Ratemaking Considerations for Multiple Peril Crop Insurance

Frank F. Schnapp, ACAS, MAAA,
James L. Driscoll, Thomas P. Zacharias, and
Gary R. Josephson, FCAS, MAAA

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Submitted by:

Frank Schnapp A.C.A.S., M.A.A.A.
Director, Actuarial Analysis and Research
National Crop Insurance Services

James L. Driscoll
Senior Actuary
U.S. Department of Agriculture
Risk Managment Agency

Thomas P. Zacharias
Executive Vice President
Actuarial, Statistical and Information Services
National Crop Insurance Services

Gary R. Josephson F.C.A.S, M.A.A.A.
Consulting Actuary
Milliman & Robertson, Inc.

Abstract

Multiple Peril Crop Insurance (MPCI) is a unique public/private market insurance product. This paper is intended to provide an introduction to the MPCI ratemaking process, as well as a discussion of some of the political and economic forces affecting the program.

The paper will provide a description of the coverage offered under the program and an overview of the ratemaking methodology. Specific challenges relating to the catastrophic nature of the coverage and the geographical influences on loss exposure will be discussed. In addition to current ratemaking techniques, which involve a credibility weighting of county experience with the experience of adjacent counties, the paper will discuss alternatives, including:

- fixed territorial groupings of counties,
- spatial smoothing, and
- spatial credibility techniques.

The paper will discuss unique aspects of the product and the ratemaking process, including:

- the role of the Federal Government in supporting the program,
- the high correlation of experience among exposures, and.
- the use of econometric models and non-insurance data in validating experience.

The paper will also discuss some of the recent changes in the federal crop insurance program and how these are reflected in the rate process.

I. Introduction

The Federal Crop Insurance Program

The Federal crop insurance program is a joint effort of the Federal government and private industry. The insurance product, which is known as Multiple Peril Crop Insurance (MPCI), was created to serve the needs of farm producers in the era of the Oklahoma dust bowl. For many years, the participation among farm producers was very modest despite subsidies provided by the Federal Crop Insurance Corporation (FCIC). In order to increase participation, Congress authorized private insurers to sell, service, and underwrite MPCI coverage beginning in 1980. This enabled Crop Hail insurers to market a product which previously had competed against their own.

Since 1998, the sale and underwriting of MPCI coverage has been completely privatized. The current Federal role in the program consists of three essential activities: establishing the MPCI rates and rules, subsidizing the premium and the administrative costs of the program, and administering the reinsurance mechanism for the participating insurers. These activities are managed by the Risk Management Agency (RMA) of the United States Department of Agriculture (USDA). Subsidization of the program is necessary in order to keep the cost of coverage affordable to the individual farm producer. The reinsurance mechanism, implemented in the Standard Reinsurance Agreement (SRA) between insurers and the FCIC, is necessary to protect insurers from severe or catastrophic losses. By combining the marketing efforts of the private sector with the financial strength and support of the Federal government, the Federal crop insurance program has become much more successful in achieving its aim to provide financial protection to farm producers. An indication of this success is that in cropyear 1998 the MPCI program provided coverage on 181 million acres (almost 70%) of U.S. cropland, insured $27.9 billion in crops, and generated a total premium of almost $1.9 billion.

Public Policy and Federal Crop Insurance

Federal crop insurance was authorized by the U. S. Congress in the 1930s as a pilot program. It was one of several public policies to assist agriculture's recovery from the Great Depression and the Dust Bowl years.

This legislation followed several failed attempts to offer such insurance commercially. Costs for salaries and other operating costs of the program were paid from the U.S. Treasury, and persons taking the insurance paid the full risk premium. Insurance was restricted primarily to major crops in principal producing areas, with annual premium volumes well under $100 million. Operations were managed completely by the Government.

In the 1970s, free disaster assistance protection for certain crops was authorized as part of price support legislation affecting agriculture. By the late 1970s, the dichotomy of this coexistent public assistance -- one free and the other partially subsidized – resulted in passage of the Federal Crop Insurance Act of 1980. This Act made the free assistance unavailable if crop insurance was available. To make insurance more attractive, the risk premium was partially subsidized. This Act also authorized the Government to reinsure commercial insurance companies that sold and serviced the Federally-developed insurance policies at the Federally-approved premium rates. Additional subsidies were authorized to pay the operating expenses of those companies.

Following this Act, more crops and growing areas became eligible for insurance. Premiums increased from $156 million in 1980 to $436 million in 1988. However, the 1988 premiums represented only about 18 percent of acres planted to principal crops, a level that proved inadequate to withstand demands for disaster assistance.

Beginning in 1988, several years of adverse weather conditions affected different parts of the country, culminating in the floods of 1993 that impacted urban areas as well as agriculture. Several ad hoc assistance bills (i.e., temporary rather than permanent measures) were enacted in 1988 and subsequent years. These ad hoc measures typically paid more benefits to producers who had insurance and also required beneficiaries to purchase insurance the following year. By 1994, premiums had increased to nearly $950 million and insured acres approached 40 percent of planted acres.

In 1994, Congress again amended the enabling legislation for crop insurance. Insurance was required as a condition of eligibility to receive benefits available under other Federal programs for agriculture. A level of coverage intended to provide benefits only in the event of catastrophic losses was introduced and offered to producers for a minimal fee. This legislation also increased the subsidy for those persons who carried higher coverages than this minimum. In 1995, premiums increased to $1,550 million and over 80 percent of planted acres were insured.

Although the mandatory purchase of crop insurance was rescinded for 1996, the level of crop insurance sales remains high. In 1998, premiums reached a record $1,875 million and insured acres approached 70 percent of planted.

During the 1990s, the Congress also authorized subsidies and reinsurance for commercially developed insurance products. The first of these was offered in 1996. It modified the traditional insurance plan that indemnified only losses in yield so that changes in market prices for the insured commodity also could result in an indemnity. A commercial product from a second company, again one that includes risk of changes in market prices, was introduced in 1997. A third commercial product has been introduced for 1999. More are anticipated in future years.

The thrusts of public policy during the past two decades have been twofold: encourage farmers to actively manage the risks they have in farming and to encourage commercial insurance companies to be more active in this market. Both thrusts have been successful. More acres are insured, premiums are at record levels, and private companies are much more involved with providing this coverage.

A Description of Multiple Peril Crop Insurance

MPCI coverage is designed to insure the yields of farm producers over an entire growing season on an all risks basis. The primary cause of loss is weather, either for a single identifiable event or over an extended period. More specifically, perils include wind, rain, drought, hail, fire, prevented planting due to too much rain, flood, disease, insects, cold, frost, or any other reason for low yields. Due to the high damageability of crops, coverage is only provided in excess of a large deductible. The MPCI program currently provides coverage for almost 100 crops in all 50 states, but not including the District of Columbia. The program is gradually being extended to cover additional crops not currently insured. Crops currently being evaluated in pilot programs include cabbage, sweet cherry, winter squash, wild rice, and watermelon.

Since the Federal crop insurance program is a public/private partnership, public policy considerations have a significant influence on the operation of the program. For example, insurers are required to accept all applicants. In addition, the farm producer selects the amount of coverage to be purchased. Since Congress regularly evaluates the operation of the program, pricing and policy design decisions may differ from those that would be made if MPCI were solely a private insurance program. Public policy considerations may also result in unanticipated changes to the coverage after the policies are sold.

The MPCI premium is computed as product of the published rate and the exposure. Generally, the premium is paid at the end of the cropyear. The MPCI exposure is the liability measured in hundreds of dollars. The liability represents the total insured value of the crop, and is the product of:

the APH yield
the acres planted
the selected Coverage Level
the Base Price for the crop, and
the Price Election percentage.

The first element in this calculation, the APH yield, is based on the producer's Actual Production History. The APH represents the producer's normal yield, and is based on 4 to 10 prior years of yield information.

The number of acres planted may be estimated by the producer at the time the policy is issued, in order to have an estimate of the premium. Subsequent to planting, the producer must file a report of the actual acreage planted. Since the acreage is verified at the time of loss, overreporting will not increase the producer's indemnity payment. Underreporting of acreage will result in a penalty because the total value of production on all of the producer's acreage, including any unreported acreage, is compared to the insured liability to determine the indemnity at the time of a loss.

The Coverage Level represents the producer's deductible, with a Coverage Level of 75% meaning that the insurance pays nothing if the loss is less than 25% of the value of the crop. Coverage Levels ranging from 50% to 75% are currently available, with 85% coverage being offered in some counties on a pilot basis.

The Base Price represents the price of the crop at the start of the growing season, and is established by RMA based on the latest market prices. The Price Election percentage allows the producer to further modify coverage by insuring the crop at a lower value than the Base Price. The producer may choose to insure production at any level from 60% to 100% of the Base Price for the crop. For example, a lower Price Election percentage may be selected if the producer wishes to insure only the cost of planting rather than the full value of the crop. The Base Price and the Price Election percentage are also used to determine the value of the crop for loss indemnification.

The following example reviews the steps in determining the liability, premium, and loss. The Producer Premium Percentage Factor in Step 2 is taken from a countrywide Table and represents the premium subsidy factor for the selected Coverage Level and Price Election percentage. The premium subsidy is discussed further in the next section.

Step 1: Determine the Liability		
Acres Planted	500	acres
Actual Production History (APH)	120	Based on producer's past bushels/acre
Coverage Level Selection	75%	Selected by producer
Base Price	$3.00	$ per bushel, established by RMA
Price Election	100%	Selected by producer
Liability	$135,000	= 500 x 120 x 75% x $3.00 x 100%

Step 2: Determine the Premium		
Liability	$135,000	from above
Rate	$2.00	per $100 of liability
Risk Premium	$2,700	= $135,000 x $2.00 / 100
Producer Premium % Factor	0.765	Subsidy factor for selected Price Election
Producer Paid Premium	$2,065	= $2,700 x 0.765
Step 3: Determine the Loss		
Actual Amount Harvested	40,000	bushels
Value of Production	$120,000	= 40,000 bu x $3.00/bu x 100% price
Liability	$135,000	from above
Indemnity Payment	$15,000	= $135,000 - $120,000
Summary: The producer expects to harvest 60,000 bushels and insures 45,000 bushels. Since 40,000 bushels are actually harvested, the indemnity represents the value of 5,000 bushels at the Base Price of $3.00 per bushel. The market price for the crop at the time of harvest is not considered in this calculation.		

Unlike standard Property and Casualty contracts, MPCI coverage is not triggered by an event. Instead, the indemnity payment is determined after the crop is harvested. The producer's actual production is multiplied by the Base Price, adjusted by the Price Election percentage, to determine the value of the crop. This value is compared to the Liability under the contract. If the value of the crop is less than the Liability, the producer is paid the difference.

The standard MPCI policy insures the producer for a loss of yield, not a loss of revenue. The policy includes no protection against the risk that the market price at harvest will be different from the Base Price established at the start of the growing season. If the market price is lower than the Base Price, the producer's total revenue will be less than was anticipated at the start of the growing season. The producer can obtain protection from crop price changes during the growing season through a variety of mechanisms, including forward contracts, futures, and options. A recent innovation is the development of revenue contracts which extend the standard MPCI coverage to include market price protection. For the producer, the simplicity of purchasing protection against fluctuations in crop prices as part of the MPCI coverage has proven to be very popular, with more than 13% of all crop insurance premium arising from revenue coverages in just the third year since their inception. The design and rating of revenue contracts is an interesting subject which is beyond the scope of this discussion.

Unique Features of the Multiple Peril Program

The involvement of the Federal government in the MPCI program creates a social insurance program which operates on different principles than a privately underwritten insurance market. The important differences include producer premium subsidies, insurer expense reimbursements, and pricing for an underwriting loss. This section discusses these differences and other unusual characteristics of the program.

The MPCI program offers two levels of coverage, known as Catastrophic and Buy-up. The Catastrophic level of coverage protects against only the most severe outcomes, such as a complete crop failure. Specifically, Catastrophic coverage reimburses producers only when the actual production falls short of 50% of the APH yield, with the loss of yield evaluated at a 55% Price Election percentage. The most a producer could collect under this coverage would be 27.5% of the expected value of the crop. The producer premium for Catastrophic coverage is completely subsidized except for a $60 administrative fee per county per crop which is paid to the Federal government. However, an "imputed" premium is established which represents what the producer would pay if no subsidy existed.

Buy-up coverage allows the producer to purchase additional coverage at a partially subsidized price. However, the Buy-up and Catastrophic coverages are priced and sold as different deductibles rather than as distinct products. The premium at all deductibles is subsidized by a dollar amount determined from the cost of the catastrophic coverage.

For the 1999 cropyear, additional Federal financial assistance of $430 million will be provided to encourage the purchase of more adequate amounts of coverage. The additional financial assistance originated with an emergency farm bill recently passed by Congress. Preliminary estimates are that this will result in a 30% reduction to the Buy-up coverage premium. Since the Catastrophic premium is completely subsidized, the producer paid premium for Buy-up could decrease the full 30%. However, a significant percentage of this savings is being used to purchase higher levels of Buy-up coverage, as was intended when this additional financial assistance was offered.

Congress has expressed a desire to eliminate emergency Federal disaster assistance and to use the Federal crop insurance program as the primary mechanism for directing aid to producers. This objective is consistent with recent international trade agreements which restrict the types of subsidies which nations can provide to producers. Insurance is considered to be a form of farm income protection which does not distort producers' market incentives to grow particular crops, and for this reason is excluded from the treaty restrictions. In comparison, disaster assistance provides an incentive for the producer to grow as large a crop as possible. The expectation that Congress would protect producers from unanticipated losses would encourage excessive planting, resulting in reduced crop prices.

The rates established by RMA do not include a loading for insurance company expenses. Instead, insurers are compensated by the Federal government for their expenses in a separate arrangement. Currently, Congress has authorized an expense reimbursement of 24.5% of the premium for the Buy-up coverages. The expense reimbursement is intended to compensate an insurer for its commissions, administrative expenses, and all loss adjustment expenses. In comparison, a loss adjustment reimbursement of 11% applies to the imputed premium for the Catastrophic coverage. State premium taxes do not apply to MPCI premiums. The reimbursement percentage has been reduced significantly in recent years. This reduction was partially justified based on the high crop prices in the mid 1990's, since high prices result in an increase in the expense reimbursement payments without a corresponding increase in insurers' actual expenses. The reimbursement is not intended to generate a profit for private insurers. However, the reduction in crop prices in 1998 and 1999 has not resulted in an offsetting increase to the expense reimbursement percentage. As a result, the actual expenses of the crop insurance industry now exceed the amount of the expense reimbursement according to one study.

Another unusual aspect of the program is that the MPCI rates are currently established to produce a long term loss ratio of 107.5%. Since the premiums are collected and the losses are paid at the end of the cropyear, little or no investment income can be earned. As a result, the program is not designed to produce an operating profit on a direct basis for participating insurers. To encourage private participation in the MPCI program, the reinsurance arrangements in the SRA have been designed to enable insurers to earn a reasonable profit on a net basis. The financial and operational details of the SRA are complex and are beyond the scope of this discussion.

The Standard Reinsurance Agreement between insurers and the FCIC is designed to transfer much of the crop insurance risk to the Federal government. Previously, the SRA required insurers to reinsure their exposures by county and crop. Beginning in 1998, it permitted individual policies to be reinsured. Unlike the expense reimbursement percentage, the SRA is negotiated between RMA and private insurers.

In situations in which RMA broadens the MPCI coverage subsequent to the final date for policy revisions, insurers may experience greater losses than they would have otherwise anticipated. These revisions may also arise too late for insurers to cede the affected exposures to the SRA. These situations are negotiated between RMA and the insurance industry, with an occasional recourse to litigation.

Rates for Individual Producers

MPCI rates are established for combinations of county, crop, and farming practice. Certain crops such as wheat may be rated by the variety, such as winter wheat vs. spring wheat vs. durum wheat. Farming practices differ by crop and location. An example of a farming practice would be the distinction between irrigated vs. non-irrigated crops.

Since a producer may plant several crops or use more than one farming practice, the producer is rated for each distinct crop and practice. Also, coverage for certain practices in selected counties may be unavailable in order to prevent adverse selection against the MPCI program. For example, coverage for non-irrigated extra long staple cotton is unavailable in certain counties in Texas.

The rate structure for an individual county is fairly simple. For a given crop and practice, the two key rating characteristics are Coverage Level and Rate Class. Coverage Level generally ranges from 0.50 to 0.75 in increments of 0.05. The rates for lower Coverage Levels are less than those for higher Coverage Levels since a low yield is less likely than a more normal yield. Rate Class represents a subdivision of the APH yield range. Studies have shown that producers with lower than average APH yields also have significantly higher variability of yield. Since MPCI coverage protects against lower than expected yields, these producers would have relatively greater losses than producers with average yields. For example, both a low yield and a high yield producer may purchase 75% Coverage Level, but the low yield producer is more likely to have a poor crop, resulting in more claims than the producer with the higher and more stable yield. For this reason, different Rate Classes are established for producers with different APH yields. The number of Rate Classes depends on the crop. For many crops, the APH range is generally subdivided into Rate Classes R01 through R09, with R05 representing the typical yield. The APH ranges corresponding to each Rate Class are determined by defining R01 as any yield below 50% of the average yield, defining R09 as any yield above 150% of the average yield, and defining the remaining Rate Classes using bands of equal width.

Other rate adjustments include a credit for insuring the producer's entire operation as compared to insuring individual fields and a credit for a Hail and Fire exclusion, which may be useful if the producer elects to purchase Crop Hail coverage in combination with MPCI. Disregarding these exceptions, the final MPCI premium is developed as the product of the appropriate rate, the Liability, and the Producer Premium Percentage Factor corresponding to the selected Coverage Level and Price Election Percentage.

Overview of Current Ratemaking Methodology

MPCI ratemaking follows a pure premium approach, with each crop analyzed separately. At present, only the experience arising from the standard MPCI APH yield coverage is included in the analysis. The experience arising from the MPCI revenue contracts is being considered for inclusion in future analyses. The first step in the analysis is to convert the losses for each county to a base level. The second is to stabilize the results for each county by capping the largest pure premiums. Third, the pure premium is smoothed over a local neighborhood. Next, the pure premium is adjusted to include for a risk factor and to spread back the losses eliminated by capping. The resulting pure premium is compared to the current rate in order to select the base rate change and the final rates for each Coverage Level and Rate Class.

The base level to which the loss experience is converted is the 65% Coverage Level. Paid claims are converted to the 65% level simply by restating the value of the loss for the difference in the deductibles. A further adjustment is needed for claims eliminated by the deductible. For policies insured at less than 65% coverage, the losses eliminated by the deductible are estimated from the severity distribution for policies with higher Coverage Levels.

Stabilization of the pure premiums is accomplished by the use of an 80/20 rule. Since 20 years of experience are currently used in the analysis, the 16 smallest pure premiums (80% of 20 years) are considered to be normal. The remaining four years of experience (20% of 20 years) are capped at the largest value among the 16 normal pure premiums. This rule has been selected judgmentally, based on a study of 1948 through 1979 experience for corn and wheat. This study found that the 80/20 rule resulted in a larger reduction of variance relative to the reduction in expected losses than the two alternatives of 75/25 and 70/30 which were considered. The indicated pure premium for each county is selected as the straight average of the capped pure premiums for all the years in the experience period. The pure premium is not adjusted for trend since trend is expected to have an equal impact on losses and the liability exposure.

The previous steps produce a preliminary value for the base pure premium for each county. However, even with the use of 20 years, the experience is not sufficiently credible to establish rates due to the large uncertainty in the expected value. This uncertainty can be observed from the countrywide loss ratios for all crops combined in Chart 1. The magnitude of variation in the loss ratios is much larger than that normally experienced in Property/Casualty coverages. The variability in the losses is significant even on a countrywide basis for all crops combined. The variability at a county level for a single crop is much greater.

In order to produce a more stable and more reliable pure premium, the smoothed pure premium for each county is determined as a weighted average of the indicated pure premiums over all nearby counties. This technique is known as the concentric circle method. Since counties do not possess a uniform, orderly arrangement, RMA has predetermined which counties are included in each concentric circle. The weights for each county are based on the liability of each county, and are computed separately by year. The rationale for the concentric circle method is that the causal or statistically correlated factors that determine the experience for each county operate on a broad geographic basis. A drought, for example, will typically affect an area much larger than an individual county. In comparison, standard actuarial ratemaking procedures tend to disregard the spatial relationships among rating territories, assuming instead that territorial experience is independent of the experience of other nearby territories.

After applying concentric circle smoothing, the smoothed pure premium is increased by a factor of 1.14, which is intended to satisfy the Congressional requirement that the rates be adequate to pay expected losses and build a "reasonable reserve." RMA has defined a reasonable reserve as an amount sufficient to achieve financial adequacy over a 10 year period at an 85% confidence level, evaluated on a countrywide basis. This loading may be understood to be an adjustment for risk to ensure the long term financial viability of the program. It should not be interpreted as an adjustment to the historical experience to more accurately estimate the expected losses, which may be potentially underestimated due to the absence of a catastrophic year in the 20 year experience period. The development of the factor will not be discussed here.

The final pure premium is determined by adding a statewide loading for the losses that were removed by the 80/20 rule to the smoothed pure premium loaded for the safety factor. A charge for losses that were excluded from the analysis, arising from prevented planting and other causes which are not directly related to yield loss, is also included. The final pure premium is divided by the current rate to produce a normalized loss ratio. The normalized loss ratio is compared to a judgmentally predetermined schedule of rate changes centered at the mandated target loss ratio of 107.5%. For example, if the normalized loss ratio falls between 90% and 115%, the current rate may not be revised. If it falls between 80% and 90%, a 5% rate reduction may be indicated, and so on.

Once the new base rate for a county is determined, rates for each farming practice must be developed. All practices within a county had been combined for ratemaking purposes. However, practices such as irrigation have a significant influence on yield variability, and consequently on the expected losses. The indicated rates for each practice are determined by multiplying the new county base rate by factors which reflect the relative riskiness of each practice relative to the county average. The factors are based on insurance data drawn from larger geographic areas as well as on the relative importance of the various practices within the county.

The rates by Coverage Level and Risk Class are determined by applying factors which are uniform for all states and crops, with minor exceptions. All rate increases are limited to no more than 20% in accordance with Federal law.

The rates established by these procedures are for coverage provided on an optional unit basis, meaning that each field is insured independently of any other field farmed by the producer. The producer also is permitted to insure the production of all these fields in total. Since this option diversifies the risk, a reduced rate is provided.

II. Challenges in Ratemaking

Catastrophic Nature of the Coverage

MPCI can be considered to be a catastrophic form of coverage. For an individual producer, MPCI compensates the producer for a portion of his loss when his yield is abnormally low. In this sense, MPCI is a high deductible product. However, when one producer has a poor year because of climatological factors, it is likely that many other producers will also have a poor year. This strong correlation of the experience between exposures limits the insurer's ability to reduce its risk through diversification. As a result, even the statewide MPCI experience can vary dramatically between years. For example, Chart 2 of Iowa experience shows two years since 1980 with loss ratios in excess of 350% and another year with a loss ratio in excess of 200%. If the experience were examined over the past 5 years only, Iowa would seem to be a very profitable market.

Since weather is the primary determinant of MPCI experience, exposures which are located in geographical proximity to one another will be highly correlated. This can be observed in the similar historical pattern of loss ratios for Iowa corn as compared to Iowa soybeans as shown in Chart 3. In years with severe weather, exposures separated by even greater distances can have similar experience. This can be observed in Chart 4, which compares the historical experience of Iowa, Minnesota, and Missouri.

Another perspective on the catastrophic potential of MPCI coverage can be obtained by examining a simulated distribution of producer outcomes rather than the loss ratios in aggregate. Chart 5 provides an illustration of how a weather induced shift in yields of -10% can result in much greater frequency of claims. Consider a producer whose APH yield is 120 bushels. The probability of this producer experiencing a loss in excess of a 25% deductible, i.e., an actual yield of less than 90 bushels, is under 16% in a normal year. This probability increases to 25% if weather results in a 10% reduction in yields. As a result, the expected number of claims would rise by 60%, six times as great as the change in the expected yield.

The limited ability to eliminate the risk through diversification affects the ratemaking analysis by increasing the uncertainty of the expected pure premium. One method used to address this uncertainty is to include many years of experience in the analysis. Currently, 20 years are used, and this will be increased in future reviews. A second is to limit the extreme losses from the analysis of individual counties, and a third is to smooth the pure premiums over a broader geographic region, as is currently done with the concentric circle method.

Geographical Influences on Farming and Risk

This section provides summary information on MPCI and farming in general as an introduction to current ratemaking issues.

Chart 6 shows the distribution of MPCI premium by major crop groupings over the period from 1980 through 1998. For example, cotton premium has increased in share in recent years. This may be due to high crop prices resulting in higher production, both of which result in higher insured values and greater premiums. In contrast, the premium market share for soybeans has decreased in recent years. Chart 7 shows the Herfindahl index, defined as the sum of the squares of the market shares for each crop grouping, which demonstrates that the shifts between crops being grown has not led to an increase in concentration. On an individual state basis, the corresponding market share and Herfindahl index exhibits (not included) would show a persistence of the preferred crops over time. This is primarily due to the limitations that climate places on certain crops. Another reason is governmental disincentives, recently eliminated, which discouraged producers from planting different crops.

The insured liabilities for 1998 in millions of dollars for the four major crops are shown in Charts 8 to 11. Average yields per acre for these crops are shown in Charts 12 to 15. The maps indicate where each crop is grown and how productive it is. For example, the availability of water for irrigation in California and Arizona has resulted in very high cotton yields. Texas cotton producers do not have access to inexpensive water, resulting in much lower yields. Despite this, the bulk of the nation's cotton crop is grown in Texas. The primary reason that cotton is grown in Texas is that this is the most productive use for the land.

The concentration of exposures in limited geographical areas, as for Texas cotton, is one reason for the non-independence of the loss experience. Not only weather conditions, but soil types, elevation, and rainfall can be expected to be similar for exposures situated in close proximity to one another. The question of how much influence geography plays on the expected losses is an important issue. This will be discussed with regard to the recent increase in participation in the MPCI program.

In the past decade, the participation of producers in the MPCI program has roughly doubled. Most of this increase occurred in 1995 due to a federal requirement, now rescinded, that producers purchase insurance coverage in order to qualify for other government programs. This increase in exposure is thought to result in a wider spread of risk, which should lead to more stable loss costs and less risk for insurers. There is also a question whether the spread of risk should result in lower loss costs and lower rates. This would be the case if the doubling of the insured exposures has reduced any adverse selection operating against the program. In some sense, these expectations have been proved true by the experience. Chart 1 shows that the countrywide loss ratios in the period from 1994 through 1998 to be much lower than in any year from 1980 through 1993. However, this argument disregards two key factors. The first is general weather conditions, which have been very good in recent years. Except for a drought in Texas during 1998, weather has not resulted in major disruptions to farming. The Deputy Chief Economist of the USDA has reported to the Senate "with the exception of regional loss events like the drought in Texas and parts of the South in 1998, most of the country has enjoyed relatively benign weather since 1995." The El Nino and La Nina events of the past two years have had little impact. For this reason, the experience from 1994 through 1998 should be expected to be excellent.

The second factor is the effect of geography on experience. If the producers who have purchased MPCI coverage only in the last five years are in close proximity to the previously insured producers, their experience should be expected to be similar, solely due to the common influences of weather, soil types, elevation, and other factors. Insuring additional exposures which are similar to and highly correlated with other insured exposures may not result in a significant reduction to the loss costs or to the risk. At an extreme, if all exposures within a county were 100% correlated, then the experience of a county would model the experience for each producer within the county. Consequently, the variability of yields for the county over time would be a reasonable proxy for the variability of yields for the individual producer. Since the variability of yields (or more specifically, the shortfall in yields) for each individual producer determines the loss payments under MPCI, the variability of county yields should be highly correlated to the county's historical loss costs. This is demonstrated for Iowa corn experience by county on Chart 16, where the measure of variability of yields is defined as the 100 times the coefficient of variation of yields over time. This evidence supports the idea that the yields, and hence the losses, of individual producers are strongly influenced by external factors. Consequently, producers results are highly correlated, which would suggest that the recent increase in exposures may have limited influence on MPCI loss costs or risk.

The previous discussion also raises the possibility of predicting expected loss costs based on yield information. Chart 17 shows the relationship between the aggregate loss costs and the yield for a given year. This relationship could be used to provide an estimate of the expected loss costs based an estimated distribution of the yields. Past yields by county could be trended to reflect productivity improvements in order to obtain an estimate of the distribution for the current year. However, the coefficient of variation of yields is a reasonable alternative to using the distribution of the trended yields. The coefficient of variation distills the distribution of yields into a single number for each county, and appears to be effective in predicting the loss costs. This makes it possible to consider either approach as a technique for estimating the expected loss costs whenever past loss experience is not available. This could also be used to test the indicated loss costs for reasonableness. Furthermore, counties with high coefficients of variation of yields are those in which farming is more uncertain. Not only are these counties expected to cluster together, but it is likely that the uncertain growing conditions will apply to all crops grown within the county. As a result, the variability of yields for one crop may be a means for predicting the variability of yields for a crop being newly introduced or with minimal loss history.

The Effect of Increased Producer Participation

The most recent five year period has produced very good results for the MPCI program, as seen in Chart 1. The same five year period has seen much greater producer participation in the program than in earlier years. One interpretation of these results is that the increased participation has brought lower risk producers into the program, reducing the adverse selection and improving the experience. The issue to be addressed here is whether this conclusion is justified. The approach to be taken will be to examine whether farming risk and insurance risk have diminished in recent years.

Chart 18 shows countrywide yields for Corn from 1980 through 1997. The years 1983, 1988, and 1993 all show abnormally low yields relative to the preceding and subsequent years. The long term trend in corn yields is +1.7% per year. The chart also includes the fitted yield curves. The second exhibit, Chart 19, shows the absolute value of the residuals from the first regression. If farming were becoming less risky, yields might be expected to follow the long term trend line on Chart 18 more closely than in the past. As a result, the absolute value of the residuals on Chart 19 should decline over time. A fitted trend line is included on this chart to show that the data does not have a strong downward trend. The absolute residuals in the final three years are below the trend line, but this is also true for the first three years as well as for the period from 1989 through 1991. Also, the t statistic for the slope of the fitted line is not statistically significant at the 95% confidence level. That is, the fitted line is essentially flat. This analysis does not support the conclusion that farming risk is less than in past years.

A similar analysis can be performed for the countrywide loss costs for corn from 1980 through 1997, as shown in Chart 20. The test of the residuals in Chart 21 leads to a conclusion similar to that for yields, that there is no significant decrease in insurance risk over this period. Again, the slope of the fitted line is not statistically significant from zero at the 95% confidence level.

This issue can be considered from another perspective. The discussion of spatial and intertemporal correlation, presented below, provides a means for evaluating how strongly the experience in one county is correlated to the experience in adjacent counties. This would imply that external factors which operate over large geographic areas are the source of much of the risk in farming. Consequently, an increase in producer participation in a given county may not have a significant effect on the overall riskiness of the MPCI program. The location of the farm rather than the skill of the individual producer may be the primary determinant of the risk. If this conclusion is true, it would imply that the improved MPCI experience in recent years may due to good weather conditions rather than increased producer participation.

III. Future Considerations for Ratemaking Analysis

Using Non-Insurance Information in Ratemaking

An important aspect of MPCI coverage is the linkage between the loss experience and non-insurance information. A potential use of this external information is to test the reliability of the indicated rates. Another is to provide a means to develop rates for counties in which past experience for the crop is not available.

The first link to be considered is that between MPCI pure premiums and yields. For individual producers, the yield determines the indemnity payment. Since the results for individual producers are strongly influenced by the weather, the loss experience and the yields among producers are highly correlated, even when aggregated to the county or state level. An analysis of this relationship at the statewide level for Iowa Corn is provided below.

Consider Chart 17. The illustrated relationship between the natural logarithm of the loss ratio and the natural logarithm of yield has been fit to the straight line:

$$\ln y = a + b * \ln x$$

This is equivalent to:

$$y = e^{a} * x^{b}$$

where x is the yield and y is the loss ratio. The best fitting curve has parameter values a=34.0 and b=-6.3. In economic terms, this formula describes the elasticity of the loss costs relative to the yields. The interpretation is that a 1% increase in the average yield for Iowa Corn results in a -6.3% change in the loss ratio. As a result, even a small change in yields has a highly leveraged impact on losses.

The volatility of the loss ratios implied by the elasticity coefficient highlights one of the difficulties in MPCI ratemaking. When losses vary widely between years, as for MPCI, the uncertainty in the estimate of the mean pure premium will be large. However, the additional information provided by the relationship between losses (pure premiums) and yields can improve the analysis in the following manner.

Suppose that the distribution of the yields over time is known or can be estimated. For example, the actual yields for the past 20 years could be considered. The distribution of yields for the coming year can be estimated by applying trend factors to yields from past years. Using the known relationship between yields and pure premiums, estimates of the potential pure premium outcomes for the coming year can be determined. The average of these outcomes is an estimate of the expected pure premium.

While it is unlikely that this technique would be used as part of the standard ratemaking process, several aspects may prove useful. One simple use is to identify data processing errors by identifying years in which the losses and yields are not consistent. A second use is to estimate pure premiums when insufficient loss information is available. For example, when a new crop is introduced into a county, it may be possible to estimate the variability of the yields based on the variability of the yields for other crops or other counties. A third use of this technique would be in smoothing past experience. Since a large portion of the losses are produced in a few abnormally poor years, the number of abnormal years in the experience period has a strong influence on the average pure premium. Because the number of abnormal years is always an integer, the average pure premiums can increase or decrease sharply when an abnormal year enters or leaves the experience period. These fluctuations can be reduced by taking the distribution of yields or pure premiums into consideration. For example, the expected number of abnormal years can be used in place of the actual number, with the corresponding severity based on a larger body of experience.

A second link to consider is that between MPCI loss costs and geographic and climatological information. This would involve the use of econometric modeling techniques, but without the need to consider time dependency as was the case with yields. The concept is that the yields and the variation in yields, and hence the pure premiums, are related to the suitability of the land for the crops being grown. For example, average county pure premiums could be modeled as a function of independent explanatory variables, such as average annual rainfall, growing days, soil type, and elevation. The advantage of this form of analysis is that is can be used to estimate the pure premiums even if yield experience is not available.

Potential Enhancements to Ratemaking Techniques

The previous section considered the use of non-insurance information in testing or modeling insurance experience. However, non-insurance information is generally considered to be supplementary to rather than as a replacement for insurance experience. The following discussion considers several approaches to improving the accuracy and increasing the stability of the rates based solely on insurance experience.

One recent proposal for improving the accuracy of the rates is to create fixed rating territories consisting of adjacent counties with similar agronomic characteristics. The rating territories could vary depending upon the crop being rated. The rationale for this proposal is that it would eliminate a perceived problem with the current concentric circle technique, due to the potential inclusion of experience from neighboring counties having dissimilar agronomic characteristics.

A more technically demanding approach is known as spatial smoothing. For example, the current concentric circle method is a simple form of spatial smoothing. A more sophisticated approach, known as locally weighted regression smoothing, has previously been introduced into Crop Hail insurance ratemaking by Dr. Michael Lewis. The advantages of this technique are its ability to produce smoother results than the concentric circle method and its ability to take spatial correlation into account. This technique may also eliminate the need to spread excess losses for each county across the state. A detailed explanation of the spatial smoothing process is included in the appendix.

A third approach for improving MPCI ratemaking analysis is to extend the concept of credibility to consider the spatial and intertemporal correlation between territories, that is, to create a spatial credibility model. This model is still in the early development stage, and its development is deferred to the appendix.

The spatial credibility technique is similar to spatial smoothing in that the experience in nearby counties is given more weight than that of more distant counties. However, it may allow for greater local fluctuations than spatial smoothing would produce. Each county's loss cost is used to the extent it is credible, with the remainder of the credibility being assigned to nearby counties, based on the relevance of their information.

The spatial credibility technique permits the loss costs to be estimated even for counties with little or no experience by taking advantage of the redundant information in nearby territories. In comparison, the classical credibility technique is generally applied to the indicated price changes, which may reduce or eliminate the spatial correlation between territories. As a result, classical credibility produces price changes for small territories that are similar to the statewide price change. Consequently, if these territories had been previously misrated, the classical credibility approach may not correct the misrating.

IV. Conclusion

Crop Insurance is a unique public/private market insurance product. In addition to public policy considerations, ratemaking needs to consider risk elements that are not common to other property/casualty coverages. This paper has intended to provide an introduction to the crop insurance product, and an overview of the ratemaking methodology.

Appendix

Spatial Smoothing

Locally weighted regression smoothing ("loess") in two spatial dimensions can be considered to be analogous to linear regression using a single independent variable. For linear regression in a single variable, the straight line which best fits the data is found, where the best fit is determined by minimizing the sum of squares of the residuals. This produces a curve of a known functional form, $y = a + bx$, which is linear in the parameters a and b. In comparison, loess finds fitted values using a local regression technique. The fitted values produced by this process are a surface of the form $z = a + f(\text{latitude}, \text{longitude})$, where z is a transformation of y. Unlike linear regression, the shape of the fitted surface is not describable using a known functional form, i.e., it is a non-parametric surface. The transformation used to modify the loss costs is $z = \log(y/(1-y))$. Since the MPCI loss costs are bounded between 0 and 1 and tend to be closer to the low end of the range, this transformation produces a less skewed dependent variable, which helps to improve the quality of the fit. In addition, the form of the transformation guarantees that the fitted loss costs will be non-negative.

The data used in the loess procedure is a single value for each location. In this example, the data is the average yield for Iowa corn by county over the period from 1981 through 1997. For ratemaking, the average loss costs over the experience period would be used instead. By using the average for each county, all intertemporal correlation is eliminated from the analysis. Even though the experience in adjacent counties may be correlated over time, this is not considered to be essential in estimating the expected values. Instead, spatial smoothing is only concerned with the spatial correlation of the data. The underlying concept is that the yields or loss costs change smoothly over space, and that knowledge of the yields in nearby counties provides redundant information which can be used to produce a better estimate of the expected value of the variable in each county.

The loess procedure determines the fitted value z by performing a local regression for each county. The transformed loss costs are fitted to the independent variables of latitude and longitude including an interaction term. The set of fitted values over all counties defines the fitted surface. Each local regression includes only those points that are in the neighborhood of the point being fit, where a neighborhood consists of the nearest k% of points in the sample space. A small value of k results in greater local accuracy, whereas a large value of k results in a smoother surface. For this analysis, 100% of the data points have been included in each neighborhood. However, greater weight is assigned to nearby counties than the more distant counties by the use of the tri-cube formula $(1 - d^3)^3$. The distance d between any two counties x_0 and x_i is defined as $d = |x_0 - x_i| / \max(|x_0 - x_k|)$, where the denominator is computed over all values k within the neighborhood. Here, each point x_i represents the joint latitude and longitude coordinates at the center of a specified county. The coordinates of the county midpoints must be transformed to the Euclidean coordinate system using a distance preserving projection prior to their use in the loess procedure.

The best fit local regression for each county is determined by using a maximum likelihood technique under the assumption that residuals have a normal distribution with constant variance. The residuals are weighted by the actual cumulative liability (i.e., exposure) for each county in order to improve the accuracy of the smoothed results. As in actuarial credibility, the loss costs of counties with larger weight, as measured by cumulative liability, reflect their own experience to a greater degree than counties with smaller weight. The amount of smoothing produced by this process can be evaluated from a comparison of Charts 22 and 23, which show cotton loss costs for Crop Hail insurance in the southeastern states. The perspective on these maps is looking west from the Atlantic Ocean, with Florida shown to the left and North Carolina to the right.

Despite the complexity of the description of spatial smoothing, it can be implemented very efficiently in the S-Plus programming language. In the following programming statement, lo represents the loess function, while latitude and longitude are the projected coordinates of the county midpoints. The span of 1 defines each neighborhood as consisting of the nearest 100% of points in the sample space. Also, the dependent variable uses the untransformed loss costs, with the transformation being performed by the logit function.

```
gam(loss.cost ~ lo(longitude, latitude, span = 1),
    family = quasi (link = logit, variance = "constant"),
    data = your.data, weights = liability, na.action = na.omit)
```

From a practical standpoint, the primary weakness of spatial smoothing is its complexity, which increases the difficulty of explaining the results to insurance regulators. Since the analysis cannot be reproduced in a spreadsheet, the reliability of the results cannot be easily confirmed.

The loess procedure is actually a simple form of spatial smoothing. More sophisticated forms of spatial smoothing have been developed, but these require a knowledge of the field of spatial statistics.

Development of the Spatial Credibility Model

Classical credibility theory can be used to develop a best estimate for a territory by weighting the territorial average loss cost with the overall statewide loss cost. Generally, credibility is applied to the indicated changes in loss costs instead. However, the classical credibility formulas are developed under two assumptions which are not valid for MPCI. The first is that the true territorial expected loss costs are independent of one another, i.e., that there is no spatial correlation. The second is that the intertemporal random fluctuations in one territory are independent of the random fluctuations in other territories.

For MPCI, the spatial correlation between counties as a function of distance can be described using a variogram. The first step in the preparation of the variogram is to calculate the statistic Y_{ij} as ½ of the squared difference in pure premiums for each pair of counties (i,j). The distance between each pair of counties is also required. Given this information, distances are grouped into ranges and the average of all Y_{ij} within each range is determined. This produces a variogram similar to that shown in Chart 24 for yields. The variogram is an estimator for $E[(X_i-X_j)^2/2 \mid \text{counties } i,j \text{ in distance range } k]$, where X represents pure premium. The variogram is also a proxy for the spatial covariance. Notice that $E[(X_i-X_j)^2/2] = ½\, VX_i + ½\, VX_j - Cov(X_i,X_j) + ½\, (\mu_i - \mu_j)^2 = \sigma^2 - Cov(X_i,X_j)$, where all X_k are assumed to be from the same distribution. That is, a small value for the variogram implies a high value for the spatial covariance. The chart shows that the variogram is low for nearby counties and gradually increases as the distance increases, within a certain range.

Similarly, the intertemporal correlation of a county's experience to that of its nearest neighbors is also greater than its correlation to more distant counties, as shown in Chart 25 for Iowa corn in Adams county. The average intertemporal correlation across all counties as a function of distance is shown in Chart 26. Each type of correlation needs to be taken into account in a spatial credibility formula.

The spatial credibility formula determines the best estimate of the projected loss cost for county t in future year "0" using a linear combination of the known observations. Using Formula 4.1 from Chapter 7 of the "Foundations of Casualty Actuarial Science" text, the objective is to determine the coefficients which minimize:

$$E[X_{t0} - (a_0 + \Sigma_{i,u}\, a_{iu}\, X_{iu})]^2$$

where t is the county being evaluated. Here, X_{iu} represents the loss costs in county i (from 1 to N) in year u (from 1 to n). It will be assumed that the loss costs can be decomposed into three components:

$$X_{iu} = m + R_i + Q_{iu}$$

The first component, m, represents the mean loss cost over all counties. R_i represents the variation of the individual county loss costs from the overall mean. These are selected such that the average deviation over all counties is zero, $E(R_i) = 0$. Individual year random fluctuations are represented by Q_{iu}, with the average of the Q's over all years and counties being zero, $E(Q_{iu}) = 0$. The R's are assumed to be independent of the Q's. These assumptions imply that the overall expected value $E(X_{iu})$ is m and that the expected value for a particular county i is $E(X_{iu}|R_i) = m + R_i$.

In order to determine the coefficients, the partial derivations of the expected value with respect to the coefficients are set to zero, which produces the following equations:

(1) $$E(X_{t0}) = a_0 + \Sigma_{i,u}\, a_{iu}\, E(X_{iu})$$

(2) $$Cov(X_{t0}, X_{jv}) = \Sigma_{i,u}\, a_{iu}\, Cov(X_{iu}, X_{jv})$$

for each j and v. The county t is assumed to be fixed.

Equation 1 can be evaluated as:

$$m = a_0 + \Sigma_{i,u}\, a_{iu}\, m$$

which yields:

$$a_0 = m\,(1 - \Sigma_{i,u}\, a_{iu})$$

Notice that the sum of the coefficients equals 1.00 as in classical credibility if a_0 is replaced by ma_0.

Equation 2 requires that the covariances be evaluated. This can be done by considering the following identity:

(3) $$Cov(X_{iu}, X_{jv}) = E[Cov(X_{iu}, X_{jv}|R_i,R_j)] + Cov[E(X_{iu}|R_i,R_j), E(X_{jv}|R_i,R_j)]$$

But,

$$E(X_{iu}|R_i,R_j) = m + R_i$$

and:

$$E(X_{jv}|R_i,R_j) = m + R_j$$

This permits the second term on the right side of equation 3 to be simplified:

$$Cov[E(X_{iu}|R_i,R_j),\ E(X_{jv}|R_i,R_j)] = Cov(m + R_i,\ m + R_j) = Cov(R_i,\ R_j)$$

It will be assumed that:

$$Cov(R_i,\ R_j) = f(d(i,j))$$

That is, the spatial covariance is a function of the distance d between counties i and j. If another pair of counties are separated by the same distance, the value of f will be assumed to be identical. For simplicity in notation, f(d(i,j)) will be replaced by f(i,j).

The first term on the right side of equation 3 can also be evaluated:

$$E[Cov(X_{iu},\ X_{jv}|R_i,R_j)] = E[Cov(m + R_i + Q_{iu},\ m + R_j + Q_{jv}|R_i,R_j)] = E[Cov(Q_{iu},\ Q_{jv})]$$

When $u \neq v$, the independence of the experience between different years implies that the covariance of the random fluctuation term is 0. When $u = v$, it will be assumed that:

$$E[Cov(Q_{iu},\ Q_{ju})] = g(d(i,j))$$

That is, the expected intertemporal covariance is a function of the distance between the two counties. For simplicity, g(d(i,j)) will be replaced by g(i,j). By defining δ_{uv} as 0 when $u \neq v$ and 1 when $u = v$, the first term on the right side of equation 3 can be expressed as:

$$E[Cov(X_{iu},\ X_{jv}|R_i,R_j)] = \delta_{uv}g(i,j)$$

As a result, equation 3 can be expressed as:

$$Cov(X_{iu},\ X_{jv}) = \delta_{uv}g(i,j) + f(i,j)$$

Inserting this into equation 2 gives:

$$Cov(X_{t0}, X_{jv}) = \Sigma_{i,u}\, a_{iu}\, Cov(X_{iu}, X_{jv}) = \Sigma_{i,u}\, a_{iu}\, [\delta_{uv} g(i,j) + f(i,j)]$$

or:

$$Cov(X_{t0}, X_{jv}) = \Sigma_i\, a_{iv}\, g(i,j) \;+\; \Sigma_{i,u}\, a_{iu}\, f(i,j)$$

Notice that the left hand side of this equation can also be evaluated as:

$$Cov(X_{t0}, X_{jv}) = \delta_{0v} g(t,j) + f(t,j) = f(t,j)$$

This produces the following simplification of equation 2:

(4) $$f(t,j) = \Sigma_i\, a_{iv}\, g(i,j) \;+\; \Sigma_{i,u}\, a_{iu}\, f(i,j)$$

for all values of year v. Defining $b_i = \Sigma_v\, a_{iv}$ and summing both sides of equation 4 over v produces:

$$n\, f(t,j) = \Sigma_i\, g(i,j)\, \Sigma_v\, a_{iv} + n\, \Sigma_i\, f(i,j)\, \Sigma_u\, a_{iu}$$

or:

$$n\, f(t,j) = \Sigma_i\, g(i,j)\, b_i + n\, \Sigma_i\, f(i,j)\, b_i = \Sigma_i\, b_i\, [g(i,j) + n\, f(i,j)]$$

which represents N equations (j = 1 to N) in N unknowns b_i. It should be observed that the values of b_i depend on the covariance functions f and g, but not on the loss costs. We will assume that these equations can be solved for the values of b_i.

Substituting the known values of b_i into equation 4 yields:

(5) $$f(t,j) = \Sigma_i\, a_{iv}\, g(i,j) \;+\; \Sigma_i\, b_i\, f(i,j)$$

or:

$$\Sigma_i a_{iv} g(i,j) = f(t,j) - \Sigma_i b_i f(i,j)$$

Since all of the terms on the right hand side are known and depend only on j, the right hand side can be written more simply as c_j:

$$\Sigma_i a_{iv} g(i,j) = c_j$$

This is a system of Nn equations in v and j, with Nn unknowns a_{iv}. This can be written as the product of the transpose of NxN matrix $[g(i,j)]$ with Nxn matrix $[a_{iu}]$. Since the Nxn product matrix $[c_{ju}]$ has $c_{ju} = c_j$ for all u, its column rank is 1. Assuming that matrix $[g(i,j)]$ is non-singular, the column rank of matrix $[a_{iu}]$ must also be 1. This means that each column is a multiple of the first column, that is, $a_{iv} = k_v a_{i1}$. Substituting this into the previous formula results in the conclusion that $k_v = 1$ for all v. This conclusion can also be reached intuitively by noting that the right hand side of the equation is independent of v. This permits the symbol a_i to be used in place of a_{iv}, so that:

$$\Sigma_i a_i g(i,j) = c_j$$

for each value of j. An immediate solution to this system of equations can be obtained by observing that $b_i = \Sigma_v a_{iv} = \Sigma_v a_i = n a_i$. Since the values of b_i are known, $a_{iv} = a_i = b_i / n$. The value of a_0 can also be determined from $a_0 = m (1 - \Sigma_{i,u} a_{iu}) = m (1 - \Sigma_i b_i)$. This also shows that the coefficients depend on the county but are independent of the year.

The reader can confirm that this result is consistent with the classical credibility formula under the assumption of the covariance structure $f(i,j) = \delta_{ij} \sigma^2$ and $g(i,j) = \delta_{ij} s^2$.

It should also be noted that the functions f and g, or more properly, f_t and g_t, represent the spatial covariance and the intertemporal covariance in a neighborhood A_t around county t. The neighborhood needs to be large enough to reliably estimate f_t and g_t, but small enough to represent the covariance structure near county t. In practice, it may be appropriate to assume that f_w and g_w are essentially identical to f_t and g_t for all counties w in a neighborhood B_t of t. Further refinements in the model could be achieved by permitting the functions f and g to depend on location and direction, rather than on distance only.

A simplification of the spatial credibility result can be obtained by approximating f(i,j) and g(i,j) with discrete valued functions. Recall that these functions depend solely on the distance between counties i and j, not on their specific locations. For example, let f and g take distinct values for a series of distances such as 0 to 50 miles, 51 to 100 miles, 100 to 150 miles, and so on. This would enable the references to specific counties for the functions f(t,j), f(i,j) and g(i,j) in equation 5 to be replaced by a small number of values. If it can be assumed that the functions f and g are independent of county t, and if all counties formed a uniform pattern such as a rectangular grid, then the resulting b_i coefficients would be independent of t. In this situation, the same coefficients would be applied for all counties, eliminating the need to reevaluate the coefficients for each individual county t. It may be advantageous to superimpose a rectangular grid to replace the actual county structure in order to achieve this simplification. The result would be a smoothing process analogous to the current concentric circle technique, with more weight given to nearby counties than to those that are further away.

References

Arlinghaus, S.L.,
Practical Handbook of Spatial Statistics,
CRC Press, 1996

Driscoll, James L.,
"Changes in Rate Making for Federal Crop Insurance" Internal Memorandum
Federal Crop Insurance Corporation, USDA

Eves, Howard,
Elementary Matrix Theory,
Dover Publications, Inc., 1966

Glauber, Joseph W.,
"Statement of Joseph W. Glauber
Deputy Chief Economist, U.S. Department of Agriculture
Before the Committee on Agriculture, Nutrition and Forestry
United States Senate
March 10, 1999"

Kaluzny, S.P.; Vega, S.C.; Cardoso, T.P.; Shelly, A.A.,
S+SPATIALSTATS User's Manual, Version 1.0, February 1996
MathSoft, Inc.

Kitanidis, P.K.,
Introduction to Geostatistics: Applications to Hydrogeology
Cambridge University Press, 1997

Knight, Thomas O. and Coble, Keith H.,
"Survey of U.S. Multiple Peril Crop Insurance Literature Since 1980"
Review of Agricultural Economics, Volume 19, Number 1, Pages 128-156

Lewis, Michael,
"Louisiana Loss Costs"
Internal Memorandum,
National Crop Insurance Services

Milliman & Robertson, Inc.,
"Analysis of Catastrophe Provisions – Task 3"
Contract 12-27-129-372
Prepared for Federal Crop Insurance Corporation, September 9, 1983

PricewaterhouseCoopers LLP,
"Federal Crop Insurance Program Profitability and Effectiveness Analysis, 1999 Update"
Prepared for Morrison & Hecker L.L.P.on behalf of National Crop Insurance Services, Inc., May 1999

S-Plus 4 Guide to Statistics,July 1997
MathSoft, Inc.

"Crop Insurance for Cotton: Premium Rates and Related Matters"
Prepared for U.S. Senate in response to Report accompanying S. 2159 Agriculture, Rural Development, Food and Drug Administration, and Related Agencies Appropriation Bill, 1999
by Federal Crop Insurance Corporation of United States Department of Agriculture, August 11, 1999

Venter, Gary G.,
Chapter 7, "Credibility"
Foundations of Casualty Actuarial Science, Second Edition, 1990

Zacharias, Thomas P.,
Chapter 7, "Impacts on Agricultural Production: Huge Financial Losses Lead to New Policies"
The Great Flood of 1993, Causes, Impacts, and Responses, Stanley A. Changnon, Ed.
Westview Press, 1996

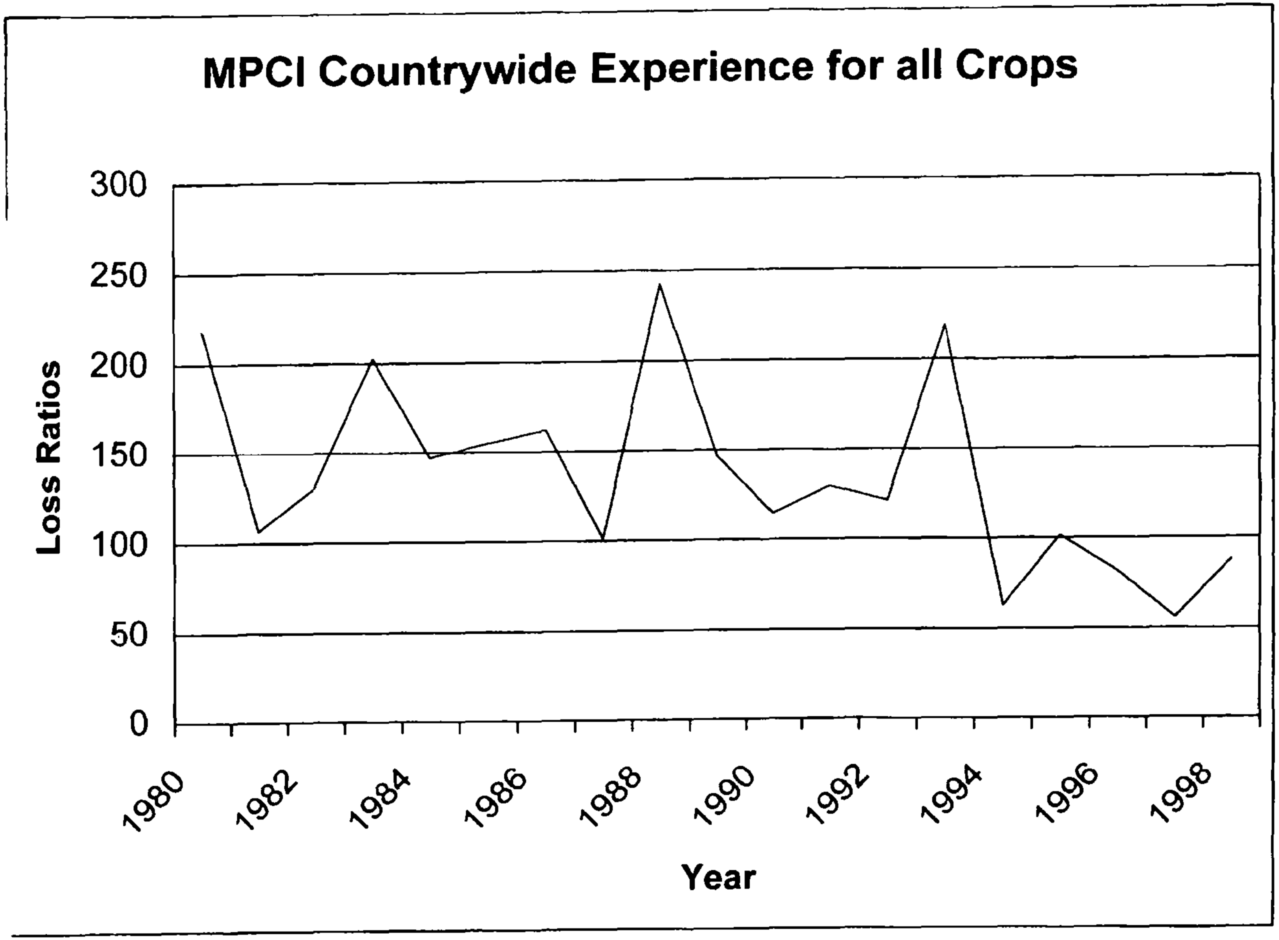
MPCI Countrywide Experience for all Crops
Loss Ratios
300
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Year

Exhibit 1

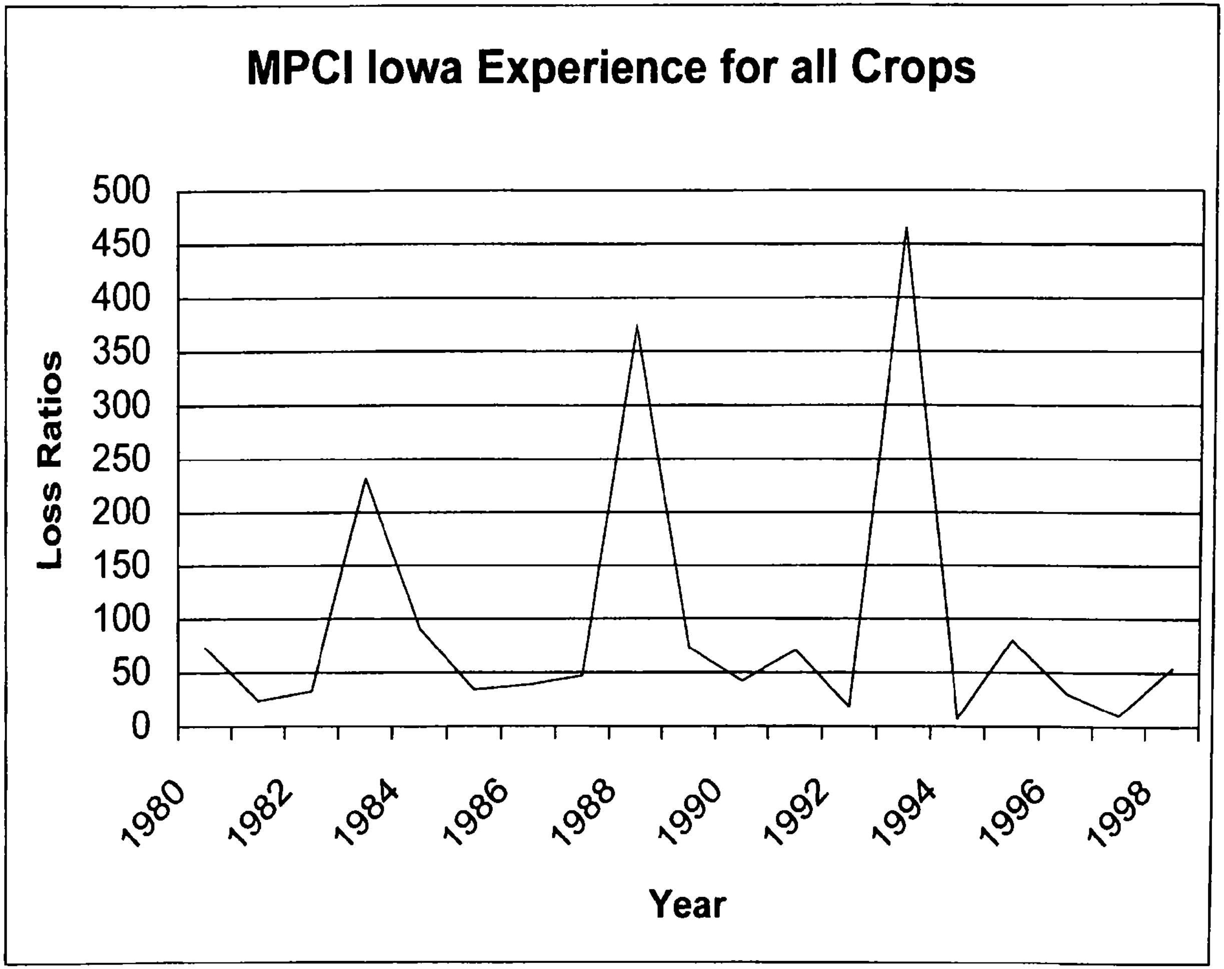
MPCI Iowa Experience for all Crops
Loss Ratios
500
450
400
350
300
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Year

Exhibit 2

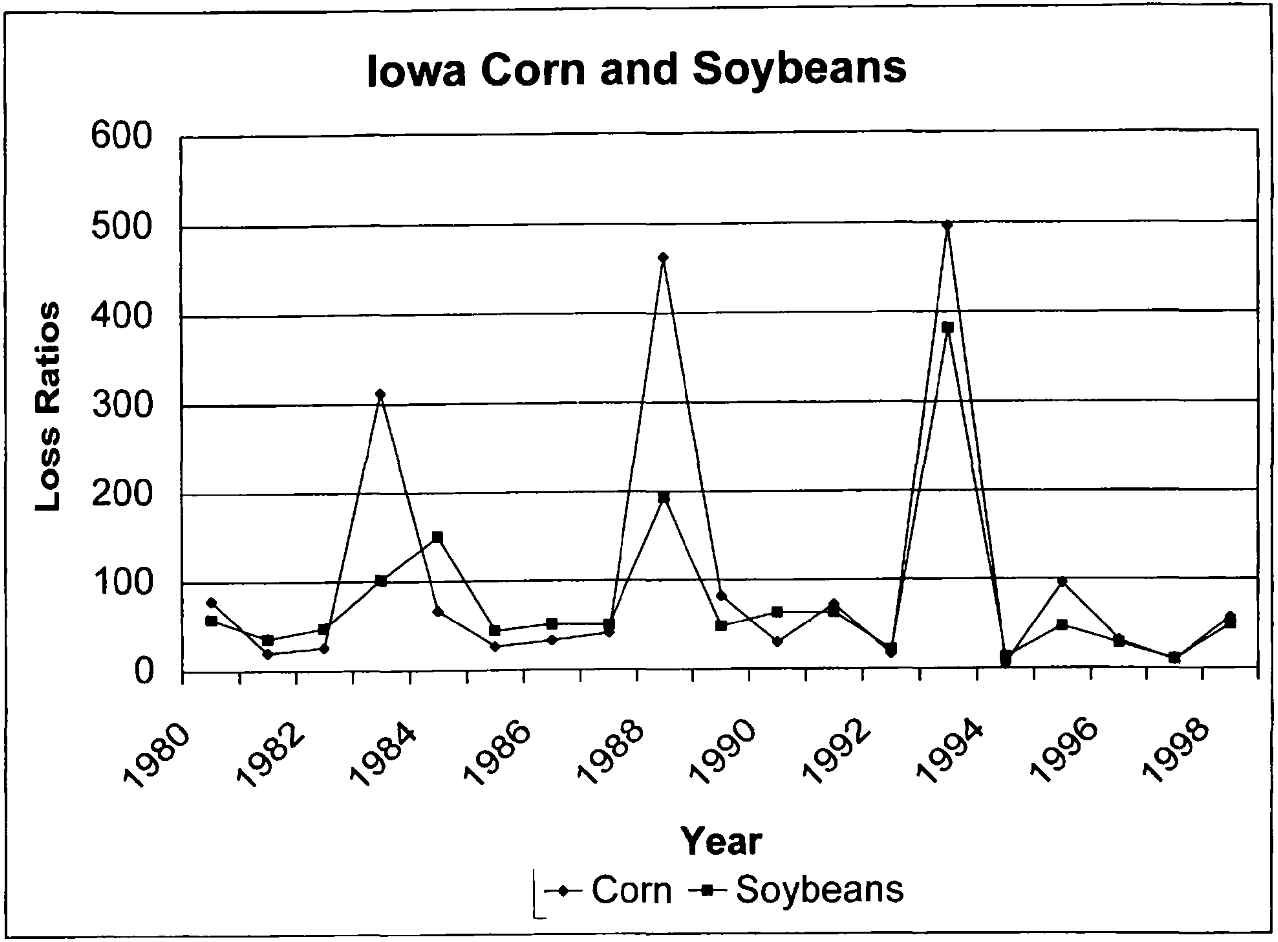
Iowa Corn and Soybeans
600
500
400
300
200
100
0
Loss Ratios
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Year
Corn
Soybeans

Exhibit 3

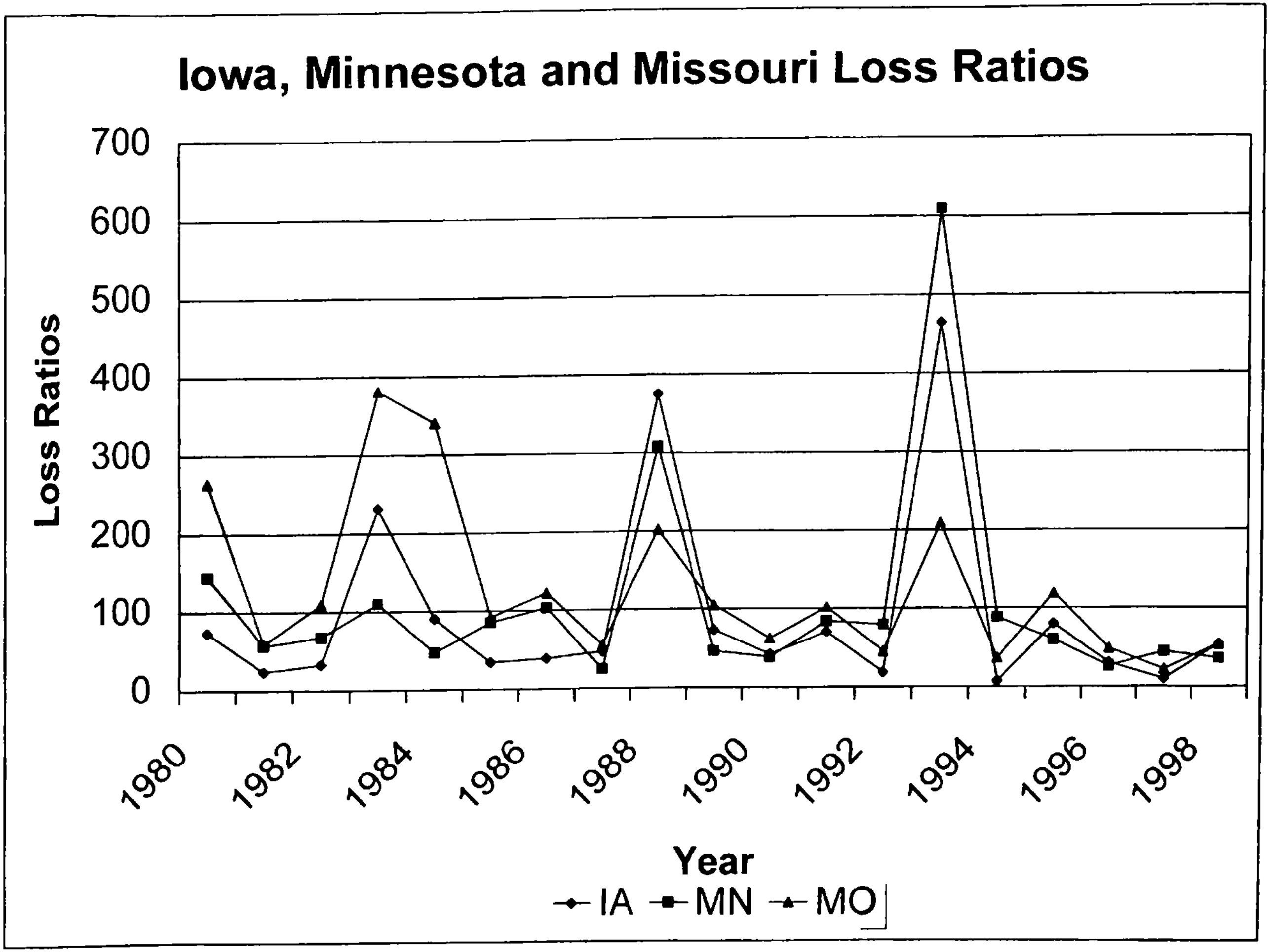
Iowa, Minnesota and Missouri Loss Ratios
Loss Ratios
700
600
500
400
300
200
100
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Year
IA
MN
MO

Exhibit 4

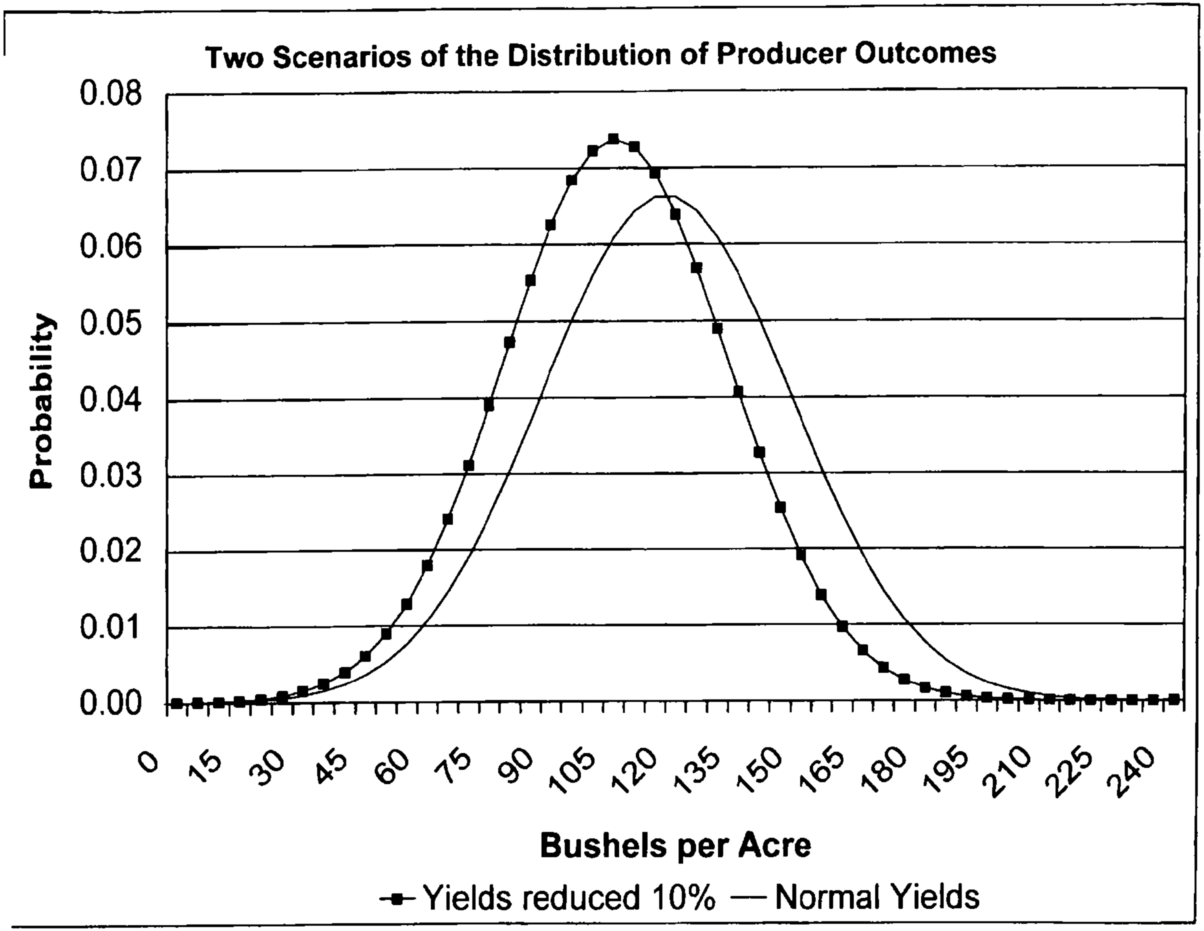
Two Scenarios of the Distribution of Producer Outcomes
Probability
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
15
30
45
60
75
90
105
120
135
150
165
180
195
210
225
240
Bushels per Acre
Yields reduced 10%
Normal Yields

Exhibit 5

MPCI Cumulative Market Shares by Crop

Crops from bottom to top are Corn, Cotton, Grain,Soybeans, Tobacco, Other
STATE=Countrywide

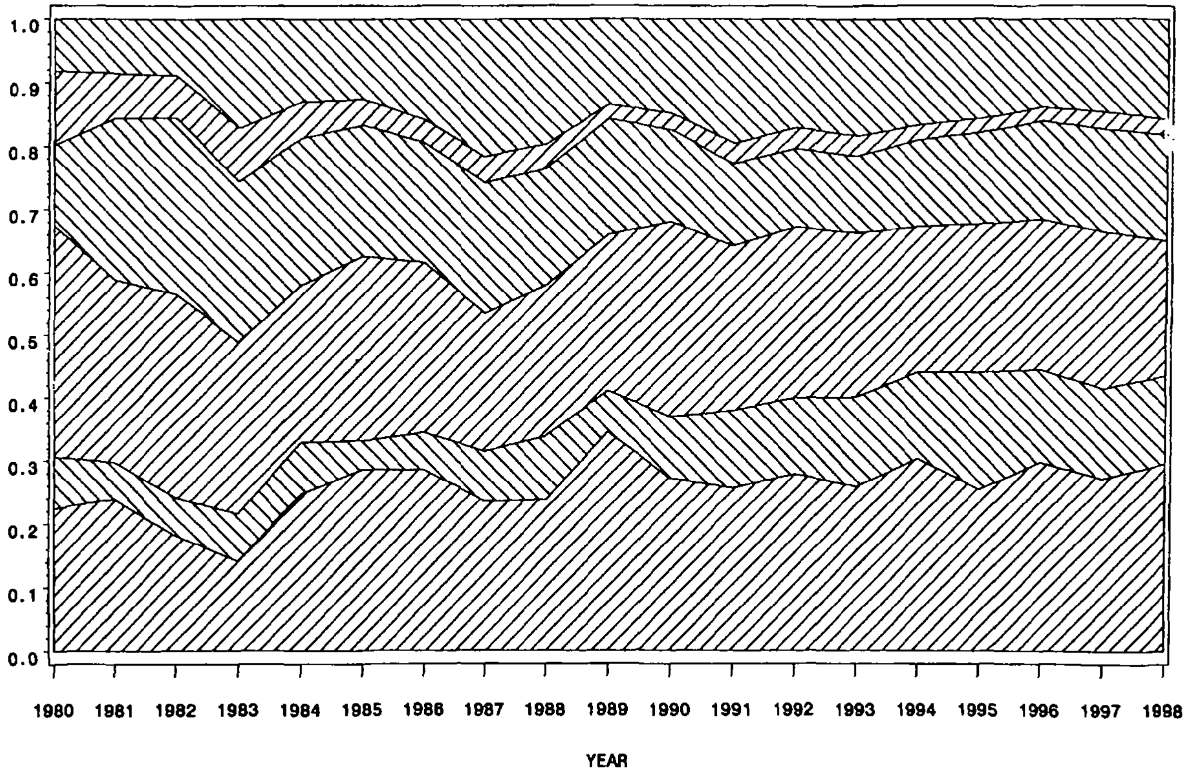

Exhibit 6

Herfindahl Index for Crop Hail Data

STATE=Countrywide

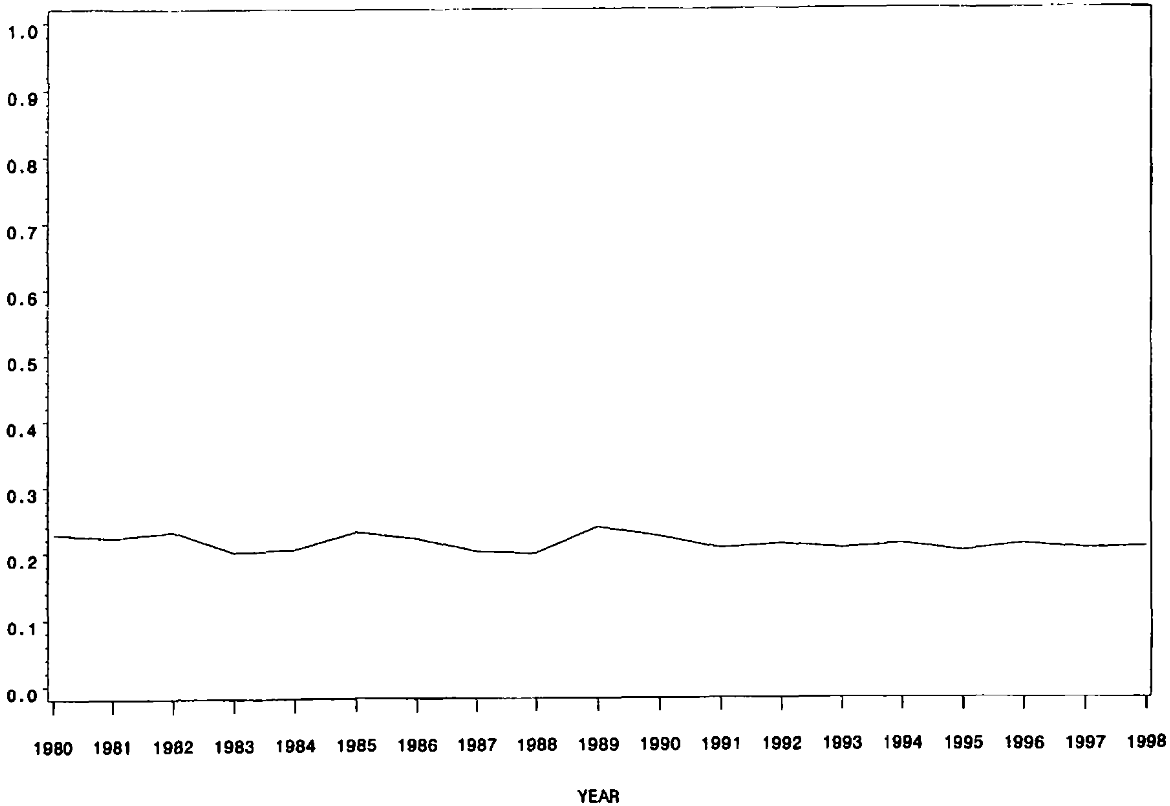

Exhibit 7

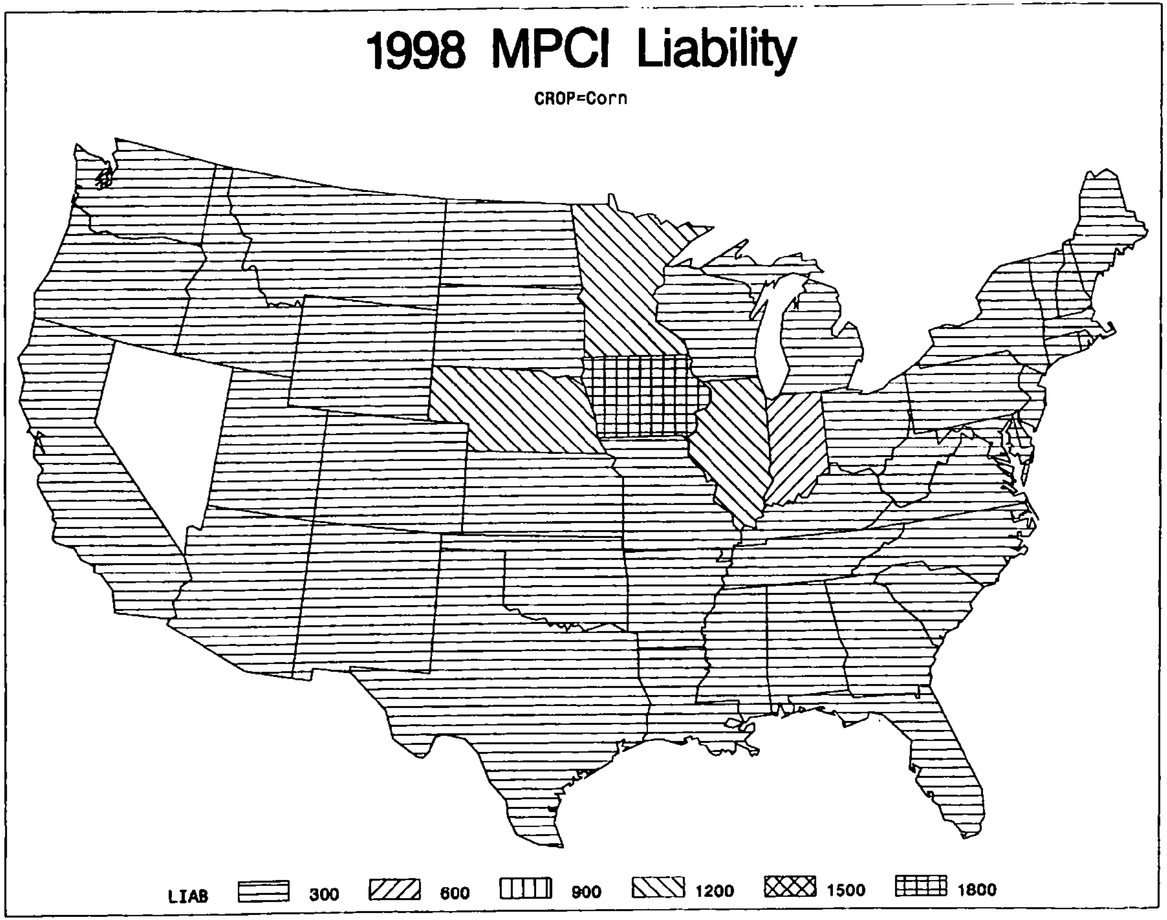
1998 MPCI Liability
CROP=Corn
LIAB
300
600
900
1200
1500
1800

Exhibit 8

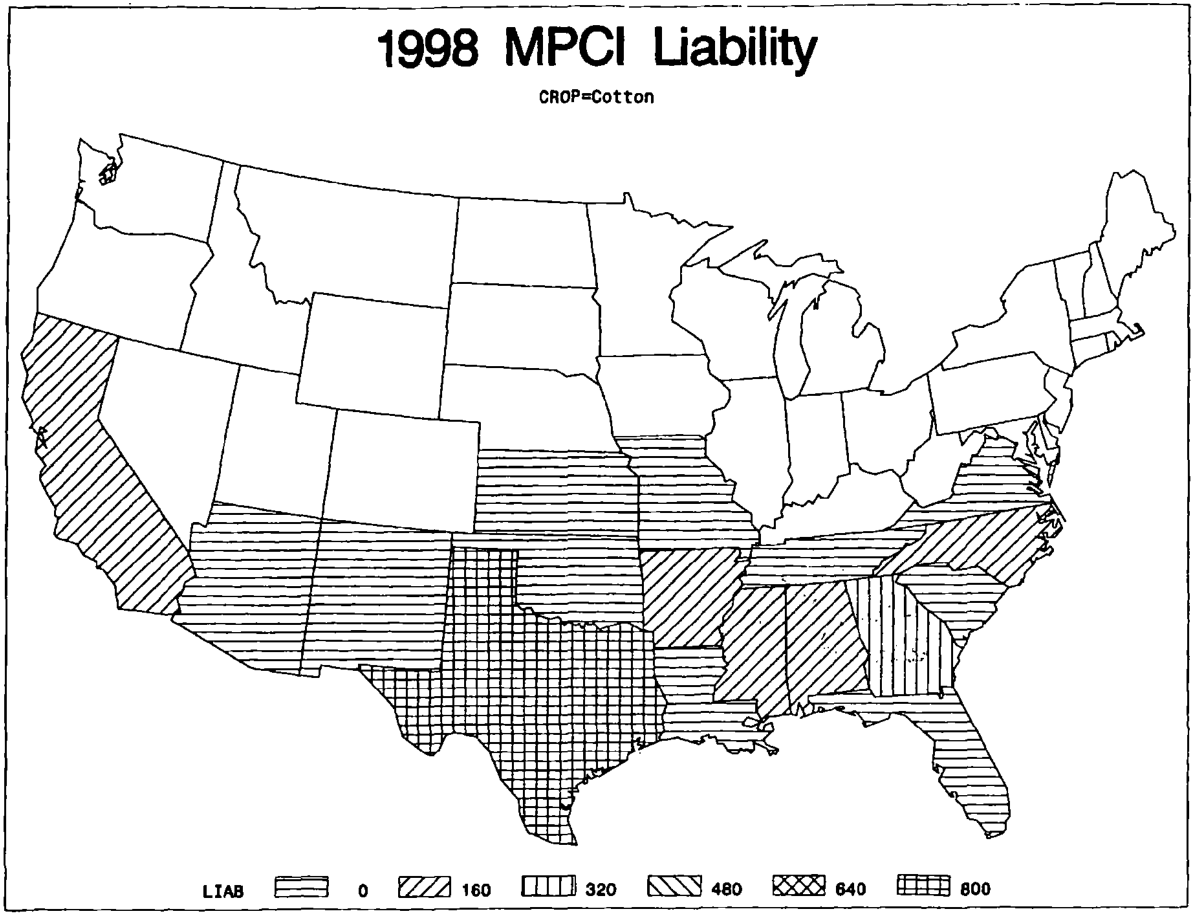

Exhibit 9

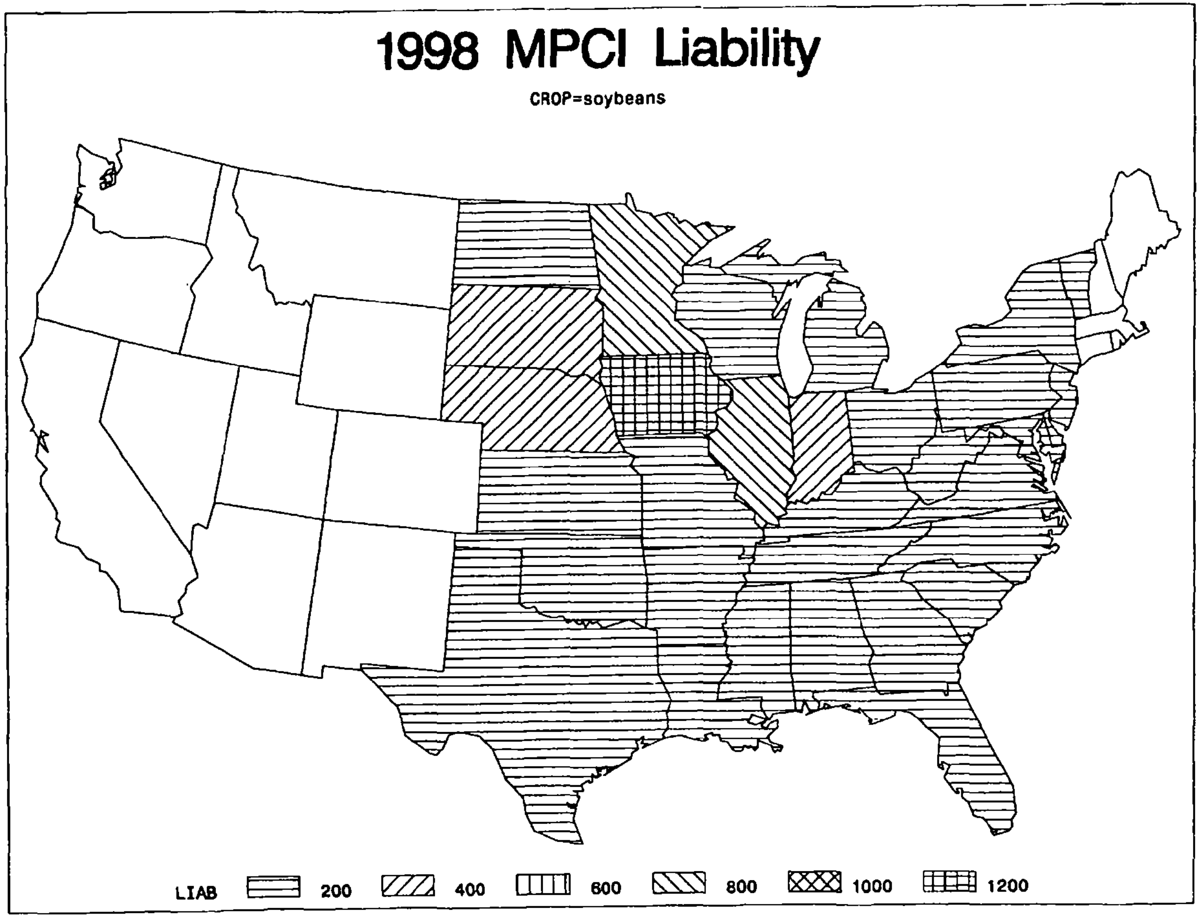
1998 MPCI Liability
CROP=soybeans
LIAB
200
400
600
800
1000
1200

Exhibit 10

1998 MPCI Liability

CROP=Wheat

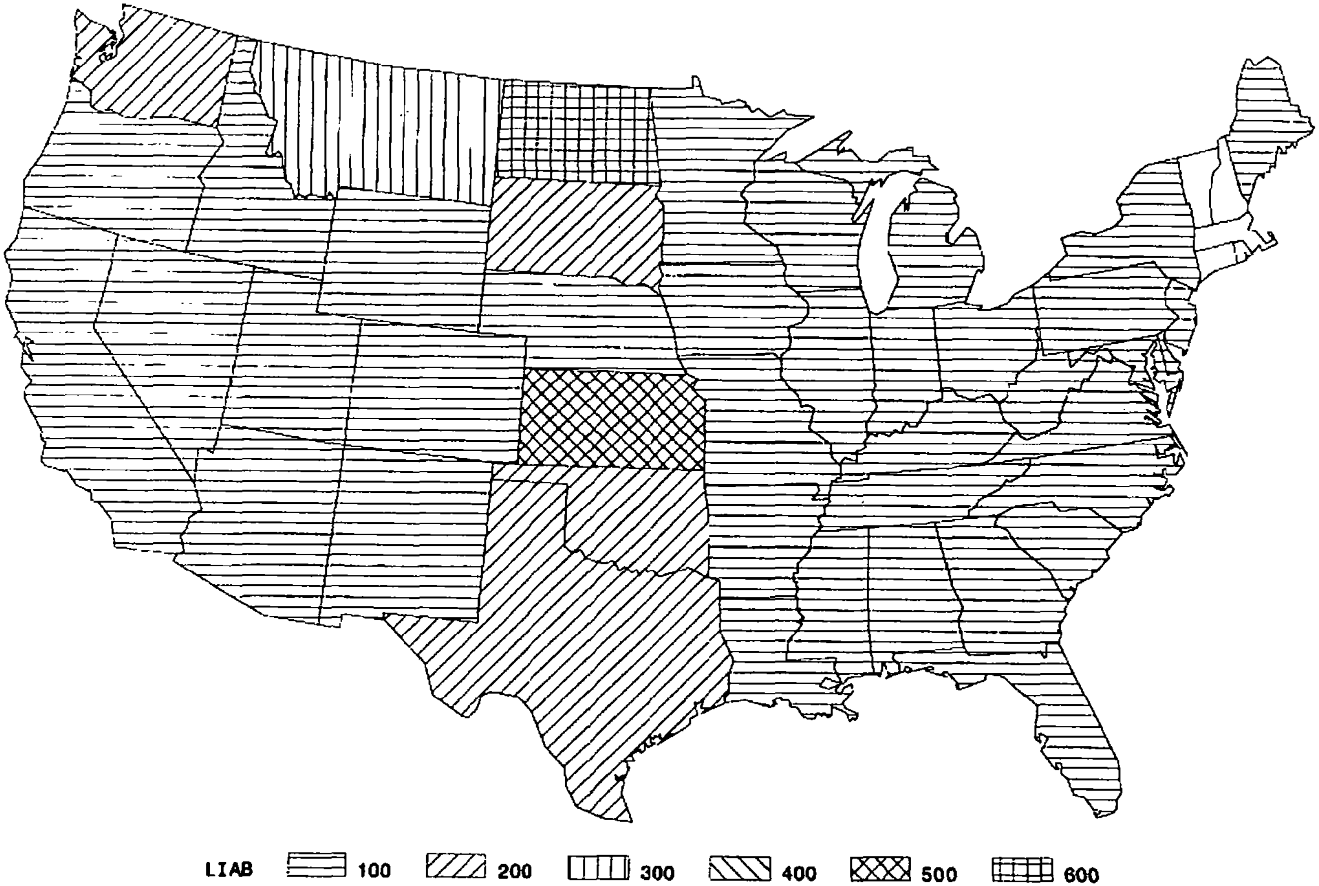

Exhibit 11

Average Harvested Yields, 1990 – 98

CROP=Corn - Bushels/acre

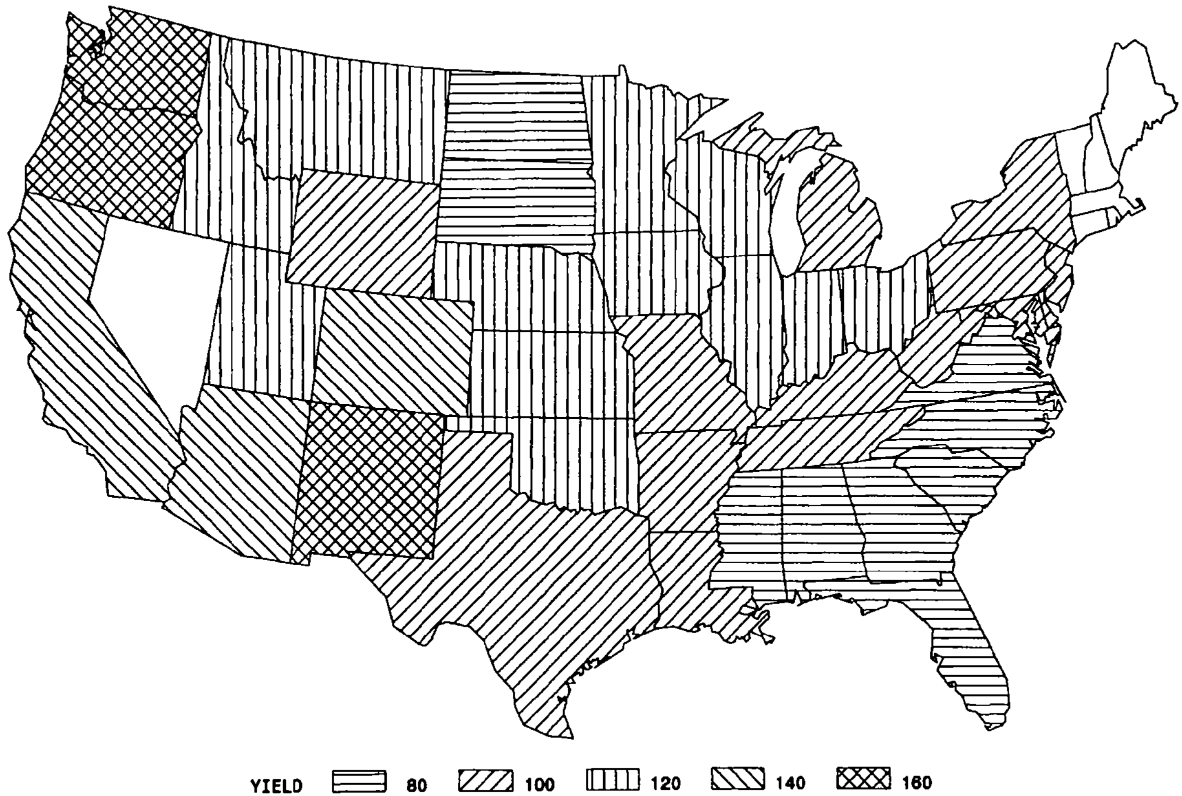

Exhibit 12

Average Harvested Yields, 1990 – 98

CROP=Cotton - Lbs/acre

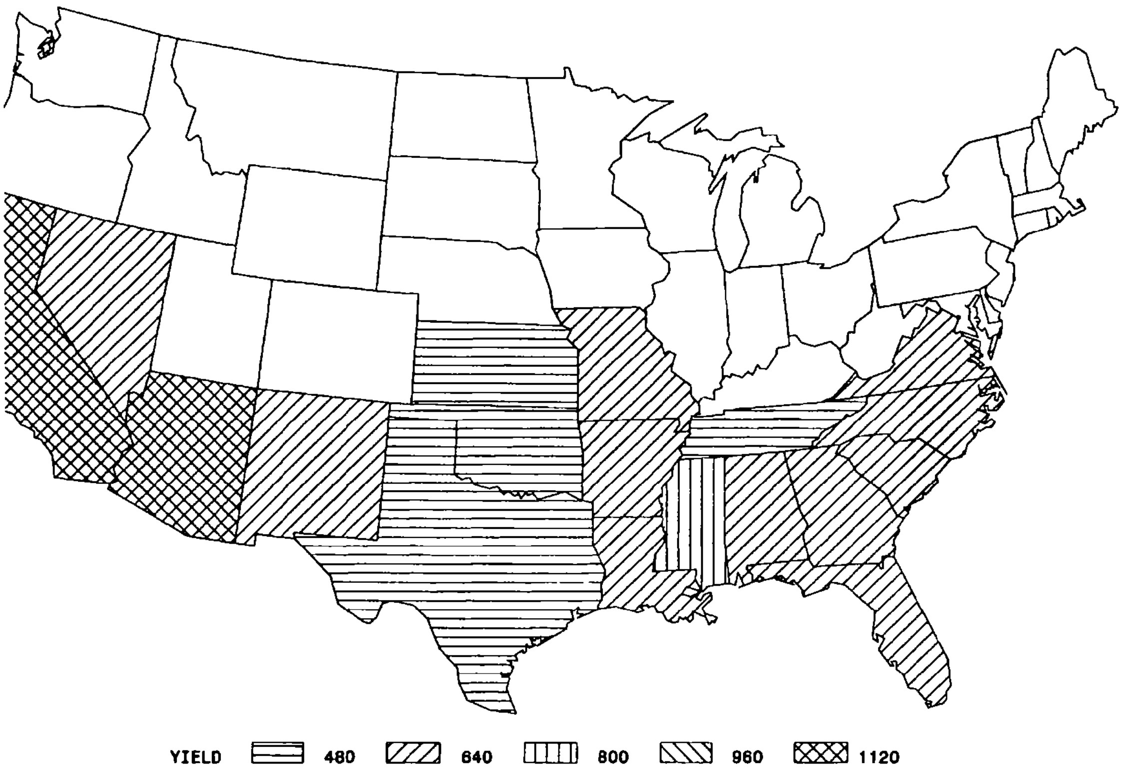

Exhibit 13

Average Harvested Yields, 1990 – 98

CROP=Soybean - Bushels/acre

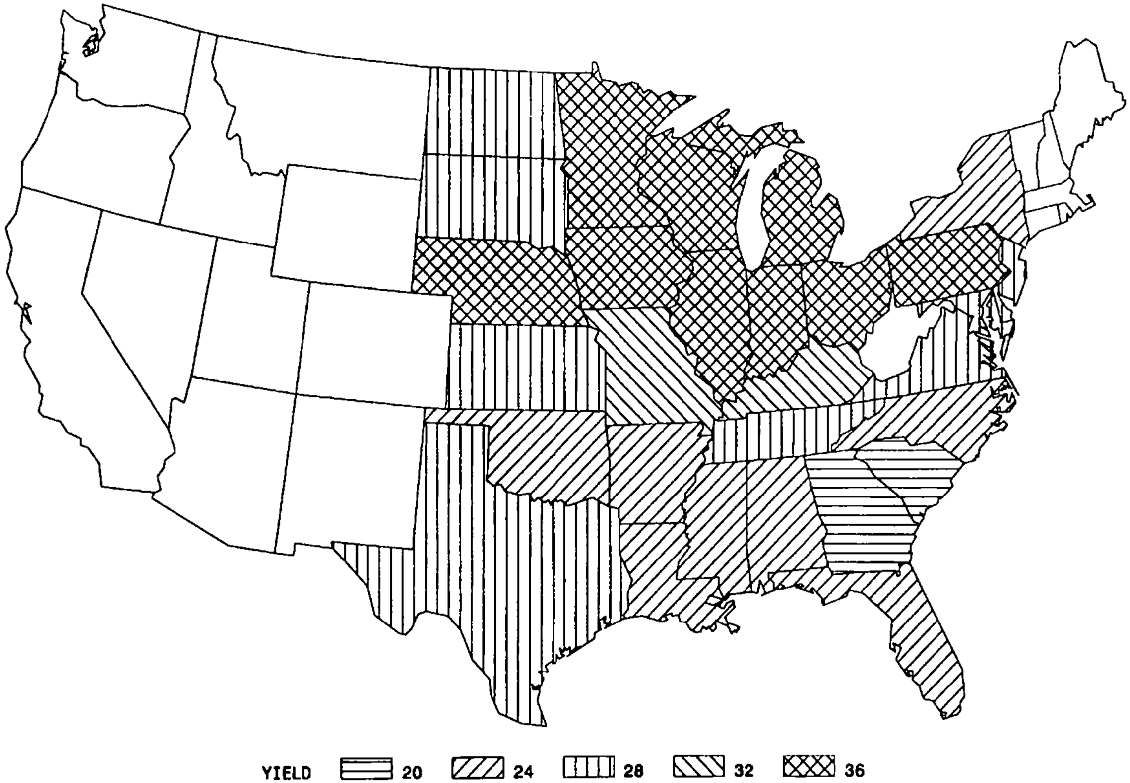

Exhibit 14

Average Harvested Yields, 1990 – 98

CROP=Wheat - Bushels/acre

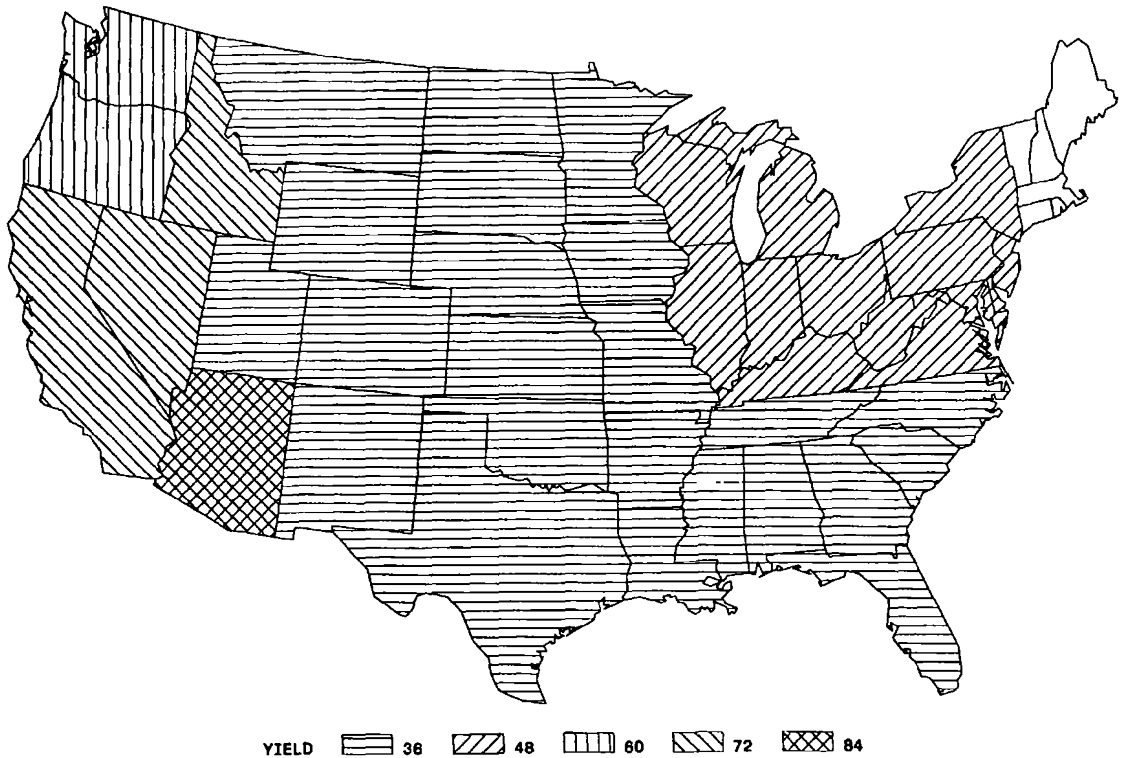

Exhibit 15

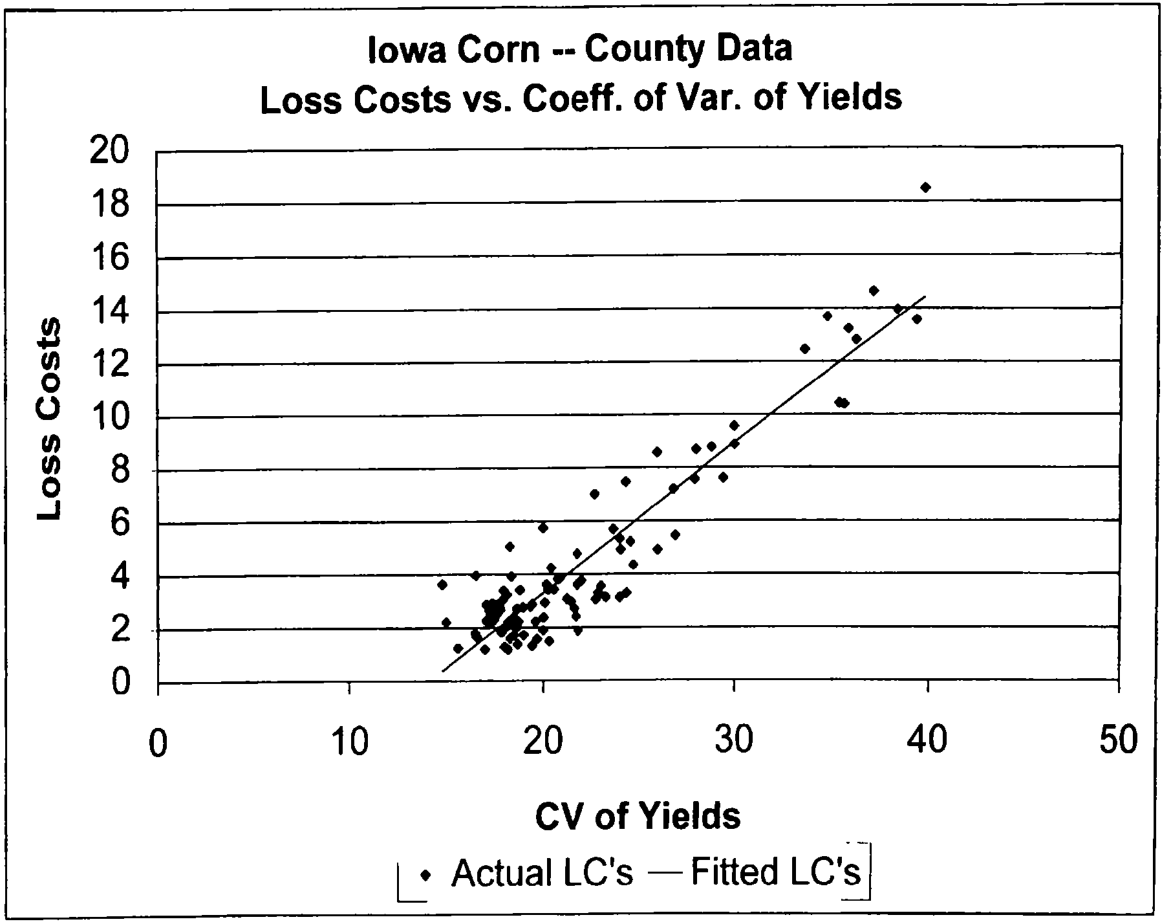
Iowa Corn -- County Data
Loss Costs vs. Coeff. of Var. of Yields
Loss Costs
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
CV of Yields
Actual LC's
Fitted LC's

Exhibit 16

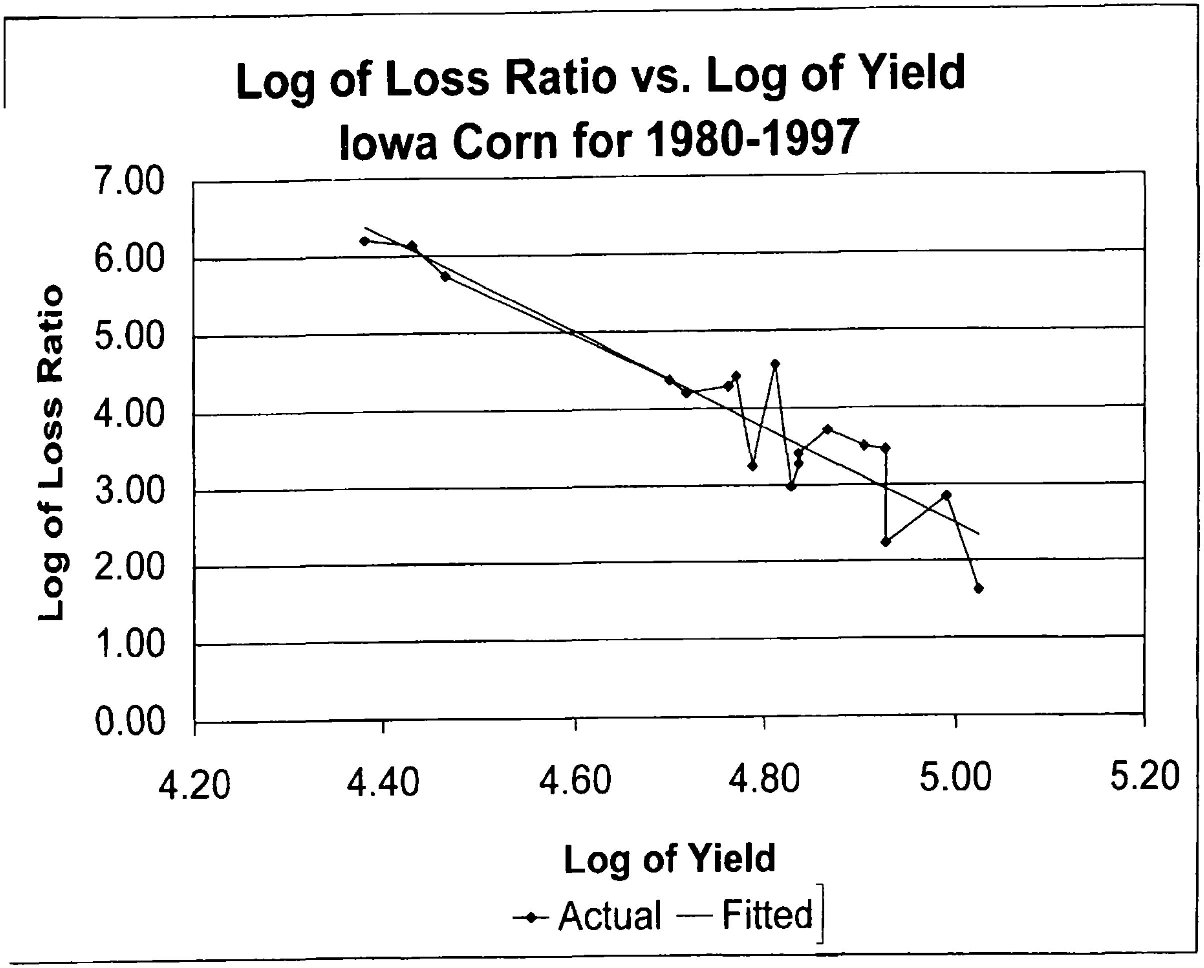
Log of Loss Ratio vs. Log of Yield
Iowa Corn for 1980-1997
Log of Loss Ratio
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4.20
4.40
4.60
4.80
5.00
5.20
Log of Yield
Actual
Fitted

Exhibit 17

Corn: Countrywide Yields over Time

Actual vs. Exponential Fit

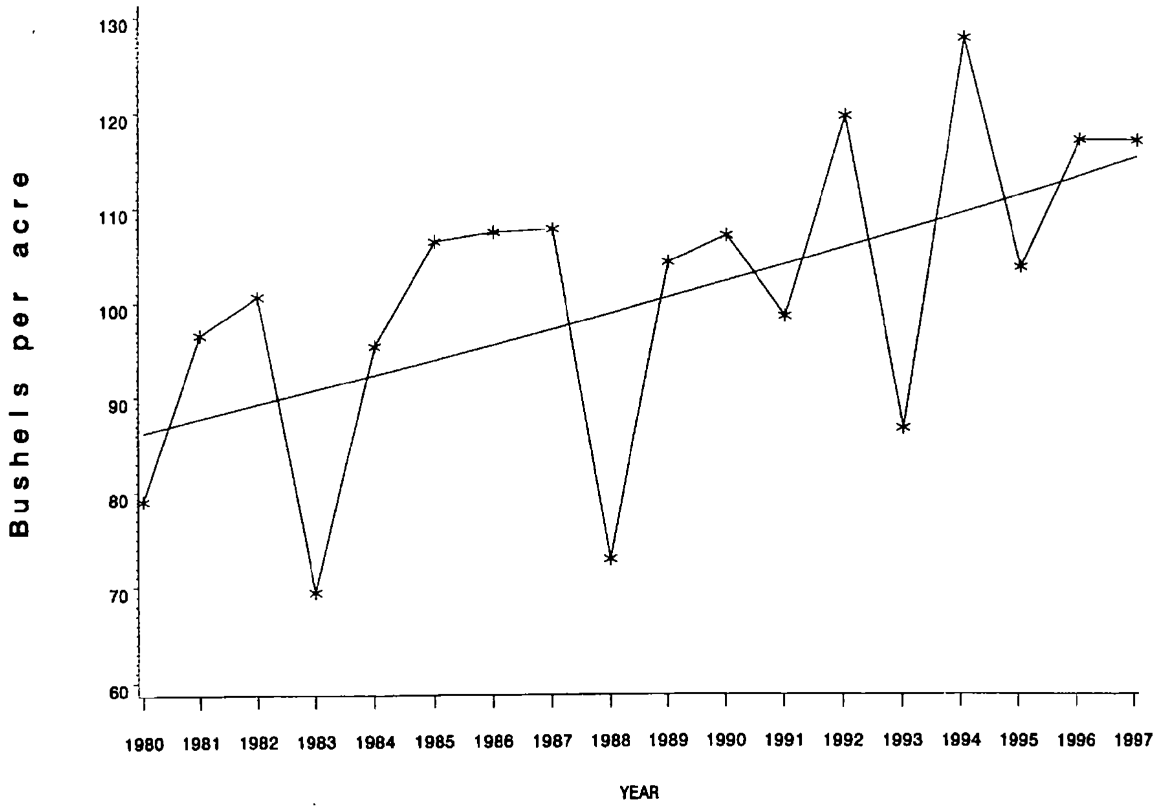

Exhibit 18

Corn: Heteroscedasticity test of Yield residuals

Note: the t statistic of the fitted slope is not significantly different from 0

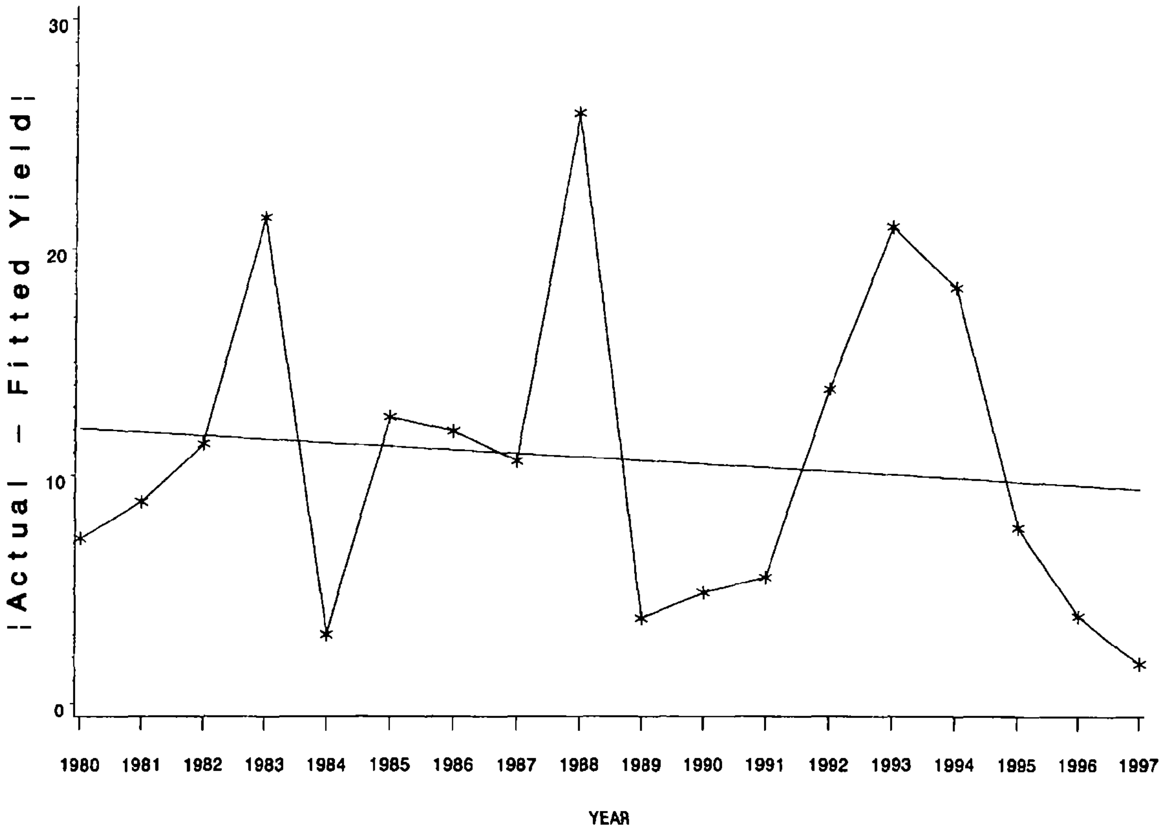

Exhibit 19

Corn: Countrywide Loss Costs over Time

Actual (stars) and Exponential Fit of Loss Costs vs. Yield

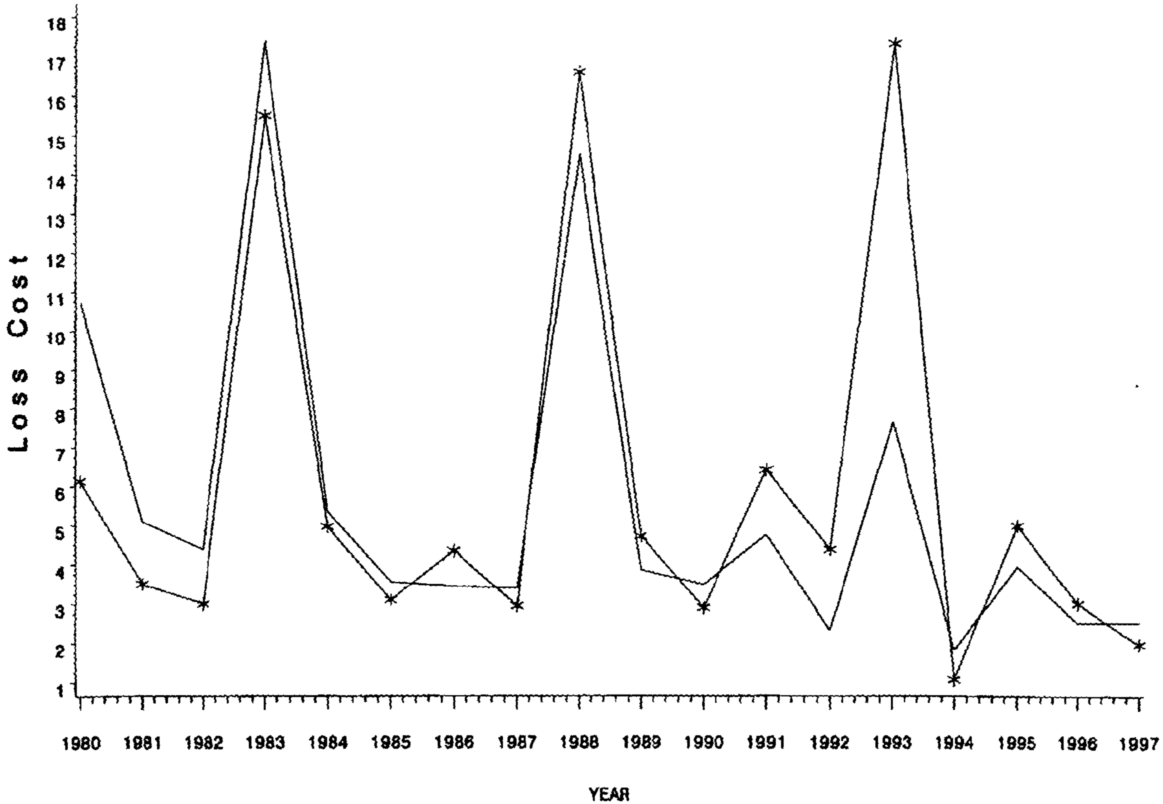

Exhibit 20

Corn: Heteroscedasticity test of Loss Cost residuals

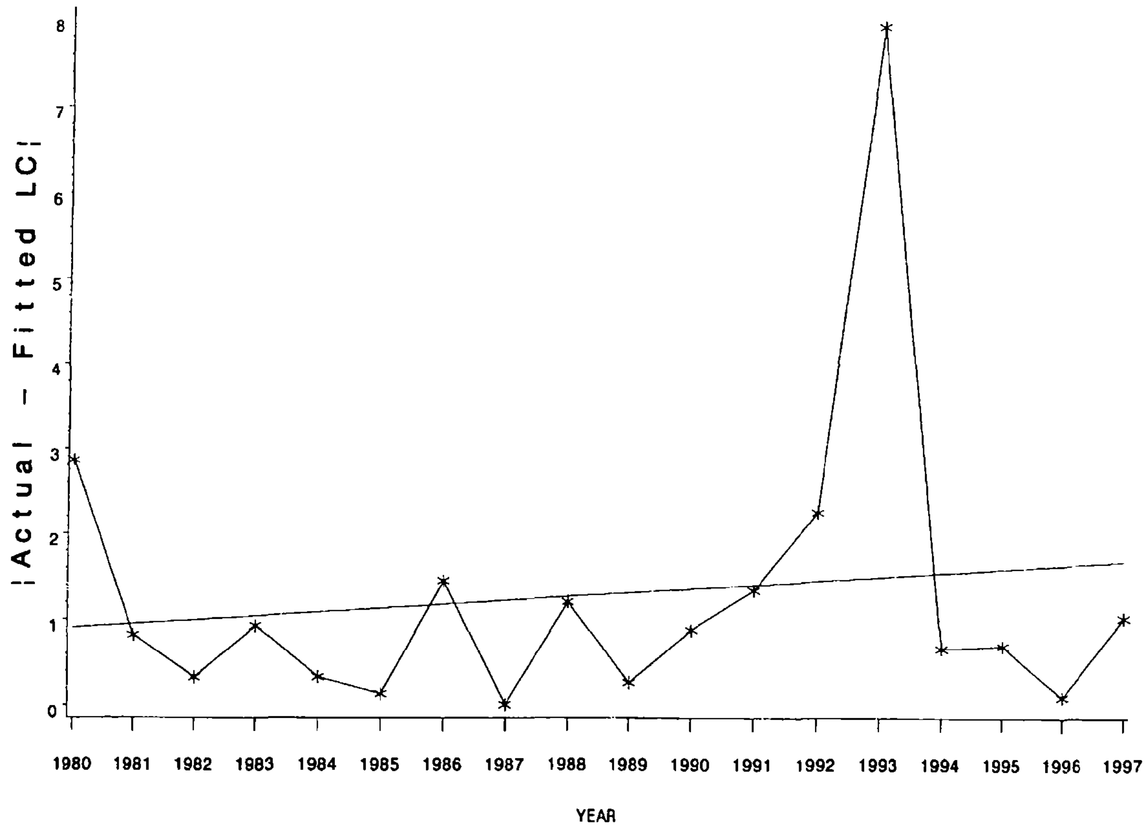

Exhibit 21

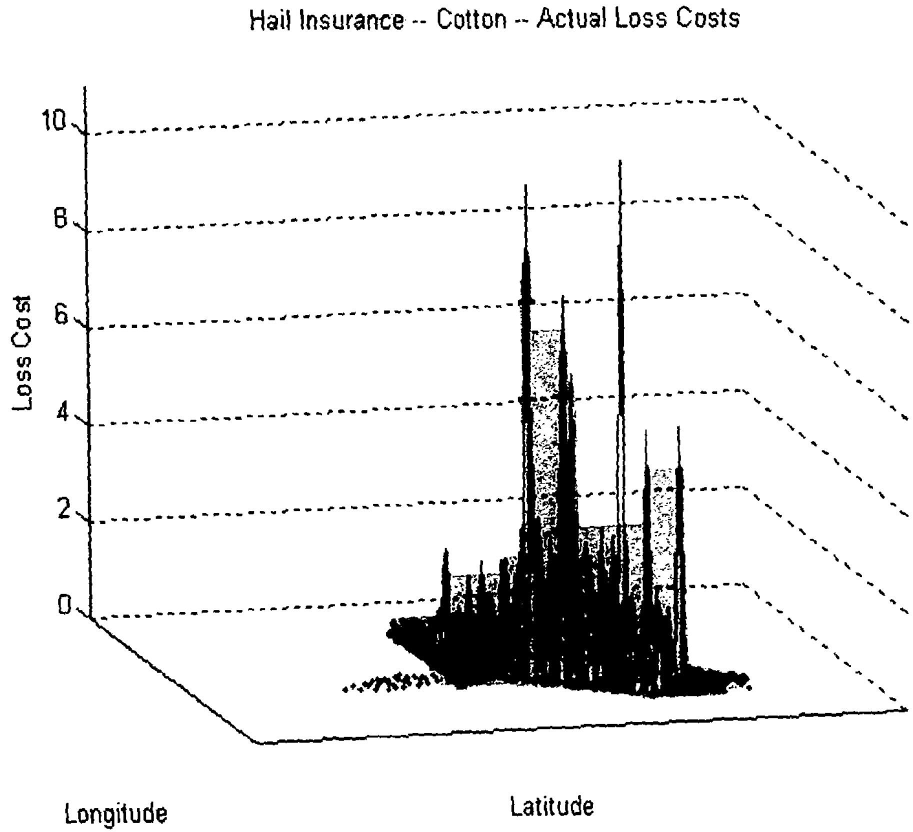
Hail Insurance -- Cotton -- Actual Loss Costs
Loss Cost
10
8
6
4
2
0
Longitude
Latitude

Exhibit 22

Hail Insurance -- Cotton -- Optimally Smoothed Loss Costs

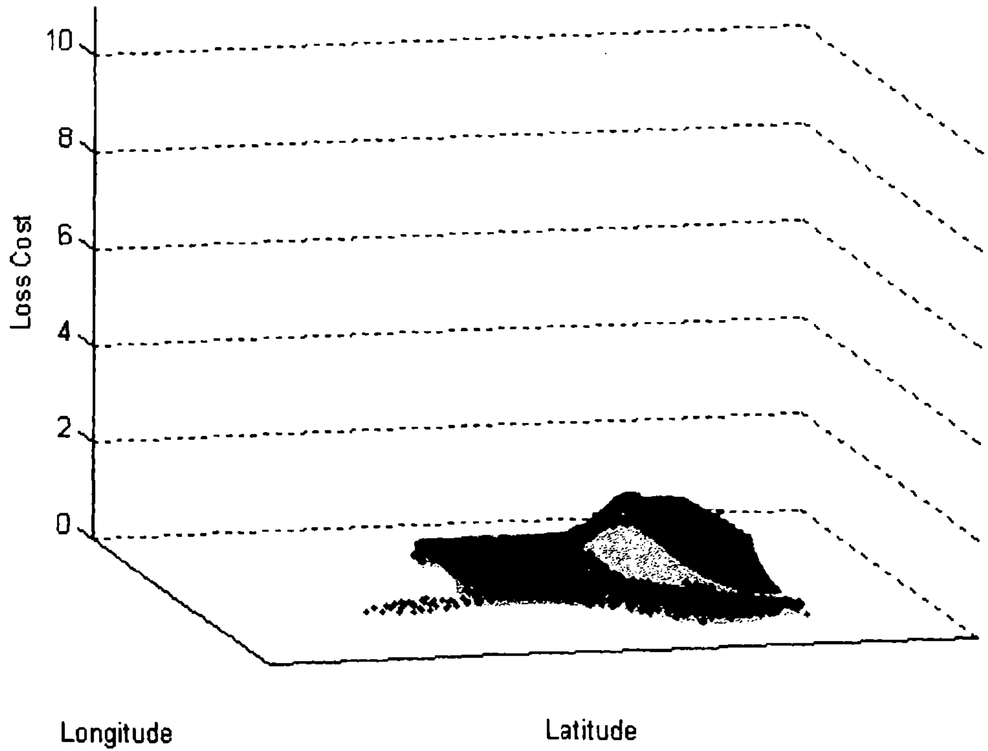

Exhibit 23

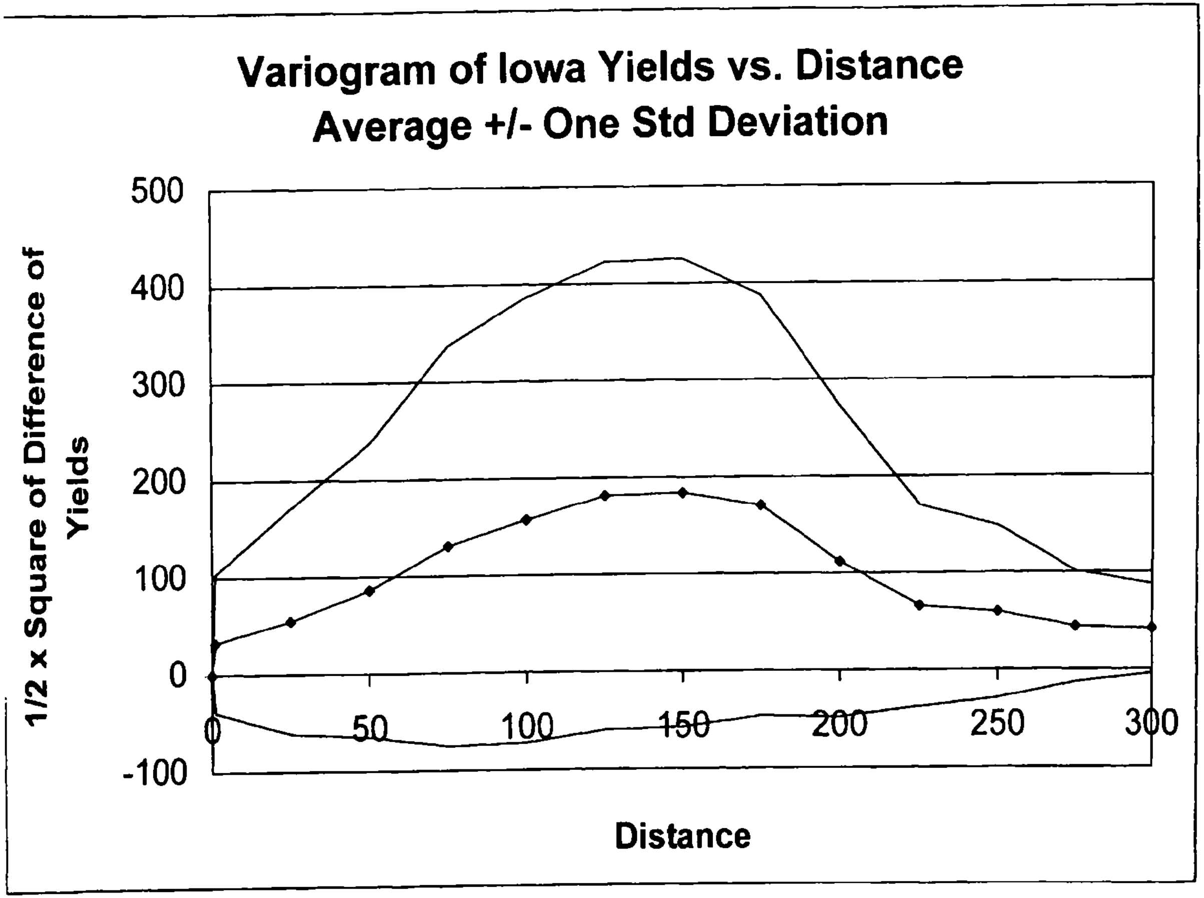
Variogram of Iowa Yields vs. Distance
Average +/- One Std Deviation
500
400
300
200
100
0
-100
0
50
100
150
200
250
300
1/2 x Square of Difference of Yields
Distance

Exhibit 24

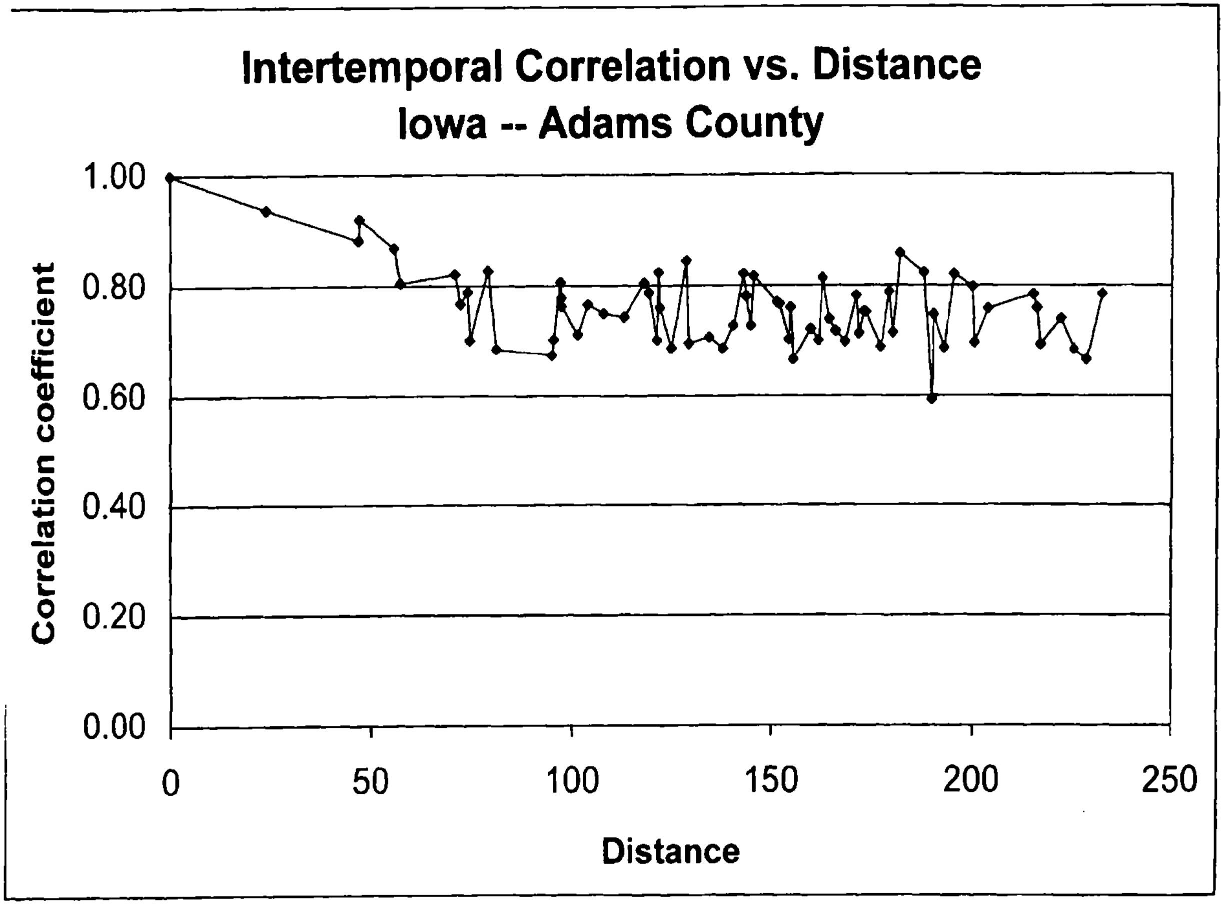
Intertemporal Correlation vs. Distance
Iowa -- Adams County
Correlation coefficient
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
250
Distance

Exhibit 25

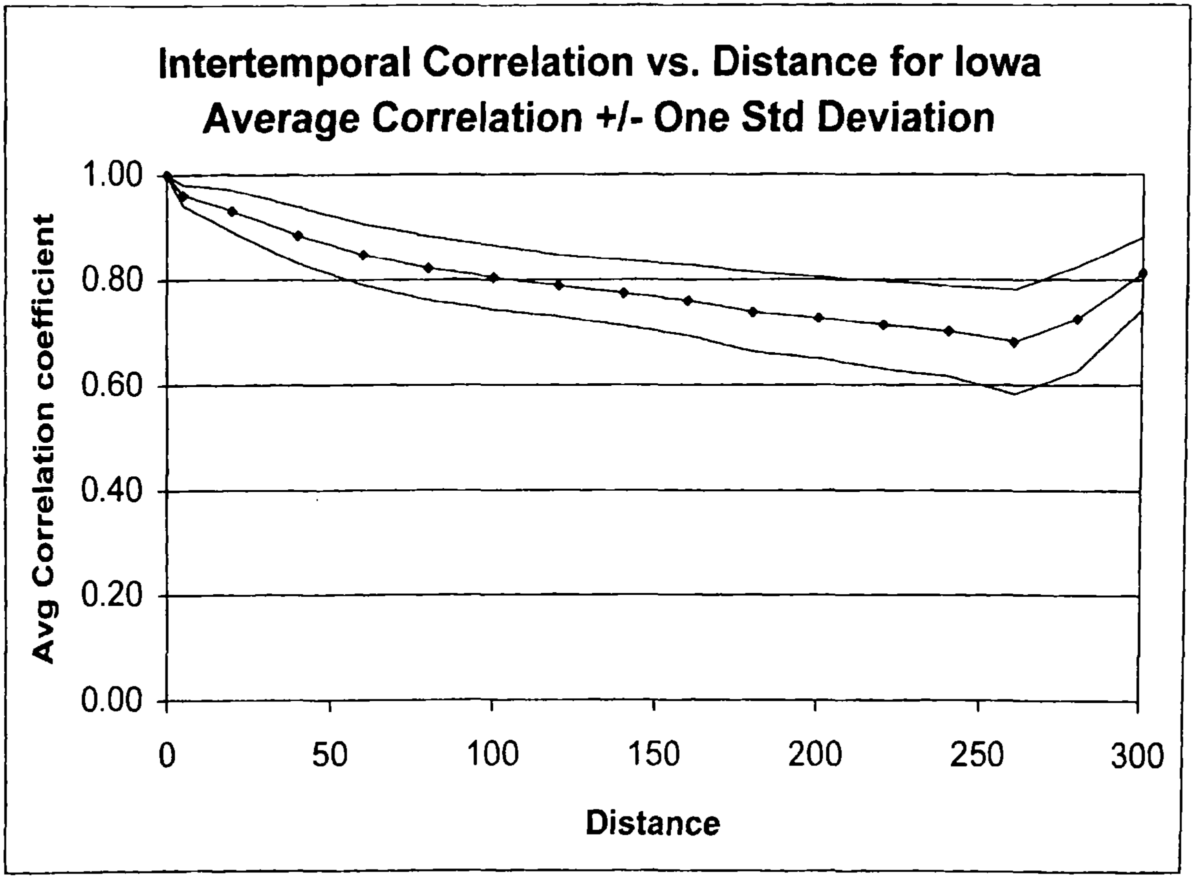
Intertemporal Correlation vs. Distance for Iowa
Average Correlation +/- One Std Deviation
Avg Correlation coefficient
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
250
300
Distance

Exhibit 26