KS

90-9



# STAFF PAPER

## RISK REDUCTION UNDER AN AREA YIELD-BASED CROP INSURANCE PLAN FOR SOUTHCENTRAL KANSAS WINTER WHEAT

Gordon L. Carriker, Jeffery R. Williams,
G. Art Barnaby and J. Roy Black*

March 1990
No. 90-9

Department of Agricultural Economics
Kansas State University

# RISK REDUCTION UNDER AN AREA YIELD-BASED CROP INSURANCE PLAN FOR SOUTHCENTRAL KANSAS WINTER WHEAT

Gordon L. Carriker, Jeffery R. Williams,
G. Art Barnaby and J. Roy Black*

March 1990
No. 90-9

Contribution No. 90-423-D from the Kansas Agricultural Experiment Station, Kansas State University, Manhattan, Kansas.

*The authors are assistant professor, professor and associate professor, Department of Agricultural Economics, Kansas State University and professor, Department of Agricultural Economics, Michigan State University.

KSU
KANSAS STATE UNIVERSITY

Department of Agricultural Economics
Kansas State University, Manhattan, Kansas 66506

# Risk Reduction Under An Area Yield-Based Crop Insurance Plan for Southcentral Kansas Winter Wheat

Gordon L. Carriker
Jeffery R. Williams
G. Art Barnaby
J. Roy Black

Presented at the meetings of The Crop Insurance Extension Advisory Group, Ft. Myers, Florida, March 26-29, 1990

The authors are assistant professor, professor and associate professor, Department of Agricultural Economics, Kansas State University and professor, Department of Agricultural Economics, Michigan State University.

Contribution no. 90-423-D from the Kansas Agricultural Experiment Station, Kansas State University, Manhattan, Kansas.

Risk Reduction Under An Area
Yield-Based Crop Insurance Plan
for Southcentral Kansas Winter Wheat

This study compares the effectiveness of two crop insurance plans: an individual farm-yield measurement similar to the current Federal Crop Insurance Corporation multi-peril program and an area-yield measurement method. These methods are examined for reduction in yield and gross farm income variability, including deficiency payments, using farm-level wheat yield data from 100 southcentral Kansas farms. Although an individual farm-level measurement plan is complex and suffers from moral hazard and adverse selection problems, it provides more gross farm income risk reduction than an area plan.

Key Words: Crop Insurance, Risk, Wheat

Risk Reduction Under An Area
Yield-Based Crop Insurance Plan
for Southcentral Kansas Winter Wheat

*Therefore the general condition in respect to the all-risk type of crop insurance is that it will work in a satisfactory manner only under a system of conditions so exacting in their specification that they will be found to rather limited extent in American Agriculture.*

*Harold G. Halcrow*
*JFE, August, 1949*

Halcrow proposes in his 1949 article an alternative to all-risk crop insurance based on an area-yield measure rather than the expected farm yield and deviations from that yield. In his area-yield insurance plan, the premiums and indemnities are based on the yield received in an area of uniform crop production. Indemnities are paid in bushels to any insured producer in any year in which the average of the yield for the area falls below the guaranteed level (the historical mean of the area yield or a percentage thereof). All participating farmers receive the same per-acre indemnity and pay the same premium rates based on historical area-yield data. For example, if the historical area yield for wheat is 32 bu/acre and the average area yield in the current year is 24 bu/acre, each insured producer receives 8 bushels for each acre of planted wheat (assuming 0% deductible) regardless of his own production.

To date, little analysis has been performed to determine the effectiveness of an area-yield measurement plan. Miranda recently completed a preliminary analysis of Halcrow's alternative using farm level data for 102 Western Kentucky soybean farms. He concludes that by comparing the reduction in variance of insured and uninsured yield distributions, without crop prices or deficiency payments, an area-yield measurement is capable of providing effective yield-loss coverage.

The objective of this study is to compare the effectiveness of the individual yield measurement plan in the current Federal Crop Insurance Corporation (FCIC) program with that of the area-yield method proposed by Halcrow and an area percentage measurement proposed by Barnaby and Skees. These plans are examined for reduction in yield and gross income variability using farm-level wheat yield data from 100 southcentral Kansas farms. A gross income distribution (income less insurance premiums) is estimated for each farm with and without government deficiency payments.

## BACKGROUND AND JUSTIFICATION

The Federal Crop Insurance Act of 1980, P.L. 96-365, expanded the availability of multiple peril (all risk) crop insurance with the goal of replacing the USDA's low-yield disaster assistance program. The direct-payment disaster aid programs were criticized for being expensive (averaging $436 million per year between 1974 and 1980) and encouraging production in areas susceptible to natural disasters (GAO). Although the 1980 act expanded the scope of crop insurance and made it more widely available, Congress has continued to provide disaster assistance payments to farmers via emergency loans and direct payments, most recently in 1988 and 1989. One of the reasons for providing disaster aid is that sales of crop insurance have remained relatively low. Although enrollment is increasing, the amount of eligible acres enrolled in 1988 was 24.5%, or 25.5% below the 50% goal established for the program in 1980 (GAO). Even with the increase in current participation rates to about 46%, which is largely attributable to the recent crop disasters and requirements of crop insurance participation for some producers in 1989 under the Disaster Assistance Act of 1988, the most ardent supporters of crop insurance will not dispute that the multiple peril program has not worked as expected.

Adverse selection and moral hazard are two significant problems that exist in the current crop insurance program. There are also competing government programs that provide substitute income variability reduction such as disaster aid, FmHA emergency loans, and the deficiency payment program. Adverse selection occurs when farmers with higher relative yield risk can buy insurance at the same cost as farmers who have lower relative yield risk and yield guarantees are based on the expected individual farm yield (Skees and Reed). If farmers recognize this, the insurance program eventually will attract a larger group with relatively high risks, thereby causing insurance rates to increase and compounding the problem.[1] Alternatively, this could create a situation in which indemnity payments increase relative to premiums, if rates are not increased (under the pretense of increasing participation). In fact, indemnities paid to farmers in each year from 1980-1988 exceeded the premium collected (GAO). Moral hazard occurs when the farmer has incentive to alter production or harvest practices to increase the chance of collecting crop insurance. This can happen when indemnity payments are based on farm measured losses and the market price is less than the price election that is used to calculate the indemnity payment for lost bushels.

Under the area plan or the "area-hedge" approaches suggested by Halcrow and Barnaby, a large amount of the adverse selection and moral hazard inherent in the current crop insurance program is reduced. In the current FCIC program, insurance premiums are based on the insured pool of farmers. By contrast, the area plan pays each producer an average area-yield loss with no individual loss adjustment. The probability of collecting an indemnity is the same for all

---

[1]Skees and Reed conclude that the current program leads to adverse selection because farmers with relatively high expected yields can expect small and infrequent indemnity payments when insurance guarantees are a measure of expected farm yield.

insured farmers in the area, although the "effective" cost and coverage will vary. The area average loss measurement includes both insured farmers and uninsured farmers, thus reducing adverse selection. Moral hazard is prevented because an individual farm cannot influence the amount of indemnity it will collect by altering production and harvest practices. In addition, accurate farm-level yield data, which historically have been difficult to obtain, are not needed to actuarially determine the insurance premiums. Therefore, the area-yield method deserves examination.

## PROCEDURES AND DATA

The first step in comparing the impact of an "area-hedge" versus individual farm yield measurement is to compare the yield variation in the insured yield distribution for each method to that in the uninsured distribution by farm.[2] The second step is to repeat the comparison using gross income, including indemnity payments with and without government deficiency payments. These comparisons are made using distributions derived from three insurance methods described in equations (1)-(3). The coefficients of variation of wheat yield and gross returns are calculated for each farm for each insurance method, as well as for no insurance, and compared. Market prices for southcentral Kansas for the period 1973 to 1987 are converted to 1988 dollars using the USDA index of prices received by farmers. Government deficiency payments are calculated using 1988 government program rules. Historical wheat yield data from 100 southcentral Kansas farms with continuous yield data from 1973-1987 are used. For the majority of the analysis, the mean area yield and annual deviation from the area average is the weighted average for all 100 farms. An example using a county

[2]The term "area-hedge" more appropriately describes this type of insurance to the industry because of their past experience with the FCIC area plan.

average yield for the area yield (Reno County) is also presented to determine its impact on the farms. A summary of the wheat yield statistics are reported in Table 1.

Individual Farm Yield Measurement

Under current FCIC procedures, each farm has an insurance yield based on historical farm-level production. The farm is reimbursed for any yield loss below the guaranteed yield, which is the insurance yield less an adjustment for the deductible selected by the producer. The farm gross returns per acre under this plan are described in equation (1),

$$(1) \quad GR_F = (\max\{P,EL\} \bullet Y_F) + [(TP \bullet \max\{EP,EL\}) \bullet PY] + INDEM - CIP \quad ,$$

where:

$GR_F$ = gross returns to farm ($/acre)
P = market price ($/bu)
EL = effective national average loan rate ($/bu)
$Y_F$ = actual farm yield produced on planted acres (bu/acre)
TP = target price ($/bu)
EP = expected national average price ($/bu)
PY = program yield (bu/acre); based on farm yield 1980-1984
IP = indemnity price; the value at which bushels are insured ($/bu)
$IY_F$ = historical average farm yield; the insurance yield (bu/acre)
LC = 1-% deductible; $IY_F \bullet LC$ is the guaranteed yield (bu/acre)
CIP = actuarially fair crop insurance premium ($/bu); actuarially fair assumes total premiums equal total indemnities for the actuarial period
INDEM = indemnity payment ($/acre); $\max\{0, IP \bullet [(IY_F \bullet LC) \bullet Y_F]\}$.

Halcrow's Area Yield Measurement

The method described in equation (2) is based on an area-yield average and negative deviations (losses) from the area average and does not use farm-level data for calculating the indemnity payment. Equation (2) presents the indemnity payment calculation that would replace the one in equation (1); the remainder of equation (1) is unaffected,

$$(2) \quad INDEM = \max\{0, IP \bullet [(IY_A \bullet LC) \bullet Y_A]\} \quad ,$$

where:

$IY_A$ = historical average area yield; the insurance yield
$Y_A$ = actual area yield produced on planted acres.

Halcrow suggests that the indemnity be paid in bushels. Therefore, when a gross, income measure is not used (a strict interpretation using yields only) for comparing the impact on the farm, IP is removed from the equation.

Area Percentage Yield Measurement

The area percentage method described by Barnaby is presented in equation (3). It is similar to the previous method under a restriction assuming that the total insurance liability purchased is equivalent to that in equation (2),

$$\text{(3)} \qquad \text{INDEM} = \max\{0,\ \$\text{LIAB} \bullet [((IY_A - Y_A)/IY_A) - (LC - 1)]\} ,$$

where:

$LIAB = dollars of liability purchased; when $LIAB = IP • $IY_A$ and LC is constant equations (2) and (3) are equivalent
LC-1 = % deductible.

Gross income is estimated using equation (3) and assuming that $LIAB is equivalent to the value of the area insurance yield (area mean). Relaxation of this assumption for implementation is discussed in the conclusions.

Following Halcrow's proposal, the initial analysis using equations (1)-(3) is conducted only on a per bushel basis. In effect, this is equivalent to fixing the value of each bushel produced and reimbursed or ignoring the gross income and government payments and charging a crop insurance premium in bushels rather than dollars. In addition, to simplify the comparison, we assume that the crop is insured with a 0% deductible plan and that the premiums are actuarially fair (indemnity payments equal premium costs over the actuarial period). Therefore, the mean of the yield distribution is not influenced by the insurance method.

After initial analysis, the assumption that indemnity payments would be made in bushels is relaxed, and further analysis is conducted using gross income including government deficiency payments. Indemnity payments are based on a price election equivalent to target price.

Although area-yield insurance may offer numerous advantages compared to individual farm-level yield insurance, there is concern that indemnities paid from an area plan may not be closely correlated with actual indemnity needs at the individual farm level. Farmers whose yield distribution is not highly correlated with the area yield distribution may find an area-yield plan ineffective. To test the relationship, a simple analytical model suggested by Miranda is used. The model, as described in equation (4), is estimated using regression procedures for each of the 100 farms in the data set,

$$(4) \qquad Y_F = IY_F + \beta\ (Y_A - IY_A) + \epsilon \quad .$$

If the estimated $\beta$ for a farm is equal to 1, the farm has identical yield deviations as the area. If $\beta>1$, the farm has deviations from its average yield that are larger than the average area-yield deviation. The opposite is true if $\beta<1$. The higher the farm $\beta$, the greater the chance that an area-yield measurement will be risk reducing for the farm.

Miranda presents a method for calculating a critical $\beta$, which is presented in equation (5),

$$(5) \qquad \beta_c = -\frac{\sigma_I^2}{2 \bullet \mathrm{Cov}(Y_A, I)} \quad ,$$

where:

$\sigma_I^2$ = Variance of the indemnity payments
I = Indemnity payments.

The value of $\beta_c$ is the point at which variability reduction from insurance is zero. If an individual farm $\beta$ is less the $\beta_c$, the area measurement method will be risk augmenting for the farm. Estimated $\beta$'s are reported in Table 2.

## RESULTS

A relative variability reduction (% reduction in coefficient of variation) in insured yield distributions occurs on 100% of the farms when an individual farm measurement is used and on 94% of the farms when either of the area measurement plans is used as opposed to no insurance.[3] Under the individual farm measurement method, the range of relative variation reduction in yield is 27% to 67%, with an average of 42% (Table 3). Under the area-yield plans, variability is reduced by an average of 10% but variability increases for six farms.

Comparisons using the insured gross income distribution without government deficiency payments indicate that relative variability is reduced on 100% of the farms when an individual farm measurement is used and on 90% of the farms when either of the area measurement plans is used (Table 3). The individual farm-level measurement method reduces relative variability by an average of 20% and ranges from 3% to 34%. The area plans reduce it by an average of 5% with a range of -4% to +14%. When deficiency payments are included in the gross income distribution, the individual farm-level measurement plan reduces variability by 15 to 56% (an average of 37%); the area-yield plans reduces it by 4% to +21% (an average of 11%).

The government deficiency payment program is more effective in reducing gross income variability than either insurance program. The government

[3]Halcrow's area method and the percentage area method proposed by Barnaby are equivalent when liability in the percentage method is limited to the mean area yield.

deficiency payment program reduces relative gross income variability by an average of 36% when compared to no program and no insurance usage (Table 3).

Estimates of the $\beta$'s from the model presented in equation (4) are provided in Table 2 and correspond to the yield results presented in Table 3 for the area measurement. Estimates of $\beta$ range from .16 to 1.73. There are six farms that have risk augmentation when the area method is used (Table 3). As expected, six farm $\beta$'s fall below $\beta_c$ = .26786 (Table 2).

Reno County, which contains 11 of the 100 farms, is examined separately. The Reno County average yield reported by the Kansas State Board of Agriculture is used rather than the average yield of the 11 farms in the county. One farm has a $\beta$ less than the critical $\beta$ and, therefore, the area-yield method is risk augmenting for this farm (Table 2). Five of the 11 farms have more relative risk reduction in gross income when the county average is used, whereas six farms have greater risk reduction when the 100-farm area average is used.

## CONCLUSIONS AND IMPLEMENTATION CONSIDERATIONS

Although an individual farm-level measurement method is complex, it provides more reduction in farm gross income variability than the area plan. The government deficiency payment program is also very effective in reducing relative income variability. The deficiency payment program reduces relative variability by an average of 36% (Scenario 5, Table 3). The area insurance program alone reduces relative income variability by an average of 5% (Scenario 2). Together, they reduce relative variability by an average of 43% compared to the deficiency payment program and the individual measurement plan, with an average reduction of 60% (Scenario 4). This indicates that some adjustments in the deficiency payment program might be as effective as an area-yield measurement program combined with the deficiency payment program.

As demonstrated, the percentage method is equivalent to the Halcrow method if total liability for each method is assumed to be equal. However, this assumption does not allow for complete liability coverage as the individual farm measure does. Additional work is needed to identify how the optimal full coverage strategy for each farm may compare in reducing relative variability. Further, if an area method is considered appropriate, the percentage method may offer significant implementation advantages. These advantages are only briefly discussed due to space limitations. Implementation procedures may be similar to the private hail insurance procedures with which the insurance industry is acquainted. A method that allows payments to be related to dollars of liability rather than bushels would eliminate the problem FCIC faces in forecasting crop prices to determine premiums. In addition, the percentage method could use a percentage premium rate that would be multiplied by dollars of liability purchased. Each farmer would determine the optimal amount of liability to purchase, if it was not restricted to the equivalent value of the historical county average yield, rather than the FCIC determining the farm's insurance yield and the amount of additional bushels of protection needed to obtain full coverage under the Halcrow method. This procedure allows for a closed liability policy. Halcrow's method may effectively create an open ended liability. Because prices may rise within years of low crop production producers may make premium payments in bushels of lower value before the end of the production season and later collect indemnity bushels with a higher value.

Additional analysis should use a broader scope to consider these insurance methods. Important issues to consider in further evaluation of the alternatives include ease of implementation for farmers as well as for FCIC, administrative costs, cost effectiveness compared to direct disaster payments, and the appropriate area yield-measure for different crops in production regions of different relative variability.

Table 1. Characteristics of Dryland Wheat Yield Data.

| | 100 Southcentral Kansas Farms | | Reno County | |
|---|---|---|---|---|
| | Area Yield | All Farms | County Yield[1] | All Farms |
| Mean (bu/acre) | 34.58 | 34.80 | 29.09 | 35.50 |
| Std. Dev. (bu/acre) | 3.89 | 8.15 | 4.08 | 7.84 |
| Coef. Var | 0.11 | 0.2342 | 0.14 | 0.2210 |
| Minimum Value (bu/acre) | 28.66 | 3.71 | 21.30 | 11.61 |
| Maximum Value (bu/acre) | 41.11 | 60.00 | 35.50 | 54.62 |
| Observations | 15 years | 100 farms | 15 years | 11 farms |

[1]Source: Kansas State Board of Agriculture

Table 2. Frequency of $\beta$ Estimates (# of Farms)

| Estimate of $\beta$ | Southcentral Kansas Farms[1] | Reno County[2] |
|---|---|---|
| 0.00 - 0.20 | 1 (lowest $\beta$ = .16) | 1 (lowest $\beta$ = .13) |
| 0.21 - 0.40 | 6 | 0 |
| 0.41 - 0.60 | 8 | 1 |
| 0.61 - 0.80 | 13 | 2 |
| 0.81 - 1.00 | 24 | 3 |
| 1.01 - 1.20 | 15 | 3 |
| 1.21 - 1.40 | 21 | 0 |
| 1.41 - 1.60 | 11 | 1 (highest $\beta$ = 1.59) |
| 1.61 - 1.80 | 1 (highest $\beta$ = 1.73 | 0 |

[1]Critical $\beta$ = 0.26786. # of farms below $\beta_c$ = 6.
[2]Critical $\beta$ = 0.33511. # of farms below $\beta_c$ = 1.

Table 3. Frequency of Relative Variability Reduction In Wheat Yield and Gross Income for 100 Southcentral Kansas Farms by Insurance Method (# of Farms)[1].

| Percent[2] Reduction | Scenario 1 IFM[3] | Scenario 1 HAM[4] PAM[5] | Scenario 2 IFM | Scenario 2 HAM PAM | Scenario 3 IFM | Scenario 3 HAM PAM | Scenario 4 IFM | Scenario 4 HAM PAM | Scenario 5 No Insurance |
|---|---|---|---|---|---|---|---|---|---|
| -10 to -5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -4 to 0 | 0 | 5 | 0 | 10 | 0 | 3 | 0 | 0 | 0 |
| 1 to 5 | 0 | 18 | 1 | 52 | 0 | 17 | 0 | 0 | 0 |
| 6 to 10 | 0 | 29 | 9 | 35 | 0 | 26 | 0 | 0 | 0 |
| 11 to 15 | 0 | 36 | 24 | 3 | 1 | 31 | 0 | 0 | 1 |
| 16 to 20 | 0 | 11 | 29 | 0 | 1 | 23 | 0 | 0 | 4 |
| 21 to 25 | 6 | 0 | 19 | 0 | 6 | 0 | 0 | 2 | 8 |
| 26 to 30 | 13 | 0 | 15 | 0 | 14 | 0 | 0 | 3 | 15 |
| 31 to 35 | 32 | 0 | 3 | 0 | 26 | 0 | 0 | 13 | 22 |
| 36 to 40 | 27 | 0 | 0 | 0 | 15 | 0 | 0 | 21 | 22 |
| 41 to 45 | 11 | 0 | 0 | 0 | 20 | 0 | 0 | 22 | 18 |
| 46 to 50 | 5 | 0 | 0 | 0 | 11 | 0 | 5 | 25 | 9 |
| 51 to 55 | 5 | 0 | 0 | 0 | 4 | 0 | 16 | 11 | 1 |
| 56 to 60 | 0 | 0 | 0 | 0 | 2 | 0 | 32 | 2 | 0 |
| 61 to 65 | 1 | 0 | 0 | 0 | 0 | 0 | 31 | 1 | 0 |
| 66 to 70 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 |
| 71 to 75 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 0 |
| Minimum | 27% | -6% | 3% | -4% | 15% | -4% | 48% | 23% | 15% |
| Maximum | 67% | 19% | 34% | 14% | 56% | 21% | 74% | 63% | 56% |
| Mean | 42% | 20% | 20% | 5% | 37% | 11% | 60% | 43% | 36% |

[1] Scenario
1. Yield insurance as compared to no insurance by method.
2. Insurance using gross income w/o deficiency payments compared to gross income w/o deficiency payments and no insurance.
3. Insurance using gross income with deficiency payments compared to gross income with deficiency payments and no insurance.
4. Insurance using gross income with deficiency payments compared to gross income w/o deficiency payments and no insurance.
5. Gross income with deficiency payments and w/o insurance compared to gross income w/o deficiency payment and w/o insurance.

[2] The percent reduction is the percentage change in coefficient of variation when an insurance method is compared to no insurance. The percent reduction within scenario is also the percent reduction in standard deviation.

[3] IFM - Individual farm measurement method

[4] HAM - Halcrow's area measurement method.

[5] PAM - Percent area measurement method given the restriction that total liability is equivalent in HAM and PAM.

## BIBLIOGRAPHY


Barnaby G.A. 1989. "A Dollar Liability Crop Insurance Policy Combined with a County Average Loss Adjustment." Working Paper prepared for the Federal Crop Insurance Commission, May.

Barnaby G.A. 1990. "Multiple Peril Crop Insurance Based on a Yield Hedge." Paper presented at the Crop Insurance Research Bureau, Inc. Annual Meeting, Orlando, Florida, February.

Barnaby G. A. and J.R. Skees. 1990. "Public Policy for Catastrophic Yield Risk: An Alternative Crop Insurance Program." Choices (forthcoming).

General Accounting Office. 1989. "Disaster Assistance: Crop Insurance Can Provide Assistance More Effectively than Other Programs." GAO/RCED-89-211. G.A.O., Gaithersburg, MD, September.

Halcrow, Harold G. 1949. "Actuarial Structures for Crop Insurance." J. of Farm Econ. 31(August): 418-443.

Kansas State Board of Agriculture. Annual Report and Farm Facts. Topeka, KS (Various Years).

Miranda, M.J. 1989. "Area-Yield Crop Insurance Reconsidered" Working Paper, Department of Agricultural Economics, The Ohio State University, December.

Skees J.R. and M.R. Reed. 1986. "Rate Making for Farm-Level Crop Insurance: Implications for Adverse Selection." Amer. J. Agri. Econ. 68(August):653-659.