alpha > 0.9$ were constrained to set α equal to 0.9 and to select the optimal value for ϕ , as long as it did not exceed 1.5 given that $\alpha = 0.9$.

Equation (16) was used to calculate the risk reduction offered by the restricted contract, AYC1, for each producer. Finally, the absolute values of each producer's risk reduction under each contract were divided by the variance of uninsured individual yields to show the percentage reduction in yield variance obtained under the contract.

Table 2 presents estimates of the average proportional decreases in net yield variances under the three area yield

contracts for Chouteau county. The estimates of risk reduction are presented in absolute values; thus larger percentage changes imply larger reductions in risk. The restricted contract, AYC1, provides a 49.7 percent reduction in average individual yield variance. The "almost ideal" contract, AYC2, reduces the average yield risk by 63 percent, a substantial improvement over the restricted contract. The "ideal" contract allows the average producer to decrease yield variance by 65.62 percent. The "almost ideal" contract, which is simpler than the other area yield contracts provides substantially more risk reduction than the restricted contract and only slightly less risk reduction than the "ideal" contract.

On average the "almost ideal" contract provided much more risk protection for the Chouteau producers than the restricted contract, however some farms were made worse off by using the "almost ideal" contract. The Chouteau farms were separated into two groups, A and B. Group A contains the 112 farms that achieve larger reductions in yield risk under the "almost ideal" contract than under the restricted contract. Group B consists of the remaining 11 farms that are worse off under the "almost ideal" contract.

Group B consists of farms whose individual yields are not closely correlated to the area yield. They receive less

TABLE 2

**Proportional Decreases in Average Farm Net Yield
Variances Under Three Alternative Area Yield
Contracts in Chouteau County**

	Number of Farms	AYC1 ^a	AYC2 ^a	AYC3 ^a
		Percent Change		
All Farms	123	49.69	63.00	65.62
Group A ^b	112	52.39	67.02	69.86
Group B ^c	11	22.22	22.13	22.42

^a The contracts are as defined in Table 1.

^b Group A consists of farms that can achieve larger reductions in net yield variance under the "almost ideal" contract, (AYC2) than under the restricted contract, (AYC1).

^c Group B consists of farms that can achieve larger reductions in net yield variance under the restricted contract than under the "almost ideal" contract.

than 50 percent of the risk reduction achieved by group A from selecting any of the area yield contracts. The "ideal" contract on average generates the most risk reduction for group B farms, but represents only a marginal improvement over the restricted contract and the "almost ideal" contract. In contrast, group A on average enjoys substantial risk reduction by switching from the restricted contract to the "almost ideal" contract. However, little additional risk reduction is obtained by group A farms changing from the "almost ideal" contract to the "ideal" contract.

The estimated proportional decreases in average farm level yield variances under the three area yield alternatives in Sheridan county are presented in Table 3. Again, the "almost ideal" contract provides much greater yield risk protection than the restricted contract and only slightly less protection than the "ideal" contract. In contrast to Chouteau county, all 29 producers in Sheridan county enjoy more risk reduction from the "almost ideal" contract than from the restricted contract. This may occur because individual yields in Sheridan county are more closely correlated to the average area yield than in Chouteau county. The Sheridan producers can improve their risk protection by increasing their trigger yield and coverage levels.

Table 3

**Proportional Decreases in Average Farm Level Net Yield
Variances Under Three Alternative Area Yield
Contracts in Sheridan County**

	Number of Farms	AYC1 ^a	AYC2 ^a	AYC3 ^a
		Percent Change		
All Farms	29	47.66	77.84	79.12

^a The contracts are defined in Table 1.

Average and maximum trigger and coverage levels under the area yield contracts for Chouteau county are presented in Table 4. Under the restricted contract the average trigger level for all farms of .887 is very close to the program limit of .9. Only those in group B have average trigger levels measurably below the .9 limit. The average coverage level of 1.38 is considerably lower than the program maximum of 1.5. However, producers in group A have average coverage levels of 1.413 while those in group B have average coverage levels of 1.02. This may be explained by the higher β_i 's of group A which lead to higher optimal coverage level as determined by equation (17).

The "almost ideal" contract allows producers to select any non-negative trigger level while constraining the coverage level to be one. The average selected trigger level of the entire Chouteau county sample, 1.246, greatly increases the critical yield from what the restricted contract allows with α limited to be 0.9. Group A on average selects a trigger level 1.295 which approaches the 1.35 limit on risk reduction. About half of the group A producers chose a trigger level of 1.35. Those in group B select the trigger level they chose under the restricted contract since they selected a trigger level below 0.9 for the restricted contract anyway.

TABLE 4

**Average and Maximum Trigger Levels and Coverage
Levels Selected Under Three Area Yield
Contracts for Chouteau County**

Average Values	AYC1		AYC2		AYC3	
	α_i	ϕ_i	α_i	ϕ_i	α_i	ϕ_i
All Farms	.887	1.378	1.246	1.000	1.246	1.074
Group A	.900	1.413	1.295	1.000	1.295	1.079
Group B	.755	1.020	0.755	1.000	0.755	1.020

Maximum Values	AYC1		AYC2		AYC3	
	α_i	ϕ_i	α_i	ϕ_i	α_i	ϕ_i
All Farms	.900	1.500	1.350	1.000	1.350	1.926
Group A	.900	1.500	1.350	1.000	1.350	1.926
Group B	.800	1.095	0.800	1.000	0.800	1.095

The limitation of the "almost ideal" contract is that it forces the average farm to reduce the coverage level it chooses. The average decline is much greater for those in group A than for those in group B. The small effect on group B's choice of coverage level reveals the reason they suffer little effects from being forced to move from the restricted program to the "almost ideal" contract. The optimal contract changes little for them under the "almost ideal" contract.

The "almost ideal" contract assumes the coverage level is one, but allows the trigger level to be optimized. The "ideal" contract uses the α associated with the optimal trigger level of the "almost ideal" contract to determine the optimal coverage level, ϕ_1^* , in equation (17). The average optimal coverage level increases beyond the "almost ideal" coverage level to 1.074. The small increase in the coverage level permits the average farm to obtain a small decrease in yield variability relative to the "almost ideal" contract.

Information on the average and maximum characteristics of the three area yield contracts for Sheridan county are presented in Table 5. Under the restricted contract, the trigger level chosen by the average farm is 0.9, the limit value under this contract. The average coverage level under the restricted contract is 1.478, which is also closer to the program limit than in Chouteau county. Producers in

TABLE 5

**Average and Maximum Trigger Levels and Coverage
Levels Selected Under Three Area Yield
Contracts for Sheridan County**

Average Values	AYC1		AYC2		AYC3	
	α_i	ϕ_i	α_i	ϕ_i	α_i	ϕ_i
All Farms	.900	1.478	1.864	1.000	1.864	1.026

Maximum Values	AYC1		AYC2		AYC3	
	α_i	ϕ_i	α_i	ϕ_i	α_i	ϕ_i
All Farms	.900	1.500	1.950	1.000	1.950	1.377

Sheridan, who are more homogeneous, can benefit more on average from area yield insurance than the Chouteau county producers.

The average trigger level under the "almost ideal" contract for Sheridan county is 1.864 which creates greater risk reduction from this contract in Sheridan than in Chouteau (63% to 77.84%). Again, the optimal coverage level allowed in the "ideal" contract, 1.026 averages slightly higher than 1 and creates a small decrease in yield variability.

Premiums Under The Area Yield Contracts

The bushels per acre premium of each contract may prove vital when considering implementation of these contracts. Although actuarially fair premiums may vary substantially across contracts they create no effect on the reduction of yield variability. These premiums were not considered when evaluating the risk reduction associated with each contract.

Average actuarially fair premiums were determined by first using equation (7). The indemnity each producer would receive each year given their optimal trigger level and a coverage level of one was determined. The average of all these indemnities equals the average premium under the "almost ideal" contract. Next, the indemnity found above for each year and every producer was multiplied by the optimal coverage level selected by each producer. The average of these indemnities equals the average premium for the "ideal"

contract. Finally, the indemnity associated with the trigger level required from the restricted contract multiplied by the coverage level selected under the restricted contract are the indemnities of the restricted contract. The average of all these indemnities equals the average premium under the restricted contract.

Table 6 contains the average per acre premiums under the three contracts for Chouteau county. Under the restricted contract premiums average 4.12 bushels for the entire sample. The actuarially fair premium more than doubles under the "almost ideal" contract to 11.05 bushels. The "ideal" contract generates the highest average premium at 19.18 bushels. The increases are associated mostly with group A. Group A clearly benefits more than group B as the area yield crop insurance contract becomes more flexible. The higher indemnities paid to group A imply higher premiums. Premiums per acre for group A are more than twice as high than for group B under AYC1, six times higher under AYC2, and almost 20 times higher under AYC3.

Equivalent per acre premiums for Sheridan county are presented in Table 7. The premiums increase rapidly as the area yield contract becomes more flexible. AYC1 costs only 4.76 bushels per acre. The Sheridan AYC1 premium costs only slightly more than the Chouteau AYC1 premium. For Sheridan county, the "almost ideal" contract, AYC2, costs

TABLE 6

**Average Per Acre Premiums Under Three Area
Yield Contracts for Chouteau County**

	AYC1	AYC2	AYC3
	Bushels Per Acre		
All Farms	4.12	11.05	19.18
Group A	4.33	11.94	20.94
Group B	1.95	1.92	1.26

TABLE 7

**Average Per Acre Premiums Under Three Area
Yield Contracts for Sheridan County**

	AYC1	AYC2	AYC3
	Bushels Per Acre		
All Farms	4.76	21.09	38.73

21.09 bushels per acre, nearly 5 times the cost of the AYC1. This is nearly twice the cost of the "almost ideal" contract in Chouteau county. In Sheridan county the "ideal" contract, AYC3, costs 38.73 bushels per acre, more than twice as much as in Chouteau county. The average Sheridan producer whose yield is more correlated with the average area yield benefits more from the area yield contracts than the average Chouteau producer, but the Sheridan producer also faces higher premiums.

Reduction in Yield Variance from the Individual Yield
Contracts Compared with Area Yield Contracts

Two individual yield contracts are compared with the area yield contracts. First, each farm is constrained to insure at 75 percent of its average yield (IYC1). Then the constraint is imposed to insure 90 percent of average yield (IYC2).

To obtain the reduction in variance for the individual yield contracts, first the indemnity for every year for each producer must be calculated using equation (18). The percent of average yield insured is multiplied by the non-acreage weighted average yield with the individual bushels per acre subtracted from the sum. The individual producer's premium for each year is the average of that producer's indemnities. The producer's net yield per acre is the actual yield per acre, y_i , plus any indemnity received less the premium. Equation (20) expresses the net yield risk reduction as the difference between the variance of the producer's actual yield

and the variance of the producer's net yield for the specific individual yield contract.

Table 8 compares the decrease in net yield variances between the restricted contract, AYC1, the "almost ideal" contract, AYC2, the 75 percent individual yield contract, IYC1, and the 90 percent individual yield contract, IYC2, for Chouteau county. The IYC1 contract provides slightly less risk reduction 46.55 percent on average than the AYC1 with 49.69 percent. The IYC2 contract decreases risk by 64.31 percent while the AYC2 decreases risk by 63.0 percent. Both sets of contracts generate equivalent risk reduction on average. Group A enjoys more risk reduction than group B from every contract. Group A receives more than twice the risk reduction from the two area yield contracts and the 75 percent individual yield contract. For group B the two area yield contracts and the 75 percent coverage individual contract generate risk reduction between 22-24 percent. The 90 percent individual contract decreases risk by 53.61 percent. Group B would clearly prefer an individual contract which allowed high levels of yield coverage.

Similar area yield and individual yield risk reduction comparisons for Sheridan county are presented in Table 9. The 75 percent individual contract, IYC1, decreases yield variance by 37.26 percent, the smallest risk reduction in Sheridan county. The restricted contract, AYC1 decreases

TABLE 8

**Proportional Decreases in Average Farm Level Net Yield
Variances Under Two Area Yield Contracts and Two
Individual Yield Contracts for Chouteau County**

	Area Yield Insurance		Individual Yield Insurance	
	AYC1	AYC2	IYC1	IYC2
	Percent Change			
All Farms	49.69	63.00	46.55	64.31
Group A	52.39	67.02	48.76	65.36
Group B	22.22	22.13	24.04	53.61

TABLE 9

**Proportional Decreases in Average Farm Level Net Yield
Variances Under Two Area Yield Contracts and Two
Individual Yield Contracts for Sheridan County**

	Area Yield Insurance		Individual Yield Insurance	
	AYC1	AYC2	IYC1	IYC2
	Percent Change			
All Farms	47.66	77.84	37.26	51.66

variance by 47.66 percent. The 90 percent individual contract, IYC2, reduces net yield variance by 51.66 percent. The "almost ideal" contract decreases net yield variance by 77.84 percent, the most for the average producer in Sheridan county.

The greatest net yield variance reduction is generated by different contracts in the different counties. Chouteau county receives a 64.31 percent variance reduction from the 90 percent individual yield contract, IYC2. Sheridan county receives a 77.84 percent variance reduction from the "almost ideal" contract, AYC2. Sheridan county receiving more risk reduction from the "almost ideal" area yield contract may be explained by the fact that the individual yield in Sheridan county is more highly correlated with the area average yield than Chouteau county.

Premiums Compared Between Individual and Area Yield Contracts

Average actuarially fair premiums for AYC1, AYC2 IYC1, and IYC2 for Chouteau county are presented in Table 10. The individual yield premiums are obtained by using equation (18) to determine the indemnity for each producer for every year and then using the average of each producers indemnities as the producer's premium. The average of all producer's premiums are reported.

TABLE 10

**Average Per Acre Premiums Under Two Area Yield Contracts
and Two Individual Yield Contracts For Chouteau County**

	Area Yield Insurance		Individual Yield Insurance	
	AYC1	AYC2	IYC1	IYC2
	Bushels Per Acre			
All Farms	4.12	11.05	2.63	4.17
Group A	4.33	11.94	2.63	4.17
Group B	1.95	1.92	2.63	4.22

The average per acre premium for IYC1, 2.63 bushels, is about 40 percent lower than the AYC2 premium, 4.12 bushels. The average premium for IYC2, 4.17 bushels, is close to 60 percent lower than the AYC2 premium. Although these two sets of contracts offer similar risk reduction, the individual yield contracts involve much lower premiums. This actuarially fair comparison suggests that in the absence of moral hazard and adverse selection, the individual contracts would adequately protect producers at a much lower per acre expense.

A similar premium comparison for Sheridan county is presented in Table 11. The restricted contract, AYC1, costs 4.76 bushels per acre. The 75 percent individual contract, IYC1, costs 2.39 bushels per acre. The AYC1 provides a ten percent larger decrease in variance than the IYC1, but it costs twice as much per acre. The 90 percent individual contract, IYC2, costs 3.87 bushels per acre. The "almost ideal" contract, AYC2, costs 21.09 bushels per acre. The AYC2 provides nearly 26 percent more net yield variance reduction, but it costs nearly 6 times the IYC2. The area yield contracts provide much more protection than the individual yield contracts, but the cost increases greatly. A premium of 21.09 bushels per acre for the "almost ideal" area yield insurance contract may not be feasible for many producers, although the contract remains actuarially fair.

TABLE 11

**Average Per Acre Premiums Under Two Area Yield Contracts
and Two Individual Contracts for Sheridan County**

	Area Yield Insurance		Individual Yield Insurance	
	AYC1	AYC2	IYC1	IYC2
	Bushels Per Acre			
All Farms	4.76	21.09	2.39	3.87

The potential cash flow problem may prohibit the use of this contract.

This study has shown that the restricted contract allows most producers to reduce variance quite substantially. The simpler "almost ideal" contract which assumes a coverage level of 100 percent, but permits the producer to select any trigger level, allows all the producers in Sheridan county and over 90 percent of the producers in Chouteau county to reduce yield variability by much larger amounts. The 11 Chouteau county producers who receive more protection under the restricted contract do not suffer greatly when constrained to select the "almost ideal" contract. In both samples, on average the "ideal" contract provides the greatest amount of net yield risk reduction of the three area yield contracts. However, for most producers the additional risk reduction gained by switching from the "almost ideal" contract to the "ideal" contract is minimal.

The premiums for the area yield contracts increase as the amount of risk reduction increases. The restricted contract, AYC1, on average costs half as much as the "almost ideal" contract, AYC2, in Chouteau county. The restricted contract on average costs four times less than the "almost ideal" contract in Sheridan county. The "ideal" contract, AYC3, on average cost nearly twice as much as the "almost ideal" contract in both counties. The "ideal" contract provides

little additional risk reduction at an average of nearly twice the cost of the "almost ideal" contract.

The two individual yield insurance contracts decrease yield variability for all producers. The 75 percent and 90 percent individual yield contracts, IYC1 and IYC2, were compared with the restricted contract, AYC1 and the "almost ideal" contract, AYC2. Every producer in Sheridan county and those producers in the group A of Chouteau county obtained the least amount of risk reduction from the 75 percent individual yield contract, IYC1, than from any other area or individual yield contract. Those in group B receive slightly more risk reduction from the IYC1 than from either area yield contract.

The 90 percent individual yield contract provides on average only a small additional decrease in yield variability in Chouteau county. In Sheridan county where the individual farm yields are more highly correlated with the area yield, the 90 percent individual contract provides significantly less risk reduction than the "almost ideal" contract. The farms whose yield is more correlated with the area average enjoy more risk reduction from the area yield contracts than those whose yields do not correlate with the area.

The premiums for the individual yield contracts are on average significantly less than for the area yield contracts. The 90 percent individual contract costs half the "almost ideal" contract in Chouteau county. The 90 percent individual yield contract costs six times less than the "almost ideal"

contract in Sheridan county. All the contracts are actuarially fair, but the 90 percent individual yield contract may be preferred even by those who receive more risk reduction from other contracts because the premium charge would be much less.

This chapter has presented the methodology and results of determining the reduction of net yield variance and premiums of five different insurance contracts. A summary of and conclusions about the study appear in the next and final chapter.

CHAPTER 7

CONCLUSIONS

In this study, an empirical model has been developed to evaluate reductions in farm level yield variance obtained for area yield and individual yield crop insurance contracts. The results of the analysis provide insights about the effectiveness of two individual and three area yield contracts to reduce yield risk by decreasing yield variance. Two samples were used to examine the effects of the contracts. The first sample contained 123 dryland wheat producers in Chouteau county, Montana. The second sample contained 29 dryland wheat producers in Sheridan county, Montana.

The major task of the study was to examine empirically the effectiveness of the individual and area yield insurance contracts to reduce the net yield variances of the wheat producers. A theoretical model for net yield reduction was presented for the individual yield and area yield contracts. The net yield reduction from any contract can be thought of as the difference of the variance of yield without an insurance contract and the variance of yield with a contract.

The insurance contracts studied contained different values for trigger and coverage levels. The trigger level determines the critical yield which generates an indemnity payment. The coverage level determines the amount of acreage covered by the insurance contract. Area yield contracts base indemnities on area yields. The restricted area yield

contract limited the trigger level to be less than or equal to 0.9 and the coverage level to be less than or equal to 1.5. The "almost ideal" area yield contract required the coverage level to be one, but allowed the trigger level to be optimized. The "ideal" area yield contract allowed both the trigger level and the coverage level to be optimized.

Individual yield contracts base indemnities on individual yield. The 75 percent individual yield contract constrained the producer to select a coverage level of one and a trigger level of .75. The 90 percent individual yield contract constrained the producer to select a coverage level of one and a trigger level of .90.

The net yield variance reduction produced by each contract and the actuarially fair premium associated with each contract was estimated. The estimation results provided interesting insights about the usefulness and price of each contract. The restricted contract allows most farms in both samples to significantly reduce the yield variance and yield risk. However, the simpler "almost ideal" contract would allow over 90 percent of producers in Chouteau county, and all producers in Sheridan county to reduce yield variability by much larger amounts. Producers whose yields are more closely correlated with the area yield enjoy more risk reduction when allowed to select a higher trigger level. In Chouteau county, the effects of the "almost ideal" area yield contract on the

remaining 10 percent of producers who have yields which are the least correlated with the area yield is negligible.

The "ideal" contract allows farms in both samples to achieve only small additional yield risk reduction relative to the "almost ideal" contract. However, again those whose yields correlate most closely with the area yield select both higher trigger and coverage levels. But, the increased flexibility under the "ideal" contract does not provide many producers with a significant yield risk reduction.

The cost of the area yield contracts increases as yield variability decreases, most notably for those who enjoy the greatest benefit from the more flexible contracts. In Chouteau county, the optimal "almost ideal" contract costs nearly three times as much as the optimal restricted contract. Premiums for the optimal "ideal" contracts are almost twice than that of the optimal "almost ideal" contracts.

The increase in premium rates is more dramatic in Sheridan county. Premiums for the optimal "almost ideal" contracts are over four times higher than for the optimal restricted contracts. "Ideal" contract premiums are more than double those for the "almost ideal" contracts. "Almost ideal" contracts provide nearly the same amount of net yield variance reduction as "ideal" contracts, but have premiums that are substantially lower.

For producers whose yield correlates more closely to the area yield in Chouteau county, the "almost ideal" contract

provides more risk reduction than either individual yield contract. However, on average in Chouteau county the 90 percent individual yield contract provides about one percent more risk reduction than the "almost ideal" contract. In Sheridan county the "almost ideal" contract provides much more average net yield variance reduction than the two individual yield contracts. Producers in Sheridan county, whose yields correlate more closely with area yield, can use area yield contracts to better manage risk than individual yield contracts.

Actuarially fair premiums for the contracts also increase as the amount of variance decreases. The 90 percent individual yield contract is nearly three times less expensive than the "almost ideal" contract in Chouteau county. The 90 percent individual yield contract is more than six times less expensive than the "almost ideal" contract in Sheridan county. In Chouteau county, the 90 percent individual yield contract provided equivalent risk reduction as the "almost ideal" contract, but at one third the price. In Sheridan county, the 90 percent individual contract is substantially less expensive, but provides substantially less risk reduction. Those with yields highly correlated to the area yield can gain substantially more risk reduction from the area yield contracts, but the premium cost will be substantially greater than with an individual yield contract.

The above findings suggest that, because farmers appear to benefit substantially from increased opportunities to reduce yield risk under an actuarially equivalent "almost ideal" contract, the FCIC should consider offering such a contract. The contract is actuarially sound and limits the occurrence of adverse selection and moral hazard. The "almost ideal" contract is also simpler than the restricted contract in that only a trigger level must be selected. A simpler contract that provides more risk reduction than the restricted contract may increase participation.

However, the "almost ideal" contract may cause several problems if implemented. The actuarially fair premium rates of the program are much greater than the individual yield contracts. Producers may pay a bushel per acre premium close to their per acre average yield. This may limit the political popularity and financial viability of the contract.

The results also indicate that individual yield contracts provide about the same degree of yield risk when the individual yields do not correlate very closely with the area yield. Thus, even in the absence of opportunities for adverse selection and moral hazard, those producers would prefer an individual yield contract to an area yield contract. Therefore, if individual yield contracts could be constructed without the problems of adverse selection and moral hazard producers whose yields are not correlated with area yield could benefit more from the individual yield contracts.

This study has several shortcomings. First, only producers who purchased insurance for each of the ten years examined were included in the analysis. Thus, the data only included producers who benefitted from the current insurance programs. The samples were not random. Second, some time trend may have been present in the Sheridan county data which was not considered in the analysis. This might have increased the individual yields correlation to the area yield. Finally, the actuarially fair premiums estimated may preclude the use of the area yield contracts. Although the premium is actuarially fair, the high premium may not be realistic, given many producers' cash flow situations.

This study has provided several interesting insights about the net yield reduction possible from area and individual yield contracts. However, the analysis could be extended in several useful directions. First, the risk attitudes of the producers could be examined to possibly categorize the preference of contracts by the risk attitudes of purchasers. This would increase the known characteristics about the producers who receive more risk reduction from the area yield contracts.

Second, an investigation on how to most accurately determine the definition of an area would be helpful in making area yield insurance more efficient. The use of the county as the area facilitated this study, but future studies which more

precisely determine the area may produce area yield insurance which reduces yield risk even further.

This study has provided compelling evidence for the investigation of area yield crop insurance as a possible solution to the problems of adverse selection and moral hazard in the current individual yield insurance contracts. For those producers who have yields which correlate closely with the area yield, "almost ideal" area yield insurance appears to greatly reduce yield variance.

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APPENDICES

APPENDIX A

Acreage and Yield Data

Acres Planted by Each Producer In Chouteau County from 82-91

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	534.0	2914.00	450.3	152.4	196.0	479.7	254.6	115.4	388.1	338.6
2	420.5	221.30	161.3	354.3	167.5	141.6	214.4	571.7	222.0	422.4
3	1570.0	1257.60	1282.6	1320.2	1252.6	644.4	403.6	716.7	275.8	234.9
4	180.9	16.00	157.9	78.4	250.0	220.8	141.6	252.8	110.1	142.0
5	34.4	68.70	113.8	105.9	173.0	105.9	134.1	136.4	173.1	135.0
6	76.1	90.00	72.1	111.7	80.0	103.8	100.9	117.8	100.9	120.0
7	263.9	316.40	248.9	191.4	119.1	78.0	226.3	251.0	201.2	250.8
8	120.8	107.40	121.0	198.8	80.4	42.0	160.3	240.3	240.7	198.7
9	378.2	320.30	264.3	129.0	204.0	102.5	289.2	348.7	345.9	238.9
10	27.1	30.10	64.7	47.3	46.7	45.0	47.8	46.7	63.0	56.2
11	138.7	75.00	133.8	136.2	69.8	173.6	133.9	174.1	133.9	174.1
12	86.0	44.40	14.4	52.5	52.6	53.1	53.8	52.3	53.8	53.1
13	42.9	37.90	46.0	38.1	51.7	56.9	30.2	73.5	30.2	47.3
14	79.2	79.20	14.8	59.4	79.2	19.9	79.2	79.6	78.8	59.7
15	79.6	79.60	39.9	39.7	79.9	79.3	38.2	39.5	79.4	79.3
16	60.9	79.90	32.0	18.1	39.8	79.9	72.6	79.4	72.6	79.9
17	238.5	104.10	315.1	244.6	63.8	162.9	305.0	390.1	399.3	263.3
18	170.7	70.00	196.6	137.6	87.2	161.7	58.0	74.0	70.0	161.0
19	117.0	15.00	102.0	62.3	102.8	56.4	80.0	32.7	91.0	56.7
20	239.9	229.70	269.1	249.1	235.0	227.9	269.1	184.0	323.0	375.8
21	1043.9	212.80	711.4	612.2	741.1	686.3	533.1	792.0	776.0	867.0
22	341.7	485.20	383.9	198.4	449.2	477.5	330.1	344.2	428.3	412.5
23	370.4	230.60	197.4	335.1	319.3	355.7	144.0	320.9	225.1	265.3
24	195.7	248.40	487.7	342.0	314.9	355.0	518.2	575.9	604.1	456.9
25	710.3	395.80	422.7	633.9	619.3	423.5	398.4	374.4	712.6	498.2
26	590.5	205.00	122.7	534.4	248.5	501.9	507.3	449.3	611.2	627.7
27	407.2	419.30	420.8	869.3	467.8	881.9	755.5	767.1	1145.6	1170.4
28	38.9	34.30	48.4	41.0	47.8	48.9	49.0	60.8	64.2	57.5
29	140.1	157.70	149.2	146.9	150.4	152.7	152.6	168.9	199.8	178.8
30	528.6	151.90	467.9	250.9	63.5	161.0	147.2	210.5	259.7	132.1
31	85.0	154.40	104.0	156.5	109.4	156.5	58.2	157.0	149.4	155.5
32	590.5	205.00	122.7	534.4	248.5	501.9	507.3	449.3	611.2	627.7
33	510.3	364.20	517.0	599.0	606.4	515.0	492.3	809.2	652.7	481.8
34	832.4	920.80	579.7	390.0	268.8	511.5	647.0	439.8	780.0	181.2
35	399.5	391.30	199.8	38.3	357.3	463.6	479.1	345.6	479.1	46.4
36	710.3	395.80	422.7	639.3	619.3	423.5	398.4	374.4	712.6	498.2
37	222.1	402.40	352.8	352.6	414.1	424.4	427.9	530.4	535.2	488.4
38	155.0	40.50	122.5	108.5	87.3	112.4	112.4	139.5	147.0	131.7
39	445.6	406.50	136.3	205.1	29.2	162.1	637.3	300.2	313.1	216.2
40	412.7	21.60	357.1	268.6	551.9	232.4	28.5	438.0	373.0	28.5
41	412.7	21.60	357.1	268.6	551.9	232.4	28.5	438.0	373.0	185.0
42	412.7	21.60	357.1	268.6	551.9	232.4	28.5	438.0	373.0	138.2
43	120.2	45.20	82.2	78.3	98.2	54.0	85.0	88.2	84.7	85.0
44	119.0	160.50	192.3	194.3	162.2	156.2	167.4	278.7	253.4	203.2
45	40.4	68.47	167.7	50.7	38.9	87.7	136.5	64.2	97.6	58.3
46	121.2	272.60	238.0	121.2	272.6	166.9	76.7	464.2	167.6	192.2
47	222.8	311.60	84.3	222.8	311.6	874.3	220.8	311.6	307.7	186.5
48	98.2	171.20	176.4	169.2	97.3	191.4	172.8	173.8	273.7	191.4
49	293.6	351.30	396.1	138.5	217.9	296.6	292.8	405.9	292.8	394.2
50	16.3	179.20	118.6	324.9	183.7	177.2	305.4	259.0	140.9	194.7
51	132.0	125.80	239.2	80.8	151.6	149.2	116.6	207.9	242.9	198.3
52	471.4	535.6	465.9	62.5	67.2	211.2	137.4	28.5	256.0	259.5
53	471.4	535.6	465.9	55.3	70.0	43.0	37.7	91.6	37.7	43.0
54	471.4	5356.0	465.9	114.6	119.4	45.6	44.2	113.4	44.2	45.6
55	612.0	560.9	587.7	749.7	762.9	674.7	643.2	867.3	846.0	812.1
56	711.0	689.2	339.3	320.9	305.5	370.3	395.9	488.1	548.7	496.5

57	190.5	55.2	108.8	126.8	274.4	201.1	121.8	311.5	161.1	144.3
58	60.6	59.4	82.3	60.6	59.4	82.3	60.6	59.4	82.3	60.6
59	195.7	248.4	487.7	342.0	314.5	355.0	518.2	73.3	155.0	154.3
60	195.7	248.4	487.7	342.0	314.9	355.0	518.2	575.9	203.8	110.0
61	195.7	248.4	487.7	342.0	314.9	355.0	518.2	575.9	318.6	159.2
62	195.7	248.4	487.7	342.0	314.9	355.0	518.2	575.9	8.2	187.7
63	721.5	676.9	590.2	554.8	607.6	615.5	611.2	692.3	742.9	721.7
64	230.6	220.8	201.9	99.6	142.3	189.7	247.0	231.5	52.2	55.1
65	230.6	220.8	201.9	99.6	142.3	189.7	247.0	231.5	207.4	203.3
66	506.3	310.8	405.6	296.8	285.8	479.6	450.3	523.5	374.6	472.7
67	65.6	45.7	62.2	64.3	63.0	66.0	66.6	82.6	76.6	78.1
68	132.0	125.8	239.2	80.8	151.6	149.2	116.6	207.9	242.9	33.0
69	238.5	104.1	315.1	244.6	63.8	162.9	305.0	390.1	399.3	263.3
70	86.0	44.4	14.4	52.5	52.6	53.1	53.8	52.3	53.8	53.1
71	162.3	100.0	71.0	133.0	162.3	132.8	82.3	151.6	162.3	151.6
72	224.7	107.0	199.3	108.1	80.4	152.2	190.7	168.1	210.0	241.9
73	113.8	55.3	45.3	60.8	76.8	116.1	51.9	116.1	114.6	60.8
74	149.9	94.7	67.4	113.8	69.7	147.0	148.2	164.4	188.0	178.2
75	129.9	103.7	184.7	181.3	174.6	105.0	156.0	97.5	103.2	128.7
76	185.8	141.9	144.7	101.8	52.4	156.9	106.6	194.3	194.7	88.0
77	940.1	144.6	283.8	489.9	246.2	577.2	933.3	20.4	257.4	166.5
78	99.1	78.7	99.0	24.2	78.7	74.8	24.2	103.0	74.8	24.2
79	297.9	253.9	179.4	256.9	295.7	285.7	211.9	354.9	374.6	310.8
80	185.7	152.9	153.6	153.6	164.5	156.9	159.1	197.5	207.4	210.7
81	116.4	73.4	78.8	79.0	37.7	78.1	119.4	118.0	50.5	119.4
82	73.3	120.0	86.8	144.0	173.4	191.8	218.8	213.2	174.5	213.4
83	382.9	403.4	364.6	248.2	159.2	115.4	159.2	154.4	159.2	96.3
84	26.0	53.1	40.1	63.9	89.9	48.5	47.3	97.8	78.8	18.4
85	63.1	62.7	86.5	87.9	86.9	91.4	90.5	112.7	102.9	103.6
86	86.1	128.4	74.8	65.9	123.4	61.8	48.6	98.7	45.9	106.0
87	260.3	396.3	384.2	405.2	196.2	148.8	373.0	546.7	505.4	440.6
88	180.2	125.9	152.7	152.7	93.5	118.9	157.3	192.2	205.5	177.7
89	81.5	93.2	65.7	93.2	5.2	42.6	129.4	93.2	128.0	77.7
90	90.3	62.1	82.5	61.2	65.9	65.1	66.9	83.5	89.0	77.7
91	730.9	483.8	435.0	551.8	500.2	489.6	616.6	745.9	698.5	671.3
92	687.7	751.2	691.4	643.7	589.5	649.8	540.2	483.9	345.5	232.7
93	602.8	63.3	420.7	463.0	583.3	492.8	528.5	798.0	316.7	286.4
94	602.8	63.3	420.7	463.0	583.3	492.8	528.5	798.0	515.8	187.3
95	602.8	63.3	420.7	463.0	583.3	70.1	71.3	147.4	212.3	217.3
96	59.0	140.5	111.5	66.8	130.5	124.6	168.8	118.6	175.4	172.3
97	98.5	101.6	61.0	101.4	59.3	76.1	39.3	101.4	78.5	101.4
98	307.7	308.5	105.6	287.7	216.2	250.3	192.8	226.7	268.4	286.6
99	65.3	60.4	65.3	106.3	60.1	21.3	28.9	63.7	65.3	31.3
100	656.5	482.8	852.7	834.8	611.6	659.8	830.2	311.1	367.3	290.5
101	178.8	240.9	178.8	294.8	179.0	62.8	84.1	363.3	270.5	314.5
102	174.1	96.3	139.9	196.4	196.4	104.0	203.4	252.5	216.3	140.0
103	79.9	75.0	40.1	39.8	75.3	79.9	75.3	79.9	77.6	80.3
104	80.3	77.6	38.2	39.5	77.6	80.3	75.9	80.3	75.3	79.9
105	118.4	77.7	77.8	157.3	152.1	232.3	151.1	79.5	76.2	77.8
106	519.4	345.2	299.5	420.0	257.4	252.0	252.0	312.8	326.6	297.3
107	19.2	18.1	16.8	14.2	17.2	16.4	16.4	20.3	22.6	12.2
108	249.0	180.7	237.1	285.9	162.2	272.5	263.0	432.2	263.0	159.5
109	180.8	78.1	144.5	117.7	112.6	117.0	117.7	135.5	117.0	117.7
110	96.6	93.0	225.9	87.9	96.6	219.6	105.3	229.7	92.8	105.3
111	96.0	76.2	145.3	277.8	188.4	123.8	249.1	169.7	142.8	129.3
112	291.7	285.7	305.2	307.4	111.3	324.1	361.0	373.4	378.3	250.3
113	45.1	104.4	47.0	62.9	22.4	43.8	49.8	100.2	49.0	9.4
114	313.7	240.4	293.8	197.7	206.0	160.1	141.2	176.5	245.4	167.1
115	158.9	119.0	158.9	99.6	91.2	86.6	74.1	58.2	119.2	158.6
116	159.8	99.4	159.8	99.5	99.5	84.0	75.7	90.7	121.1	118.2
117	40.1	14.0	93.2	60.0	4.9	80.0	21.0	77.1	60.0	79.2
118	146.7	109.7	234.0	77.5	74.4	116.5	155.2	206.9	77.3	144.7

119	192.0	108.0	225.9	120.0	157.6	165.5	165.3	204.2	78.6	63.0
120	475.9	640.6	343.6	358.0	345.3	315.6	277.3	264.8	91.5	74.1
121	192.0	108.0	225.9	120.0	157.6	165.5	165.3	204.2	77.7	59.7
122	153.5	157.5	195.4	118.0	149.0	148.5	110.0	236.7	234.2	236.7
123	585.0	621.3	655.5	377.8	685.7	695.4	692.6	612.5	832.6	800.9

Yield Per Acre in Chouteau County for 82-91

	82	83	84	85	86	87	88	89	90	91
1	71	64	35	42	53	43	13	33	55	72
2	71	64	41	42	57	42	7	16	55	72
3	51	56	44	14	38	30	14	23	47	43
4	47	59	56	16	39	52	18	43	51	66
5	47	59	41	19	37	48	20	38	40	50
6	47	59	38	19	34	32	13	41	41	48
7	60	45	45	42	40	38	13	25	45	55
8	60	45	45	42	40	36	10	13	47	60
9	53	38	27	40	40	39	10	47	56	54
10	55	32	48	0	33	41	1	77	87	29
11	47	42	39	16	35	42	10	42	45	58
12	46	40	37	20	37	41	12	42	39	59
13	46	40	49	15	37	45	6	38	47	44
14	46	40	44	16	38	41	10	23	43	50
15	46	40	36	22	37	38	17	47	45	46
16	34	43	40	18	33	33	10	34	40	40
17	34	43	39	20	19	27	11	26	31	33
18	47	39	33	28	20	45	23	6	62	43
19	47	39	39	20	27	45	25	31	3	43
20	49	55	47	23	50	62	45	39	66	79
21	56	44	50	16	45	34	11	37	60	60
22	56	44	37	1	39	26	14	32	52	57
23	42	55	36	20	18	32	37	40	50	24
24	34	38	50	26	45	50	34	49	52	47
25	50	38	25	16	44	36	13	43	47	45
26	50	36	27	12	32	14	6	43	56	55
27	51	43	38	27	46	10	13	43	50	45
28	44	47	54	28	49	49	20	31	47	60
29	44	47	54	28	49	44	2	23	46	51
30	40	28	27	5	33	31	11	40	35	45
31	49	63	40	33	46	36	14	46	48	59
32	50	36	27	25	31	14	5	43	56	54
33	51	55	32	30	38	33	19	49	39	52
34	51	55	31	28	42	42	15	43	39	53
35	69	50	24	24	46	45	21	48	58	70
36	50	38	25	26	43	36	13	43	47	45
37	40	38	37	19	36	34	15	25	30	38
38	40	36	37	19	33	36	14	26	34	40
39	30	56	40	17	41	13	10	32	52	48
40	33	67	48	27	46	35	2	31	46	51
41	33	67	48	27	46	35	2	31	46	44
42	33	67	48	27	46	35	2	31	46	49
43	49	44	39	29	36	44	40	40	45	49
44	60	46	45	29	47	42	31	31	33	49
45	62	55	50	3	46	33	34	53	1	50
46	53	24	44	24	43	38	15	37	50	52
47	53	51	48	20	40	39	12	34	52	45
48	54	34	35	10	25	33	15	31	0	60
49	37	39	43	18	25	33	16	34	27	21
50	48	47	26	8	32	24	18	23	40	32
51	48	47	45	19	32	45	23	49	50	36
52	47	40	39	12	42	34	19	52	0	51
53	47	40	39	12	42	34	20	50	0	55
54	47	40	39	12	42	34	20	45	0	50
55	49	40	34	22	37	34	25	47	52	58
56	49	40	30	14	33	36	29	41	47	50
57	48	65	55	12	49	45	8	44	56	65
58	48	65	45	19	47	21	0	35	44	59

59	34	38	50	26	45	50	34	49	42	39
60	34	38	50	26	45	50	34	49	49	47
61	34	38	50	26	45	50	34	49	56	46
62	34	38	50	26	45	50	34	49	36	49
63	46	36	51	21	35	34	13	28	52	56
64	43	39	9	6	38	33	10	33	31	31
65	43	39	9	6	38	33	10	33	3	46
66	48	41	54	35	43	51	39	62	54	56
67	51	67	47	21	54	54	36	64	59	59
68	48	47	45	19	32	45	23	49	50	35
69	34	43	39	20	20	27	11	26	31	33
70	46	40	37	20	37	41	11	42	39	59
71	37	30	33	17	23	28	13	27	29	46
72	37	30	40	10	32	32	14	26	14	41
73	37	30	41	10	36	26	13	30	11	38
74	63	56	59	24	53	60	40	47	60	64
75	63	56	59	24	52	58	40	54	68	71
76	63	56	59	24	52	58	62	45	62	70
77	64	46	42	30	46	59	43	58	44	74
78	64	67	41	24	36	62	37	54	21	98
79	59	58	45	32	41	48	26	28	40	69
80	55	58	45	36	30	52	26	28	46	65
81	47	55	46	20	47	50	34	44	57	62
82	45	55	46	20	50	50	36	47	50	70
83	37	30	38	14	26	34	14	28	22	47
84	54	60	53	13	39	50	22	52	39	64
85	57	57	56	21	48	41	32	53	52	60
86	45	39	30	26	22	35	20	25	45	50
87	54	50	29	2	1	27	17	46	34	40
88	37	47	25	14	30	34	6	27	1	37
89	36	54	38	14	32	38	11	33	23	23
90	37	33	39	27	41	48	26	45	53	45
91	47	55	46	14	48	47	10	40	47	58
92	69	60	34	4	39	38	9	32	62	64
93	69	60	41	7	45	31	10	40	57	49
94	69	60	41	7	45	31	10	40	58	51
95	69	60	41	7	45	30	15	37	58	49
96	51	47	40	3	44	29	10	28	54	50
97	65	40	38	18	42	42	21	53	58	64
98	65	40	38	18	42	40	29	54	65	63
99	65	40	38	18	42	41	7	58	64	61
100	70	57	43	44	57	46	7	23	58	71
101	65	55	43	44	55	42	18	53	62	61
102	52	68	49	25	44	63	40	45	63	74
103	54	53	44	16	31	34	21	36	32	59
104	54	52	40	19	33	34	19	36	28	59
105	54	53	44	17	31	36	13	35	7	59
106	59	53	48	0	42	42	10	17	55	63
107	56	52	33	0	16	37	13	38	39	64
108	61	54	56	26	41	44	0	42	56	63
109	54	46	39	0	43	51	33	39	0	63
110	54	46	39	19	53	45	30	34	4	60
111	59	57	45	25	45	42	28	40	29	57
112	59	53	59	19	35	32	27	46	47	50
113	54	43	45	5	31	46	3	45	3	59
114	40	39	28	12	25	29	16	24	32	33
115	40	39	28	10	25	35	16	24	32	36
116	39	38	26	12	28	36	14	24	38	37
117	62	43	49	19	46	32	34	46	1	62
118	62	53	37	0	43	34	36	55	0	55
119	54	31	34	18	22	37	16	37	29	47
120	42	36	30	14	28	26	20	35	45	40

121	54	31	34	18	22	37	16	37	34	47
122	54	50	33	21	25	35	16	35	35	48
123	57	44	38	16	34	46	43	41	64	60

Acres Planted by Each Producer in Sheridan County from 83-92

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1	149.3	155.7	149.3	155.7	149.3	155.7	149.3	155.7	149.3	155.7
2	157.5	78.2	232.6	243.6	218.4	231.2	191.2	231.2	232.6	231.2
3	80.4	144.9	80.4	73.6	80.4	73.6	80.4	73.6	80.4	73.6
4	215.7	190.3	215.7	147.9	164.6	157.3	270.0	261.5	271.9	249.5
5	92.2	57.1	63.9	121.4	106.5	139.4	129.5	139.4	113.4	155.5
6	150.0	126.9	121.4	133.4	120.9	133.4	122.9	123.2	109.5	152.3
7	199.8	188.8	225.1	188.8	204.3	120.6	222.6	227.7	274.3	224.5
8	161.2	144.0	161.2	144.0	161.2	144.0	161.2	144.0	161.2	144.0
9	188.3	155.2	225.9	155.2	149.0	155.2	152.3	117.5	169.3	37.2
10	197.7	221.8	182.5	221.8	185.6	221.8	119.9	226.4	203.2	229.9
11	143.8	160.3	145.9	158.9	146.2	159.9	146.2	159.9	146.2	146.2
12	58.4	40.6	77.0	79.7	77.0	79.7	77.0	79.7	77.0	70.7
13	100.4	63.8	59.1	33.7	61.2	54.2	63.3	40.7	48.3	66.2
14	193.1	172.3	193.1	270.1	74.6	279.9	193.6	180.7	234.6	141.2
15	177.2	185.2	162.6	89.2	252.7	67.1	244.8	187.5	133.9	253.0
16	77.9	27.7	39.1	56.4	76.2	56.4	66.8	109.3	86.1	109.4
17	723.1	631.4	54.4	73.7	54.3	59.4	55.7	57.9	19.0	38.5
18	74.0	45.6	64.2	68.4	66.1	66.1	82.1	85.9	80.4	89.0
19	52.1	53.2	48.4	53.2	50.5	53.2	68.9	73.2	68.9	73.2
20	106.5	93.3	93.0	99.0	96.2	96.0	119.8	103.3	116.9	112.0
21	84.9	67.2	67.9	69.2	85.9	69.2	85.9	69.2	85.9	69.2
22	40.5	41.7	42.0	49.8	28.0	43.3	54.5	64.2	52.6	70.2
23	81.7	88.4	83.5	112.4	109.2	123.9	155.4	107.8	97.1	99.3
24	50.9	16.1	29.7	31.9	10.0	31.9	35.8	31.9	29.7	31.9
25	138.4	153.4	316.3	153.4	316.3	96.0	316.3	153.4	316.3	78.2
26	604.9	427.8	604.9	583.8	427.8	427.8	604.9	583.8	604.9	583.8
27	74.6	68.9	255.3	206.8	180.7	187.6	180.7	187.6	180.7	187.6
28	602.6	513.9	745.2	300.0	378.5	419.5	734.5	86.5	145.9	113.3
29	95.3	88.3	90.5	96.3	93.1	93.9	98.4	112.9	100.2	113.4

Yield Per Acre in Sheridan County for 83-92

	83	84	85	86	87	88	89	90	91	92
1	20	35	14	25	34	8	14	10	28	46
2	18	34	13	27	39	8	14	19	31	45
3	20	20	5	27	31	8	12	17	23	45
4	16	13	4	26	24	7	14	19	33	42
5	14	10	3	25	22	5	16	20	33	39
6	16	14	4	28	25	7	14	22	37	42
7	26	21	11	33	17	13	11	17	38	49
8	26	21	8	40	38	12	18	4	45	50
9	26	21	7	33	33	10	23	24	0	55
10	34	44	18	27	48	12	33	15	45	64
11	35	29	15	31	43	7	18	19	41	46
12	43	23	9	26	46	10	13	21	39	45
13	24	33	17	30	43	8	20	18	21	53
14	19	18	11	35	18	8	7	15	38	51
15	19	18	9	26	21	11	10	22	37	45
16	19	18	11	36	18	10	12	29	28	42
17	23	24	6	30	26	7	16	20	42	50
18	20	15	13	30	31	8	13	33	42	50
19	27	22	7	31	30	11	25	15	0	43
20	18	21	11	28	24	8	16	23	36	41
21	15	17	8	35	24	9	12	20	29	42
22	15	15	11	16	25	8	15	2	31	38
23	23	23	11	26	29	8	13	28	39	51
24	23	26	14	9	31	8	16	25	41	35
25	26	20	4	25	37	7	19	11	32	52
26	27	22	8	23	34	7	19	17	33	44
27	26	20	15	24	33	7	15	25	32	46
28	24	26	25	36	43	8	23	10	50	61
29	26	14	8	21	29	2	11	14	26	32

APPENDIX B

Absolute and Percent Yield Variance Reduction

Absolute Variance Reduction for Each Producer in Chouteau County

	AYC1	AYC2	AYC3	IYC1	IYC2
1	177.497	235.200	251.683	141.337	203.743
2	142.937	187.540	191.707	109.333	150.817
3	169.463	224.122	237.015	155.117	192.951
4	102.376	131.606	131.713	75.255	100.966
5	125.560	163.578	164.631	88.949	115.021
6	83.162	105.434	105.942	96.469	123.865
7	109.130	140.920	140.924	171.440	201.243
8	79.218	99.997	100.918	106.155	133.185
9	210.569	280.809	316.710	373.323	453.653
10	148.921	195.792	201.508	127.113	152.641
11	120.336	156.374	156.894	91.425	115.004
12	132.565	173.237	175.298	151.218	176.609
13	127.925	166.839	168.194	111.120	145.973
14	74.215	92.901	94.545	56.413	78.394
15	73.962	92.536	94.223	69.725	87.600
16	46.162	51.464	56.585	35.917	55.599
17	52.821	61.725	64.748	113.827	154.172
18	23.794	23.790	23.794	101.263	129.606
19	98.367	126.076	126.392	74.544	114.878
20	194.210	258.248	283.611	163.013	202.064
21	217.449	290.295	331.173	188.715	228.639
22	13.584	13.495	13.584	51.785	82.783
23	16.523	16.517	16.523	18.093	45.428
24	111.814	144.621	144.671	94.245	128.814
25	184.259	244.525	264.371	168.828	211.082
26	97.461	124.842	124.997	134.463	172.759
27	87.036	110.651	110.877	63.749	107.607
28	128.232	167.262	168.660	172.878	215.919
29	108.936	140.652	140.655	101.503	118.082
30	118.653	154.052	154.440	86.783	120.844
31	142.478	186.907	190.965	135.847	178.382
32	78.178	98.540	99.592	38.379	73.126
33	98.496	126.255	126.562	65.668	100.760
34	180.469	239.300	257.223	138.673	194.736
35	79.461	100.336	101.228	65.154	98.326
36	50.738	58.590	62.195	33.998	53.803
37	57.378	68.378	70.335	39.864	58.983
38	122.780	159.743	160.489	134.413	170.410
39	133.755	174.879	177.144	152.377	190.542
40	117.452	152.397	152.702	145.070	178.943
41	129.097	168.455	169.975	150.266	187.169
42	19.027	18.884	19.027	5.454	17.940
43	46.240	51.588	56.681	5.004	47.227
44	96.358	123.351	123.561	311.190	350.802
45	90.724	115.698	116.321	77.875	114.944
46	134.731	176.225	178.665	111.835	141.418
47	114.146	147.837	147.966	166.199	199.674
48	21.044	20.994	21.044	24.931	46.949
49	95.693	122.453	122.700	59.827	87.511
50	60.430	72.758	75.751	57.813	88.684
51	67.675	83.337	84.832	199.546	236.829
52	73.068	91.239	93.083	200.296	237.993
53	63.781	77.725	79.948	184.365	219.569
54	88.682	112.872	113.702	39.334	68.864
55	77.221	97.191	98.374	50.892	74.135
56	232.038	310.414	362.916	265.310	304.640

57	214.973	286.881	325.931	230.770	277.416
58	6.465	6.419	6.465	12.734	31.269
59	15.185	15.178	15.185	17.148	42.584
60	17.381	17.347	17.381	19.052	48.404
61	11.612	11.549	11.612	13.860	35.503
62	122.256	159.021	159.716	80.292	115.441
63	89.997	114.690	115.389	120.096	144.753
64	94.440	120.760	121.085	172.778	208.588
65	20.090	19.982	20.090	3.470	30.740
66	99.575	127.743	127.985	94.956	134.919
67	58.579	70.087	71.807	57.050	88.142
68	46.247	51.600	56.689	34.366	53.959
69	123.711	161.028	161.871	96.756	120.435
70	61.113	73.780	76.606	30.797	46.738
71	55.696	65.954	68.272	66.103	87.800
72	51.839	60.255	63.545	77.243	99.253
73	103.102	132.606	132.688	74.323	113.478
74	127.501	166.253	167.552	88.969	133.042
75	51.933	60.395	63.659	89.719	122.176
76	65.612	80.385	82.246	30.073	61.207
77	158.950	209.624	218.484	158.158	263.253
78	110.238	142.447	142.464	47.545	93.479
79	83.780	106.275	106.730	49.343	102.631
80	93.880	120.004	120.367	65.765	97.514
81	93.878	120.001	120.365	67.688	97.689
82	61.663	74.600	77.295	40.989	61.668
83	162.661	214.741	224.938	151.382	190.963
84	113.950	147.567	147.688	78.820	117.450
85	60.562	72.955	75.915	21.680	55.394
86	139.794	183.206	186.657	205.653	237.678
87	62.172	75.357	77.934	128.754	151.459
88	48.376	54.953	59.299	62.032	93.395
89	27.072	25.212	27.072	15.888	41.027
90	176.001	233.138	248.919	182.665	214.548
91	295.223	397.549	517.155	270.261	327.558
92	244.473	327.563	391.117	232.401	282.400
93	250.218	335.486	404.504	236.845	288.459
94	229.407	306.786	357.083	201.601	251.589
95	204.545	272.501	304.309	191.435	234.112
96	167.438	221.329	233.387	116.159	152.297
97	146.124	191.935	196.896	89.622	131.577
98	213.781	285.237	323.421	210.608	248.480
99	183.800	243.892	263.501	237.966	279.803
100	111.121	143.665	143.698	99.298	128.551
101	115.054	149.088	149.259	66.063	114.096
102	132.228	172.772	174.776	70.278	104.300
103	122.974	160.011	160.776	59.573	95.101
104	128.353	167.429	168.844	169.174	208.573
105	269.405	361.945	450.841	323.414	376.834
106	228.895	306.081	355.955	228.411	269.485
107	221.416	295.766	339.661	246.188	282.992
108	105.143	135.421	135.449	315.989	346.962
109	58.167	69.502	71.301	166.124	205.912
110	85.870	109.093	109.392	43.898	85.910
111	110.365	142.623	142.642	68.164	119.427
112	180.358	239.146	257.015	317.471	360.929
113	58.281	69.665	71.442	34.560	48.168
114	67.993	83.787	85.230	47.225	63.854
115	72.634	90.608	92.530	50.218	68.317
116	61.161	73.853	76.667	205.506	247.151
117	104.031	133.888	133.942	328.125	360.000
118	79.930	100.988	101.825	47.123	73.906

119	66.990	82.361	83.973	37.495	57.228
120	85.019	107.949	108.307	51.569	79.099
121	103.536	133.206	133.273	52.398	82.924
122	85.205	108.200	108.545	78.653	109.746
123	202.215	269.287	299.579	274.149	319.163

Percent Variance Reduction for Each Producer in Chouteau County

	AYC1	AYC2	AYC3	IYC1	IYC2
1	0.51285	0.67957	0.72720	0.40837	0.58868
2	0.63184	0.82901	0.84743	0.48330	0.66668
3	0.62097	0.82126	0.86850	0.56840	0.70704
4	0.64482	0.82893	0.82960	0.47400	0.63594
5	0.67602	0.88072	0.88639	0.47891	0.61928
6	0.45208	0.57315	0.57591	0.52441	0.67334
7	0.38553	0.49783	0.49785	0.60565	0.71094
8	0.40918	0.51651	0.52127	0.54832	0.68794
9	0.26241	0.34994	0.39468	0.46523	0.56533
10	0.72276	0.95024	0.97799	0.61692	0.74082
11	0.70689	0.91859	0.92164	0.53706	0.67557
12	0.63056	0.82402	0.83383	0.71929	0.84006
13	0.68089	0.88802	0.89523	0.59145	0.77696
14	0.69548	0.87059	0.88599	0.52865	0.73464
15	0.66532	0.83241	0.84758	0.62721	0.78800
16	0.48643	0.54230	0.59626	0.37847	0.58587
17	0.20540	0.24003	0.25178	0.44264	0.59953
18	0.12801	0.12799	0.12801	0.54478	0.69726
19	0.41593	0.53309	0.53443	0.31520	0.48574
20	0.66155	0.87969	0.96609	0.55528	0.68831
21	0.65331	0.87217	0.99498	0.56698	0.68693
22	0.09080	0.09021	0.09080	0.34616	0.55336
23	0.20989	0.20981	0.20989	0.22983	0.57707
24	0.64339	0.83216	0.83245	0.54230	0.74121
25	0.55669	0.73877	0.79873	0.51007	0.63773
26	0.44158	0.56564	0.56634	0.60923	0.78274
27	0.55441	0.70483	0.70627	0.40607	0.68544
28	0.48540	0.63314	0.63843	0.65440	0.81732
29	0.67314	0.86912	0.86914	0.62721	0.72965
30	0.61641	0.80032	0.80233	0.45085	0.62780
31	0.49227	0.64577	0.65979	0.46936	0.61632
32	0.57222	0.72126	0.72896	0.28091	0.53524
33	0.64102	0.82167	0.82367	0.42737	0.65575
34	0.56781	0.75291	0.80930	0.43631	0.61270
35	0.57377	0.72451	0.73095	0.47046	0.70999
36	0.66605	0.76912	0.81644	0.44630	0.70628
37	0.72073	0.85890	0.88348	0.50073	0.74089
38	0.45758	0.59534	0.59812	0.50094	0.63510
39	0.44024	0.57560	0.58305	0.50153	0.62715
40	0.40580	0.52654	0.52759	0.50122	0.61825
41	0.43218	0.56394	0.56903	0.50305	0.62659
42	0.51193	0.50809	0.51193	0.14674	0.48269
43	0.45727	0.51016	0.56052	0.04948	0.46703
44	0.21297	0.27263	0.27309	0.68778	0.77533
45	0.52747	0.67266	0.67628	0.45276	0.66828
46	0.69672	0.91130	0.92392	0.57832	0.73130
47	0.33397	0.43254	0.43292	0.48626	0.58420
48	0.24467	0.24409	0.24467	0.28986	0.54585
49	0.59412	0.76026	0.76179	0.37144	0.54332
50	0.47277	0.56921	0.59263	0.45229	0.69381
51	0.21985	0.27073	0.27559	0.64825	0.76937
52	0.23263	0.29048	0.29635	0.63768	0.75770
53	0.23008	0.28038	0.28840	0.66507	0.79206
54	0.65016	0.82751	0.83359	0.28837	0.50487
55	0.63359	0.79744	0.80715	0.41757	0.60827
56	0.59597	0.79727	0.93212	0.68143	0.78244
57	0.54684	0.72975	0.82908	0.58702	0.70567

58	0.10065	0.09993	0.10065	0.19825	0.48681
59	0.20719	0.20710	0.20719	0.23398	0.58104
60	0.19761	0.19722	0.19761	0.21661	0.55032
61	0.15765	0.15680	0.15765	0.18817	0.48201
62	0.61483	0.79973	0.80322	0.40379	0.58056
63	0.48267	0.61510	0.61885	0.64410	0.77634
64	0.33021	0.42224	0.42337	0.60412	0.72933
65	0.27226	0.27080	0.27226	0.04703	0.41659
66	0.52359	0.67170	0.67297	0.49930	0.70944
67	0.45524	0.54467	0.55804	0.44335	0.68498
68	0.49764	0.55524	0.61000	0.36979	0.58062
69	0.70308	0.91516	0.91995	0.54989	0.68446
70	0.68232	0.82374	0.85529	0.34384	0.52182
71	0.43649	0.51688	0.53505	0.51805	0.68809
72	0.37099	0.43122	0.45476	0.55279	0.71030
73	0.65885	0.84738	0.84791	0.47494	0.72515
74	0.67165	0.87579	0.88263	0.46867	0.70084
75	0.31519	0.36655	0.38636	0.54452	0.74151
76	0.39515	0.48412	0.49533	0.18111	0.36862
77	0.29133	0.38421	0.40045	0.28988	0.48250
78	0.54863	0.70893	0.70901	0.23662	0.46522
79	0.45235	0.57381	0.57626	0.26642	0.55413
80	0.65014	0.83105	0.83357	0.45544	0.67530
81	0.57285	0.73226	0.73448	0.41304	0.59611
82	0.55275	0.66872	0.69288	0.36743	0.55280
83	0.60285	0.79586	0.83365	0.56104	0.70774
84	0.71016	0.91967	0.92043	0.49123	0.73198
85	0.53223	0.64114	0.66716	0.19053	0.48681
86	0.39916	0.52311	0.53297	0.58721	0.67865
87	0.28938	0.35075	0.36275	0.59929	0.70497
88	0.29666	0.33700	0.36365	0.38041	0.57274
89	0.34589	0.32213	0.34589	0.20300	0.52419
90	0.67187	0.88999	0.95023	0.69731	0.81902
91	0.57129	0.76930	1.00075	0.52298	0.63386
92	0.59484	0.79701	0.95165	0.56547	0.68712
93	0.59772	0.80141	0.96628	0.56577	0.68907
94	0.59280	0.79275	0.92272	0.52095	0.65012
95	0.65225	0.86894	0.97037	0.61044	0.74653
96	0.63240	0.83594	0.88148	0.43872	0.57521
97	0.57268	0.75223	0.77167	0.35124	0.51567
98	0.56055	0.74791	0.84803	0.55223	0.65153
99	0.45641	0.60563	0.65432	0.59091	0.69480
100	0.58091	0.75104	0.75121	0.51910	0.67203
101	0.52400	0.67901	0.67979	0.30088	0.51964
102	0.64818	0.84692	0.85675	0.34450	0.51127
103	0.62870	0.81805	0.82196	0.30457	0.48620
104	0.39147	0.51064	0.51496	0.51597	0.63613
105	0.55447	0.74493	0.92789	0.66563	0.77557
106	0.56077	0.74987	0.87206	0.55959	0.66021
107	0.60202	0.80417	0.92352	0.66937	0.76944
108	0.23425	0.30171	0.30177	0.70401	0.77301
109	0.19575	0.23389	0.23994	0.55905	0.69294
110	0.54807	0.69629	0.69820	0.28018	0.54832
111	0.58357	0.75413	0.75423	0.36042	0.63148
112	0.38100	0.50519	0.54294	0.67065	0.76245
113	0.71696	0.85700	0.87886	0.42515	0.59255
114	0.69184	0.85255	0.86723	0.48052	0.64973
115	0.70778	0.88293	0.90166	0.48935	0.66571
116	0.17264	0.20847	0.21641	0.58009	0.69764
117	0.21721	0.27955	0.27966	0.68510	0.75165
118	0.54395	0.68726	0.69295	0.32069	0.50295
119	0.68482	0.84195	0.85843	0.38330	0.58502

120	0.58410	0.74163	0.74409	0.35429	0.54343
121	0.65825	0.84689	0.84731	0.33313	0.52721
122	0.43618	0.55389	0.55566	0.40264	0.56181
123	0.42323	0.56361	0.62701	0.57379	0.66800

Absolute Variance Reduction for Each Producer in Sheridan County

	AYC1	AYC2	AYC3	IYC1	IYC2
1	76.428	124.761	124.773	57.235	81.341
2	78.002	127.799	127.802	52.933	82.674
3	77.927	127.655	127.658	50.814	66.240
4	74.956	121.922	121.978	49.016	67.933
5	68.174	109.080	109.399	55.847	72.494
6	78.771	129.293	129.293	57.890	80.967
7	75.942	123.823	123.846	42.331	70.058
8	118.255	205.949	217.430	117.256	154.120
9	62.607	98.787	99.432	110.878	129.675
10	119.183	207.753	219.777	109.275	150.864
11	91.453	153.914	155.118	77.894	109.861
12	93.121	157.154	158.692	89.578	123.494
13	82.666	136.854	136.974	46.153	76.918
14	97.804	166.245	168.936	59.167	86.622
15	69.972	112.466	112.635	40.767	57.218
16	47.417	71.329	73.576	35.701	56.468
17	101.310	173.053	176.817	74.148	95.364
18	89.020	149.190	149.982	71.340	104.005
19	33.529	44.402	50.809	84.861	105.554
20	59.180	92.539	93.303	35.626	52.493
21	66.309	105.593	105.830	40.443	60.872
22	58.357	91.064	91.955	39.511	51.679
23	89.814	150.733	151.650	64.376	82.964
24	41.163	59.548	63.206	49.888	70.603
25	110.871	191.614	199.216	86.694	109.332
26	77.660	127.136	127.136	54.117	72.781
27	69.421	111.427	111.637	43.648	62.227
28	128.760	226.345	244.716	99.546	141.693
29	53.355	82.105	83.461	44.771	61.836

Percent Variance Reduction for Each Producer in Sheridan County

	AYC1	AYC2	AYC3	IYC1	IYC2
1	0.49614	0.80990	0.80998	0.37155	0.52804
2	0.51787	0.84847	0.84849	0.35143	0.54888
3	0.56578	0.92683	0.92685	0.36893	0.48093
4	0.54775	0.89096	0.89137	0.35819	0.49643
5	0.50788	0.81262	0.81499	0.41605	0.54006
6	0.51713	0.84881	0.84881	0.38005	0.53155
7	0.46482	0.75789	0.75803	0.25910	0.42881
8	0.44915	0.78222	0.82582	0.44535	0.58536
9	0.25710	0.40568	0.40833	0.45533	0.53252
10	0.43462	0.75761	0.80146	0.39849	0.55015
11	0.52546	0.88434	0.89126	0.44755	0.63123
12	0.43100	0.72738	0.73449	0.41461	0.57158
13	0.46151	0.76403	0.76470	0.25766	0.42942
14	0.46377	0.78831	0.80107	0.28056	0.41075
15	0.51216	0.82319	0.82443	0.29839	0.41881
16	0.39292	0.59107	0.60969	0.29584	0.46792
17	0.52632	0.89903	0.91858	0.38521	0.49543
18	0.46084	0.77234	0.77644	0.36932	0.53842
19	0.20240	0.26804	0.30671	0.51227	0.63719
20	0.55228	0.86359	0.87072	0.33247	0.48987
21	0.51585	0.82145	0.82330	0.31462	0.47355
22	0.49906	0.77877	0.78639	0.33789	0.44195
23	0.52663	0.88384	0.88921	0.37747	0.48647
24	0.33814	0.48917	0.51922	0.40981	0.57998
25	0.52077	0.90002	0.93573	0.40721	0.51354
26	0.57744	0.94533	0.94533	0.40239	0.54117
27	0.56794	0.91160	0.91331	0.35709	0.50909
28	0.45049	0.79191	0.85618	0.34828	0.49574
29	0.53948	0.83018	0.84389	0.45269	0.62524