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Economic Impacts of Fusarium Head Blight in Wheat and Barley: 1993-2001

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Abstract

Fusarium Head Blight (FHB), commonly known as scab, has been a severe problem for wheat and barley producers since 1993. This study provides an update of economic losses suffered by wheat and barley producers in scab-affected regions in the United States. Emphasis is placed on estimating direct and secondary economic impacts of yield and price losses suffered by wheat and barley producers from 1993 to 2001. Nine states are included in the analysis for three wheat classes. Three of the nine states were also used for the analysis of malting and feed barley. The cumulative direct economic losses from FHB in hard red spring (HRS) wheat, soft red winter (SRW) wheat, durum wheat, and barley are estimated at $2.492 billion from 1993 through 2001. The combined direct and secondary economic losses for all the crops were estimated at $7.7 billion. Two states, North Dakota and Minnesota, account for about 68 percent of the total dollar losses.

Key Words: Fusarium Head Blight, scab, vomitoxin, crop losses, wheat, barley

Highlights

This study provides an update of economic losses suffered by wheat and barley producers in scab-affected regions in the United States from 1993 through 2001. Wheat and barley producers in several states have experienced significant yield losses due to Fusarium Head Blight (FHB), or scab, since 1993. Losses have been especially severe in the spring wheat and barley regions, but soft red winter (SRW) wheat producers have also experienced major outbreaks. Three wheat classes, malting and feed barley were included in the analysis for nine states in the United States.

Losses were calculated as the decline in producer revenue due to FHB in affected crop districts. This entails estimating production losses (bushels) as well as the impact of FHB on net prices ($/bushel) received by producers. The price impact of FHB can be either positive or negative, as a production shortfall puts upward pressure on market prices while, at the same time, a larger share of production may be discounted for poor quality. The average price received by producers in a given region can, therefore, be lower than normal despite favorable quoted prices for benchmark grades.

Production losses were estimated for each Crop Reporting District (CRD) by comparing actual yields to regression forecasts. Adjustments (based on input from extension specialists) were made to account for the contribution of other factors to yield shortfalls. The analysis also considers the impact of FHB on the ratio of harvested to planted acres. Price impacts were estimated for both futures and basis. Regression models were used to quantify the (positive) impact of FHB-related supply reductions on futures prices. Impacts on basis (either positive or negative) were measured by comparing actual basis values in a scab year to historical averages.

The direct combined effects of price discounts and yield reductions from FHB in hard red spring (HRS) wheat, SRW wheat, durum wheat, and barley were estimated at $2.492 billion from 1993 through 2001. Direct economic losses over the period were greatest for HRS wheat ($1.261 billion), followed by SRW wheat ($589 million) and barley ($484.7 million). Losses for durum wheat were estimated at $156 million. Combined losses with the four crops were greatest in 1998 ($467 million) and lowest in 2000 ($159 million). Losses in 1998 accounted for about 19 percent of the nine-year total.

Despite a significant decrease in direct economic losses from FHB in 2000, cumulative economic effects over the period 1993 to 2001 were substantial. The cumulative direct losses of $2.492 billion represent a substantial loss in crop revenue for small grain producers in the affected areas. To put the losses in perspective, the average annual value of all winter wheat production in the United States from 1993 through 2001 was about $5.1 billion. The average annual losses from FHB over the same period for all crops in this study was estimated at $277 million. Thus, annual losses from FHB represented, on average, 5.4 percent of the total value of all U.S. winter wheat production. When compared to the annual value of all wheat (spring, winter, durum, and other) production in the United States over the same period, annual losses from FHB represented 3.7 percent of the U.S. total.

The combined direct and secondary economic losses for all crops were estimated at $7.7 billion. North Dakota had $3.5 billion or about 45 percent of those losses during the period 1993 to 2001. Losses in other states were not as large, but substantial losses still occurred in

Minnesota ($1.8 billion), South Dakota ($620 million), Ohio ($606 million), Illinois ($514 million), Missouri ($297 million), Michigan ($195 million), Indiana ($133 million) and Kentucky ($69 million).

Scab remains a major economic problem, whether measured in relative terms to other crop sales or measured by overall direct and secondary economic impact. The scab problem is not limited to a narrow geographic region, adversely impacting producers in both the northern Great Plains and central states. Scab continues to affect several classes of wheat and barley, constituting a serious economic problem in several regions of the United States.

Impacts from scab affect not only producers, but other areas of the economy as well. A substantial portion of the impacts affect the businesses that are dependent upon revenues from crop sales (for every $1 dollar of scab losses incurred by the producer, $2.08 in losses are incurred in other areas of rural and state economies). Depressed farm economies are further affected by scab. Scab occurs in many regions of the northern Great Plains that are not only reliant on agriculture, but are predominately dependent upon small grain production. Thus, scab is having an extenuating effect in those areas. Furthermore, income losses from scab are occurring during periods of depressed farm prices and low net farm income. (Net farm income has decreased significantly since 1996.)

The level of impacts (magnitude), the relative impact (comparisons to wheat/other small grain sales), and the geographic size of the problem all suggest that continued research into developing scab resistant varieties of wheat and barley is warranted. Clearly, expenditures on scab research would be easily offset by future benefits of a reduction in scab losses.

Economic Impacts of Fusarium Head Blight in Wheat and Barley: 1993-2001

William E. Nganje, Simeon Kaitibie, William W. Wilson, F. Larry Leistritz, and Dean A. Bangsund*

1. Introduction

Fusarium Head Blight (FHB), commonly known as scab, has been a severe problem for U.S. wheat and barley producers since 1993 (Johnson et al. 1998). Yield losses due to FHB have been widely reported.[1] Johnson et al. (1998) and the U.S. General Accounting Office (U.S. GAO 1999) quantified the economic losses suffered by producers in scab affected regions, from1993-1997 for wheat and barley, respectively. The objective of this study is to update the work of Nganje et al (2001), Johnson et al. and the U.S. GAO (1999) for 1993-2001 and, in addition, assess the secondary impact of losses incurred in other sectors of the economy.

The study focused on nine states where substantial FHB outbreaks have occurred during the 1990s, involving three wheat classes and barley. The affected states for hard red spring (HRS) wheat, durum wheat, and barley include Minnesota, North Dakota, and South Dakota. For soft red winter (SRW) wheat, the affected states include Illinois, Indiana, Kentucky, Michigan,[2] Missouri, and Ohio. In these states, major yield losses began in 1993 and continued through 2001.

Direct and secondary losses due to FHB by Crop Reporting District (CRD) for each wheat class and barley were estimated. Estimation of the direct impact (first-round effects) entails two quantities: first, the production (bushels) that might have been expected under normal conditions, and second, the price ($/bushel) that might have been expected under normal conditions. The 'price effects' of FHB are an important component of the analysis, as these can either magnify or reduce the value of economic losses in individual regions. Secondary impacts (sometimes further categorized into indirect and induced effects, also known as multiplier effects) result from subsequent rounds of spending and re-spending within an economy. An input-output model developed by Coon and Leistritz (2000) was used to estimate the secondary (multiplier) and total economic effects of FHB in the affected states.

The paper is organized into five sections including the introduction. Section 2 provides a brief explanation of the conceptual approach and delineates the 'price' and 'quantity' effects of FHB. Methodology and data sources are described in Section 3. Estimates of direct and secondary economic loss by state, year, wheat class, and barley are presented in Section 4. The paper concludes with a short summary and discussion of implications.

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*Nganje is an assistant professor, Kaitibie is research assistant professor, Wilson and Leistritz are professors, and Bangsund is research scientist in the Department of Agribusiness and Applied Economics, North Dakota State University, Fargo.

[1]See McMullen, Jones, and Gallenberg (1997) for an overview of FHB in small grains.

[2]Michigan also produces white wheat; however, this is not differentiated from SRW wheat in state-level price data.

2. Illustration of Price and Quantity Effects

The following illustration of price and quantity effects is based on Johnson et al. (1998). To estimate the change in producer revenue due to FHB, it is not sufficient to know the size of a production shortfall; the impact on prices received must also be estimated. In principle, scab can either raise or lower the net price received by producers. This depends on two opposing factors. A production shortfall puts upward pressure on futures prices and can lead to higher premiums for protein and other quality factors. In addition, in scab-affected areas, a larger share of production is discounted for poor quality. As a result, the price received by producers can be lower than normal despite favorable quoted prices for benchmark grades.

Figures 1 and 2 provide an illustration of the potential impacts of FHB on producer revenue. In Figure 1, it is assumed that the price received by producers is higher than normal as a result of FHB-related production shortfalls. Thus, ps > pn, where ps and pn are prices in ‘scab’ and ‘normal’ years. The production shortfall is measured by (qn − qs), where qn is normal production, based on planted acreage and trend yields, and qs is the actual production in a scab year. The change in producer revenue due to scab is given by

$$\Delta R = (ps \times qs) - (pn \times qn) \qquad (1)$$

Producer revenue in a scab year is given by areas A + C, while producer revenue in a normal year is given by areas C + D. The change in revenue is A − D. Thus, producers would gain revenue if the positive price impact more than offsets the value of lost production (i.e., if A > D).

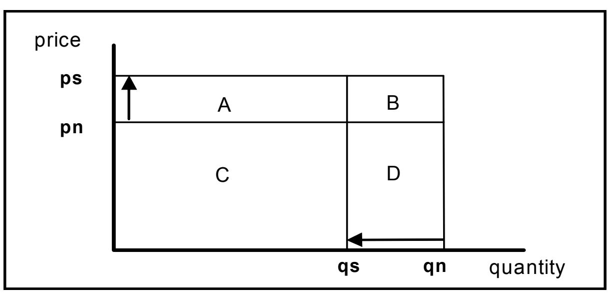

Figure 1. Change in Crop Value When Net Price Impact Is Positive

In Figure 2, it is assumed that the net price received by producers is lower than normal because of scab-related quality problems. Producer revenue in a scab year is given by area G, while producer revenue in a normal year is given by the area (E + F + G + H). The change in revenue is − (E + F + H), a negative amount. Producers lose two ways, from production shortfalls and lower prices.

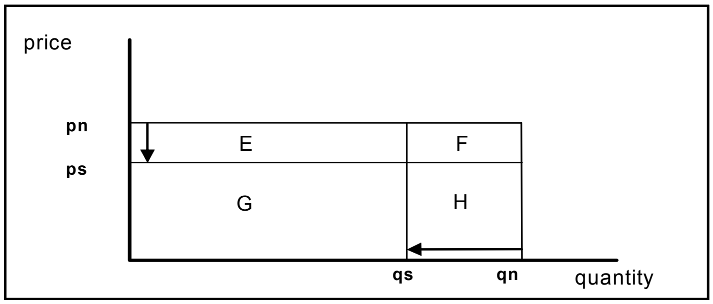

Figure 2. Change in Crop Value When Net Price Impact Is Negative

The revenue impact can be divided into separate price and quantity effects. Estimates of these effects vary, depending on whether actual prices (ps) or normal prices (pn) are used to value production shortfalls; the choice is somewhat arbitrary. In this study, we value production shortfalls as the average of the two prices. That is the area F in Figure 2 divided equally between price and quantity effects. Thus, the price effect equals − (E + ½F) while the quantity effect equals − (½F + H). Similarly, when the net price effect is positive as in Figure 1, it is measured as (A + ½B), while the quantity effect is − (½B + D).

3. Methodology and Data

Crop Reporting Districts (CRDs) where substantial FHB outbreaks occurred during the 1990s were identified with the help of researchers and extension specialists. The study area for SRW wheat, spring wheat, durum wheat, and barley are shown in Figures 3 and 4.

To estimate the economic losses due to FHB in a given CRD, the value of production under 'normal' conditions was estimated (i.e., if there had been no outbreak). Normal crop value is the product of two variables: pn, the price that farmers would have received, and qn, their expected production in absence of scab. For years of scab outbreak, both variables are unobserved and must be estimated. The lost crop value is then calculated as the difference between actual and normal crop value.

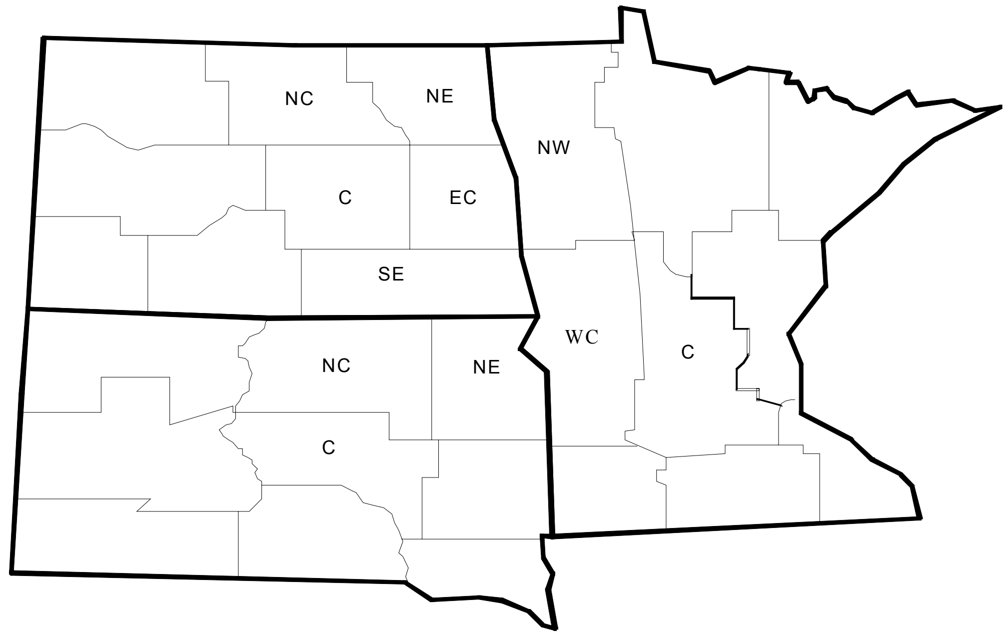

Figure 3. Crop Reporting Districts included in HRS Wheat, Durum Wheat, and Barley Study Area

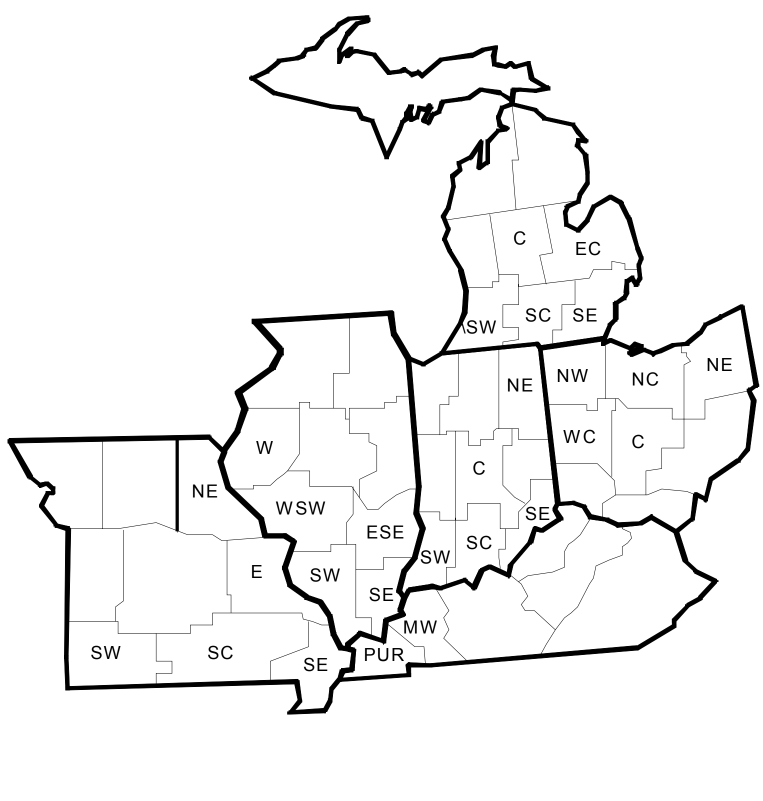

Figure 4. Crop Reporting Districts Included in Soft Red Winter Wheat Study Area

Estimating 'Normal' Production

Estimated normal production is comprised of yield and harvested acres. To derive yield in the absence of FHB, the following regression model was used:

$$yf_{ijt} = \beta_0 + \beta_1 R_{ijt} + \beta_2 T_{ijt} + \beta_3 t + e \qquad (2)$$

where yf_{ijt} is expected harvested yield (or forecasted yield) for grain j in region i, R_{ijt} is rainfall inches received during the growing season,[3] T_{ijt} is average temperature during the growing season, t is the year, and e is the error term. The last parameter (β_3) is a measure of trend yield growth caused by changes in technology, input use, and farm size. Separate equations were estimated for each CRD, using data for years preceding severe FHB outbreak.[4] Results of estimated coefficients–βs and model fitness are shown in Appendix Tables A1 to A4. Regression models were then used to derive estimates of the yields that would have occurred in later years (given growing conditions) in the absence of FHB.

A complicating factor was that, in some producing regions, FHB occurred simultaneously with other wheat diseases or in conjunction with other factors reducing yields (e.g., floods). It would be misleading to attribute all of the estimated yield shortfall in these regions to FHB. For that reason, researchers and extension specialists provided input about the relative contribution of scab to yield shortfalls.[5] Their judgments were incorporated as follows. Let yn_{ijt} denote the normal yield in absence of FHB in production region i and year t. Let yf_{ijt} denote the forecast value from the regression equation and ys_{ijt} the actual yield in a scab-affected year. The fraction of a yield shortfall attributable to scab is denoted α_{ijt} $(0 \leq \alpha_{ijt} \leq 1)$. Normal yields (i.e., the estimated yields that would have occurred in the absence of FHB) are given by

$$yn_{ijt} = \alpha_{ijt} yf_{ijt} + (1 - \alpha_{ijt}) ys_{ijt} \qquad (3)$$

Normal yield is a weighted average of the regression forecast and actual yield. If $\alpha_{ijt} = 1$ for a given region and crop year, then normal yield equals the forecast value, and any estimated yield

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[3]For HRS and durum wheat growing areas, rainfall and temperature data are for April through July. For SRW wheat growing areas, these data are for March through June.

[4]Data from 1970-92 were used to estimate yield models for HRS, durum wheat, and barley. Data for 1970-90 were used for SRW yield models. A restricted and an unrestricted model were estimated for Equation 2. The unrestricted model incorporated a square precipitation term because there is an optimal level of precipitation, beyond which yields may decrease. However, only the barley model was unrestricted, Equation 2 was the robust model for HRS, durum, and SRW (Appendix Table A4).

[5]Input from extension experts for all CRDs were requested to obtain data on the difference between normal and actual production that was due to scab. For barley, this data is collected annually for North Dakota, Minnesota, and South Dakota by Dr. Paul Schwarz of the NDSU Cereal Science Department.

shortfall ($yf_{ijt} - ys_{ijt}$) is attributed entirely to FHB. If $\alpha_{ijt} < 1$, then normal yield lies between the regression forecast and actual yield, and part of the estimated yield shortfall is attributed to other factors. For example, suppose the yield forecast (yf_{ijt}) is 40 bu/acre, actual production (ys_{ijt}) is 28 bu/acre, but only 80 percent of the shortfall is attributed to FHB. The (adjusted) normal yield is then calculated as $yn_{ijt} = 0.8 \times (40) + (1 - 0.8) \times (28) = 37.6$ bu/acre.

Figures 5, 6, 7, and 8 show actual yield, forecasted yield, and the (adjusted) normal yield for four CRDs included in the study. Figure 5 shows SRW wheat yields in western Illinois (SRW IL - W), Figure 6 shows HRS wheat yields in north-east North Dakota (HRS ND-NE), Figure 7 shows durum wheat yields in north-east North Dakota (Durum ND-NE), and Figure 8 shows barley yields in north-east North Dakota (Barley ND-NE). For SRW and Durum, 1998 and 1999 predicted and adjusted yields in the respective CRDs coincided, hence the estimated yield shortfalls are attributable to FHB (i.e., $\alpha_{ijt} = 1$). For HRS yields in northeastern North Dakota (ND - NE), only a small fraction of the yield shortfall was attributable to FHB in 1999, hence the low adjustment factor of $\alpha_{ijt} = 0.037$. Adjustment factors for all producing regions are provided in Appendix Table A5.

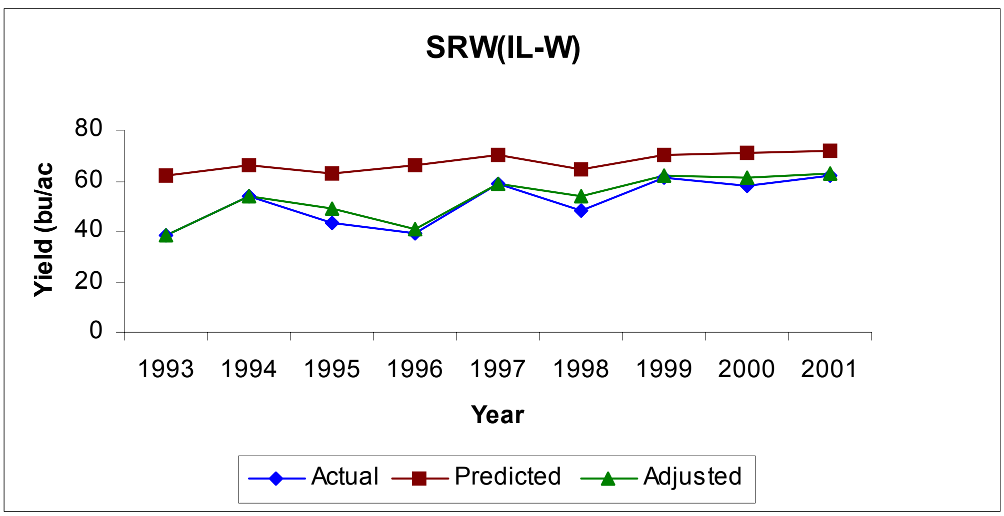

Figure 5. Predicted, Actual, and Adjusted Yields of Soft Red Winter Wheat for the Illinois West Crop Reporting District

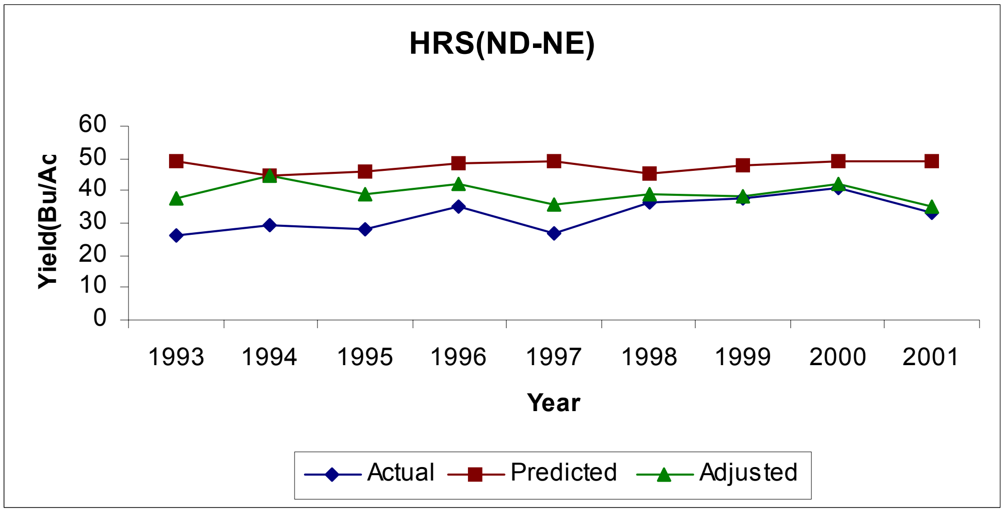

Figure 6. Predicted, Actual, and Adjusted Yields of Hard Red Spring Wheat for the North Dakota North East Crop Reporting District

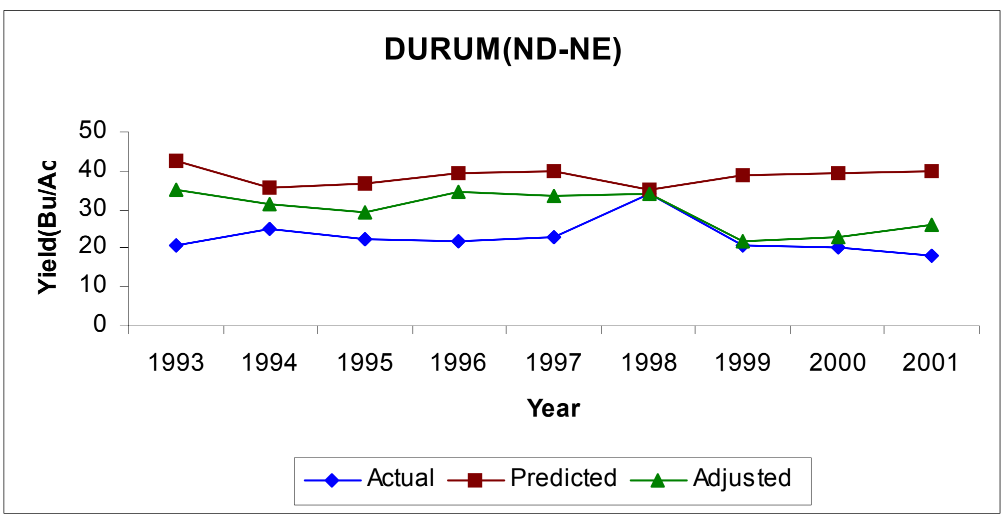

Figure 7. Predicted, Actual, and Adjusted Yields of Durum Wheat for the North Dakota North East Crop Reporting District

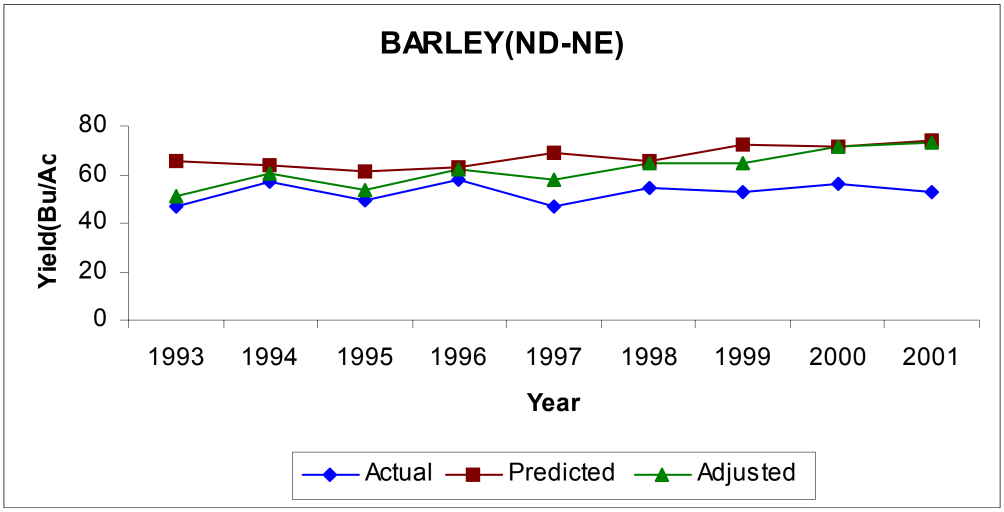

Figure 8. Predicted, Actual, and Adjusted Yields of Barley for the North Dakota North East Crop Reporting District

FHB outbreaks can induce a higher-than-average rate of acreage abandonment. To account for this, a 'normal' ratio of harvested to planted acres was incorporated in the estimate of normal production. R_{ij} represents the olympic average[6] of the ratio (ah_{ijt} / ap_{ijt}), where ah_{ijt} denotes harvested acres and ap_{ijt} planted acres, using data from seven years preceding the FHB outbreak. The 'normal' ratio (for region i, grain j, year t) is calculated as:

$$Rn_{ijt} = \alpha_{ijt} R_{ij} + (1 - \alpha_{ijt}) \frac{ah_{ijt}}{ap_{ijt}} \tag{4}$$

Equation 4 uses the same adjustment factor as was used to calculate normal yield. If $\alpha_{ijt} = 1$ for a given region, grain and year, then the 'normal' ratio of harvested to planted acres is equal to the olympic average. Otherwise, if $\alpha_{ijt} < 1$, the supposition is that factors other than FHB contributed to an abnormal ratio, and Rn_{ijt} is adjusted accordingly. Normal production, denoted qn_{ijt}, is given by the following formula:

$$qn_{ijt} = [\max(yn_{ijt}\ ,\ ys_{ijt})] \cdot [\max(Rn_{ijt}\ ,\ \frac{ah_{ijt}}{ap_{ijt}})] \cdot ap_{ijt} \tag{5}$$

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[6]An olympic average omits the maximum and minimum values contained in a given sample. Olympic averages are advantageous when the sample is small and select observations (e.g., 1988, a drought year) are viewed as exceptional or unrepresentative.

The first bracketed term represents harvested yield. The second bracketed term is the ratio of harvested-to-planted acres. The product of the second term and acres planted (ap_{ijt}) equals normal harvested acres. The max function is used to correct for two types of data anomalies. If the estimated normal yield falls below actual yield in a scab year (i.e., $yn_{ijt} < ys_{ijt}$), the latter value is selected. Similarly, if the normal ratio falls below the actual ratio of harvested-to-planted acres (i.e., $Rn_{ijt} < [ah_{ijt} / ap_{ijt}]$), the latter value is used. Thus, in the unlikely event that production is higher than normal during a scab year, the analysis will not (falsely) attribute a positive impact to the disease.

Estimating Price Impacts for HRS, SRW, and Durum Wheat

In estimating the impact of FHB on the net price received by producers, two factors were considered. First, the impact of a production shortfall on market prices was estimated. Second, the effects of crop quality on prices were considered. To capture these effects, the average price received was divided into futures and basis.[7] While FHB outbreak is expected to have a positive impact on futures (by reducing wheat supply), the impact on local basis (averaged over all wheat sold) can be either positive or negative, depending on crop quality and the premiums and discounts assessed by elevators in a given region.

SRW wheat is priced with respect to wheat futures on the Chicago Board of Trade (CBT). To derive the price impact of FHB on CBT wheat futures, a regression equation was used. The regression analysis explains the CBT futures price as a function of total wheat supply and the loan rate (a farm program parameter), using annual data from 1980 through 1999. The estimated equation follows, with t-values in parentheses:

LCBT =	13.250	− 1.004 LTWS	+ 0.211 LLR	$R^2 = .67$
	(8.996)*	(−4.004)*	(2.116)*	Obs. 20
				* significant at 1% level

Variables are defined as:

LCBT	logarithm of average CBT wheat futures price (c/bu), nearby contracts
LTWS	logarithm of total U.S. wheat supply (million bu), all classes
LLR	logarithm of loan rate for wheat (c/bu) in given marketing year.

The coefficient of interest is that which describes the relationship between future prices and total wheat supply (otherwise known as the 'flexibility' coefficient). In this case, a 1 percent change in total wheat supply would change the CBT price by 1.004 percent (in the opposite direction).

A similar equation was estimated for wheat futures on the Minneapolis Grain Exchange (MGE), which provides the futures price for HRS wheat. In this case, HRS supply (in place of total wheat supply) was used as an explanatory variable. For MGE futures, the estimated equation follows, with t-ratios in parentheses:

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[7]Basis is defined as the difference between a local cash price and the futures price, for the same commodity. As used here, basis refers to the difference between weighted average cash price received (net of premiums and discounts) and average futures price, during a marketing year.

$$LMGE = \underset{(7.121)^*}{9.115} - \underset{(-4.055)^*}{0.836}\ LHRS + \underset{(2.334)^{**}}{0.112}\ LLR \qquad R^2 = .59 \quad \text{Obs. } 20$$

* significant at 1% level
** significant at 5%

Variables are defined as:

LMGE	logarithm of average MGE wheat futures price (c/bu), nearby contracts
LHRS	logarithm of HRS wheat supply (million bu), defined as the sum of production, stocks and imports
LLR	logarithm of loan rate for wheat (c/bu) in given marketing year.

The 'flexibility' coefficient is −0.836, indicating that a 1 percent change in the supply of HRS wheat is expected to change the MGE futures price by 0.836 percent in the opposite direction.

Adjustment for Imports

If U.S. wheat supplies were determined solely by domestic production and beginning stocks, the change in supplies due to scab would be equal to the sum of estimated production shortfalls in affected CRDs. However, imports of wheat from Canada represent another component of U.S. supply. Canada is a large surplus producer of spring wheat (HRS[8] and durum), and the surge in U.S. imports since 1993 is partly explained by disease problems in the U.S. spring wheat region (Johnson et al. 1998). Higher imports offset part of U.S. production shortfalls, thereby changing U.S. supply and reducing the positive impact of U.S. production shortfalls on futures prices.

To account for imports induced by scab, it was assumed that 20 million bushels of HRS wheat would be imported annually from Canada under ordinary conditions, which is the average level of HRS imports during the three marketing years preceding 1993. Imports of durum were larger than estimated production shortfalls from 1993 to 2001. However, imports of HRS wheat were lower than estimated production shortfalls in 1993-1995 and in 1997, but exceeded estimated production shortfalls in 1996, and from 1998 to 2001 (Table 1). Of the imports exceeding 20 million bushels, the part that is attributed to scab is reflected in the following formula for expected HRS supply in absence of a scab outbreak:

$$Qn_t^{HRS} = Qs_t^{HRS} + \delta_t^{HRS} - \min[\theta_t^{HRS}(M_t^{HRS} - 20)\ ,\ \theta_t^{HRS}\delta_t^{HRS}] \qquad (6)$$

[8]HRS is a U.S. classification; the comparable Canadian wheat classification is Canadian Western Red Spring (CWRS).

where variables are defined

Qn_t^{HRS}	hypothetical supply (million bushels) of HRS wheat in absence of scab outbreak
Qs_t^{HRS}	actual supply of HRS during year of scab outbreak
δ_t^{HRS}	estimated U.S. production shortfall of HRS wheat due to scab
θ_t^{HRS}	proportion of production losses due to scab, a weighted average of adjustment factors α_{it} in HRS regions[9]
M_t^{HRS}	actual imports of HRS wheat.

The quantity selected by the min function (Equation 6) represents imports attributable to scab, partially offsetting the impact of a production loss on U.S. HRS supply. The hypothetical supply of all wheat in absence of scab, Qn_t^{ALL}, is calculated as:

$$Qn_t^{ALL} = Qs_t^{ALL} + (Qn_t^{HRS} - Qs_t^{HRS}) + \delta_t^{SRW} \tag{7}$$

where Qs_t^{ALL} is the actual U.S. supply of all wheat classes and δ_t^{SRW} is the estimated SRW production shortfall due to scab. Note that Qn_t^{ALL} reflects the production shortfall for SRW and supply reduction for HRS; it does not reflect reduced durum production. Based on recent history, any lost U.S. durum production was assumed to be entirely offset by imports from Canada.

Table 1. Imports From Canada and Estimated U.S. Production Losses from Fusarium Head Blight, HRS and Durum

	Imports from Canada (million bu)		Estimated U.S. Production Losses (million bu)		Ratio of Imports to Losses	
Marketing Year	HRS Wheat	Durum Wheat	HRS Wheat	Durum Wheat	HRS Wheat	Durum Wheat
1993	62.0	30.0	119.6	10.2	0.5	2.9
1994	49.0	22.0	90.4	4.0	0.5	5.5
1995	30.0	18.0	47.0	6.4	0.6	2.8
1996	53.0	24.0	23.5	8.4	2.3	2.9
1997	54.0	26.0	63.5	4.4	0.9	5.9
1998	58.2	25.9	8.4	0.7	6.9	37.0
1999	54.5	23.7	5.8	4.0	9.4	5.9
2000	52.0	25.1	9.4	4.6	5.5	5.5
2001	50.0	21.1	27.5	2.9	1.8	7.3

[9] For 1998-2000, values of θ_t^{HRS} are 0.5317, 0.112, and 0.2092.

Impacts on Wheat Futures and Basis

Given the flexibility coefficients and supply estimates, the futures prices that would have been observed in the absence of a scab outbreak are estimated as follows:[10]

$$Fn_t^j = \frac{Fs_t^j}{\gamma_j \left(\frac{Qs_t^j - Qn_t^j}{Qn_t^j} \right) + 1} \tag{8}$$

where j indicates the futures exchange (MGE or CBT) or appropriate supply definition, and variables are defined:

- γ_j price flexibility coefficient (for indicated futures supply category)
- Qs_t^j actual wheat supply (HRS wheat for MGE futures, all wheat classes for CBT)
- Qn_t^j estimated supply in absence of scab outbreak
- Fs_t^j futures price (annual average, nearby contracts) in a scab year
- Fn_t^j estimated futures price in absence of scab outbreak.

For SRW wheat growing regions, basis is defined as the difference between the average price received by producers and the average CBT futures. For HRS growing regions, basis is the difference between average price received and average MGE futures. Normal basis relationships for these wheat classes are represented by seven-year olympic averages, using data from years preceding the first scab outbreak.

Durum wheat was not traded on any futures exchange during the period under study. However, a long-term relationship exists between durum and spring wheat cash prices–durum tends to trade at about 50 cents/bushel above the spring wheat price.[11] The long-term price relationship between durum and HRS was built into the estimate of the 'normal' cash price for durum.

Expected cash prices in absence of scab are calculated as follows:

$$\begin{aligned} \text{SRW:} \quad & pn_{it}^{SRW} = Fn_t^C + bn_i^C \\ \text{HRS:} \quad & pn_{it}^{HRS} = Fn_t^M + bn_i^M \\ \text{Durum:} \quad & pn_{it}^{D} = Fn_t^M + bn_i^M + 0.50 \end{aligned} \tag{9}$$

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[10]The price flexibility coefficient is defined: $\gamma = (\Delta P/P)/(\Delta Q/Q)$. The formula is derived by substituting (Fs − Fn)/Fn for the numerator, (Qs − Qn)/Qn for the denominator, and re-arranging to solve for Fn.

[11]Approximately a 50 cents/bushel price premium is necessary to induce farmers to plant durum instead of HRS wheat, given differences in yield and risk factors.

where variables are defined:

- pn_{it} normal (expected) cash price in absence of scab for indicated wheat class
- Fn_t^C Chicago wheat futures price (annual average)
- Fn_t^M Minneapolis spring wheat futures price (annual average)
- bn_i^C normal (olympic average) SRW basis relative to CBT futures
- bn_i^M normal (olympic average) HRS basis relative to MGE futures.

The analysis allows estimated basis effects to be either positive or negative in individual regions. Positive basis effects could arise because of large price premiums, induced by supply shortages, for wheat that meets milling specifications. Conversely, negative basis effects could result if quality-related price discounts apply to a larger-than-average portion of local production.

Estimating Price Impacts for Malting and Feed Barley

In estimating the impact of FHB on the net price received by barley producers, two factors were considered–the impact on malting premium price, and the impact on feed grain prices.[12] The procedure to estimate both malting barley premiums and feed grain prices for 1993 through 2001, had there been no FHB, uses two steps (U.S. GAO 1999)–step one involves estimating price equations for both malting barley premiums and feed prices in the absence of scab, while step two involves predicting the malting and feed barley prices that should have been obtained in the absence of the FHB epidemic.[13]

In step one, regression analysis and historical data on price and production from 1959 through 1992 was used. Since the proportion of malting barley in the entire crop was fairly stable in the years prior to the FHB epidemic, increases in total barley production translate into increases in quantities of malting barley. Moreover, while there are differences in premiums from region to region, prices are generally transmitted from the malting and brewing industries at a more aggregate market level. Therefore, in Equation 10, the historical association between malting premiums, Pj^m, and total U. S. barley production, Q_j, for each CRD analyzed were estimated.

$$P_j^m = \alpha_0 + \alpha_1 Q_j \tag{10}$$

A negative and statistically significant relationship exists between malting barley premiums and total barley production at the national level for all CRDs (Appendix Table A1). Other variations of this regression model, including those using combinations of stocks as well as barley yields for independent variables, did not perform as well as the total barley production

[12] The U.S. GAO procedure was used to estimate the impact of FHB on malting premium price and feed barley price because it incorporates the proportion of malting and feed barley production in the absence of FHB. These proportions were necessary to estimate the shift of malting barley to feed barley due to FHB.

[13] Appendix Tables A6 and A7 provide regression equations for the CRDs in North Dakota.

variable. Because of the presence of positive serial correlation in all CRDs, the Yule-Walker[14] regression technique is used to derive the parameter estimates. In general, serial correlation causes standard errors to be biased downward, thus indicating that parameter estimates are more precise than indicated. Therefore, correcting this problem leads to more efficient parameter estimates.

In the feed grain market, corn is the primary feed grain product accounting for more than 80 percent of total feed grain consumption (U.S. GAO 1999). Because barley feed grain prices, P_i^f, are driven primarily by corn prices, in Equation 11, the historical association between feed grain barley prices, the price of corn, P_C, and total U.S. barley production, Q_j, was specified as:

$$P_j^f = \alpha_0 + \alpha_1 P_c + \alpha_2 Q_j \tag{11}$$

To correct for first-order serial correlation, as in the malting premium regression models, the Yule-Walker regression technique was used for the feed grain models. The total barley production variable for North Dakota was negative and significant at the 0.10 percent level in all CRDs except 6 (Appendix Table A6). In all CRDs, the price of corn was positively related to barley feed grain prices and statistically significant (Appendix Table A7).

The second step involved substituting actual values of barley production and corn prices for years 1993 through 2001, in Equations 10 and 11, to predict what malting barley and feed grain barley prices would have been in the absence of FHB. Malting barley prices were the sum of estimated feed grain prices and estimated malting premiums. The malting barley and feed grain barley price effects as a result of FHB were obtained by subtracting the actual prices from the estimated prices in the absence of scab.

Estimating Direct and Secondary Revenue Losses Due to FHB

Economic activity from a project, program, policy, or event can be categorized into direct and secondary impacts. Direct impacts are those changes in output, employment, or income that represent the initial or first-round effects of the activity. Secondary impacts (sometimes further categorized into indirect and induced effects, also known as multiplier effects) result from subsequent rounds of spending and re-spending within an economy.

In estimating the direct economic losses, production shortfalls were multiplied by the average of the actual and estimated price (price that would have been observed in the absence of scab) to obtain the production losses due to FHB for each CRD and for each year (1993-2001). To obtain the revenue shortfall from price effect, the price difference (estimated price if there were no FHB, less actual price) was multiplied by the average of the actual production and the estimated production if there were no FHB.

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[14]The Yule-Walker regression technique starts by forming the ordinary least-square estimate of parameters. Next, given the vector of auto-regressive parameters (using the Yule-Walker equations) and the variance matrix of the error vector, efficient estimates of the regression parameters are computed using generalized least squares.

The secondary economic effects were estimated using input-output (I-O) analysis. I-O analysis is a mathematical tool that traces linkages among sectors[15] of an economy and calculates the total business activity resulting from a direct impact in a basic sector (Coon et al. 1985). The North Dakota I-O Model was used to estimate the secondary (multiplier) and total economic effects in the affected states. Empirical testing has shown the North Dakota I-O Model is sufficiently accurate in estimating economic impacts in neighboring states (Coon and Leistritz 1994; Coon et al. 1984; Leistritz et al. 1990). The model was assumed to also be sufficiently accurate to estimate regional economic losses stemming from FHB in the central United States.

The North Dakota I-O Model has 17 economic sectors, is closed with respect to households (households are included within the model), and was developed from primary (survey) data from firms and households in North Dakota (Coon and Leistritz 2000). The model's transactions table (and the resulting technical coefficients and interdependence coefficients) reflect purchases made by firms in each sector from other sectors within North Dakota. Thus, imports of goods and services are not included in the transactions table and resultant coefficients.

The North Dakota I-O Model has two features which merit special comment. First, the model is closed with respect to households; households are included in the model as both a producing and a consuming sector. Second, the total gross business volume (gross receipts) of trade sectors was used (for both expenditures and receipts) in the transactions tables rather than the value added (margins) by those sectors. This procedure results in larger activity levels for those sectors than would be obtained if the margins were used, but this is offset by correspondingly larger levels of expenditures outside the region (state) by those sectors for goods purchased for resale. The advantage of this procedure is that the results of the analysis are expressed in terms of the gross business volumes of the respective sectors, which is generally more meaningful to most users.

Data Sources

Data on temperature and precipitation by region were obtained from the National Climatic Data Center (U.S. Department of Commerce). Data on planted and harvested acres, harvested yield, production, and average prices received by producers were obtained from the National Agricultural Statistics Service (U.S. Department of Agriculture). Average CBT and MGE futures prices were derived from a database of weekly quotes collected from *Grain Market News* (U.S. Department of Agriculture) and the *Wall Street Journal*. Basis was calculated as the difference between average price received in a region and the average futures price. For North Dakota, prices received were available by crop reporting district; in other states, prices are based on state averages. Data on national wheat and barley supplies were from the *Wheat Yearbook* published by the Economic Research Service of the U.S. Department of Agriculture.

[15]An economic sector is a group of similar economic units (e.g., communications and public utilities, retail trade, construction).

4. Results

Production Losses Due to FHB

Production losses due to FHB, by state and wheat class, and for barley were estimated (see Figures 9, 10, 11, 12 and Table 2). Aggregate losses for wheat and barley were largest in 1993, followed by 1994 and 1997. Of the total estimated losses, for all wheat classes (498.0 million bushels), HRS wheat accounted for 397.1 million bushels. During the entire period (1993-2001), HRS wheat growers incurred the greatest loss, 79.8 percent; followed by SRW wheat, 11.1 percent; and durum, 9.1 percent. North Dakota and Minnesota incurred the largest losses for all wheat classes combined, 84.9 percent.

Of the total estimated losses for malting and feed barley (123.8 million bushels), North Dakota incurred 71.2 percent, Minnesota incurred 27.4 percent, and South Dakota incurred losses of 1.4 percent.

Price impacts, future and basis effects, also account for significant losses due to FHB. Price impacts must be incorporated in the economic impact analysis. The proceeding section on price effects presents the results of the economic losses due to futures or market price and price discounts.

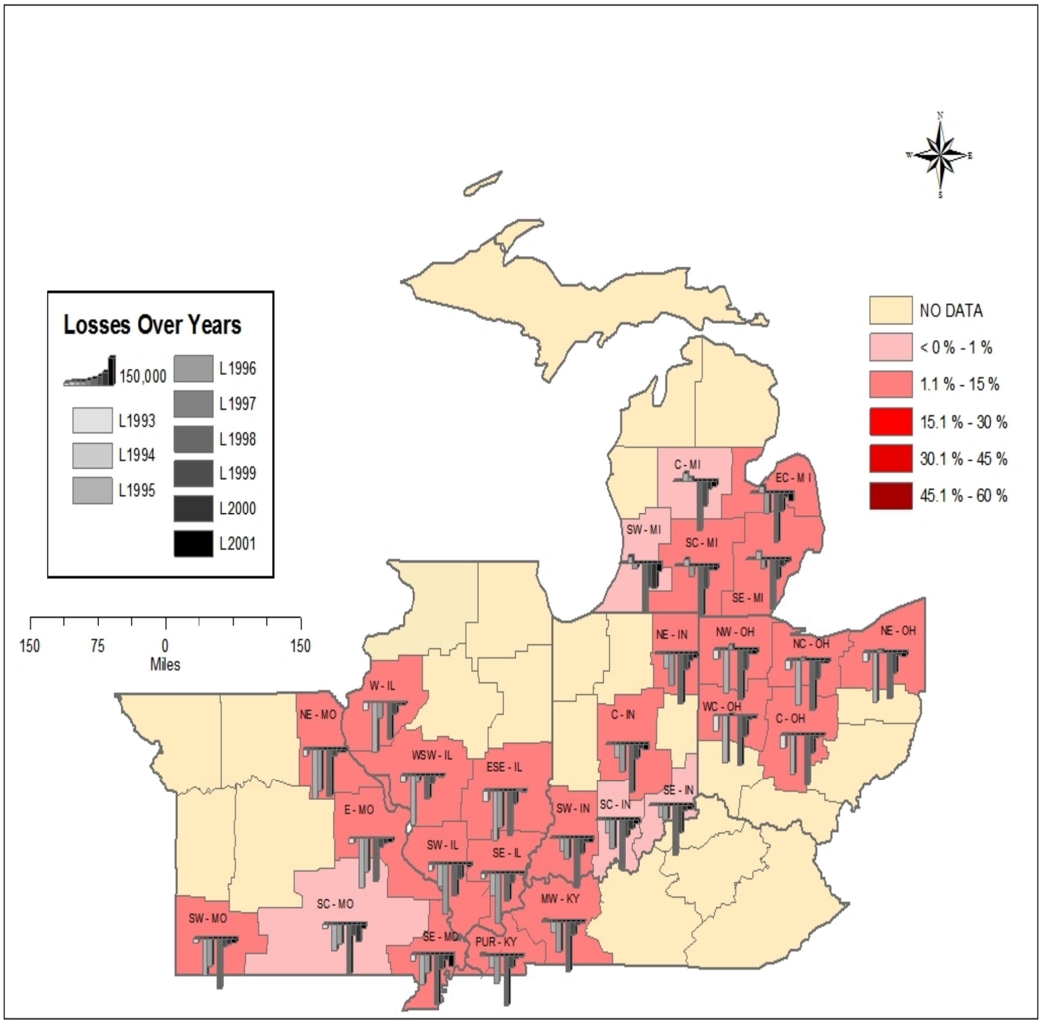

Figure 9. Distribution of Soft Red Winter Wheat Total Production Losses ($) for all Crop Reporting Districts and Years

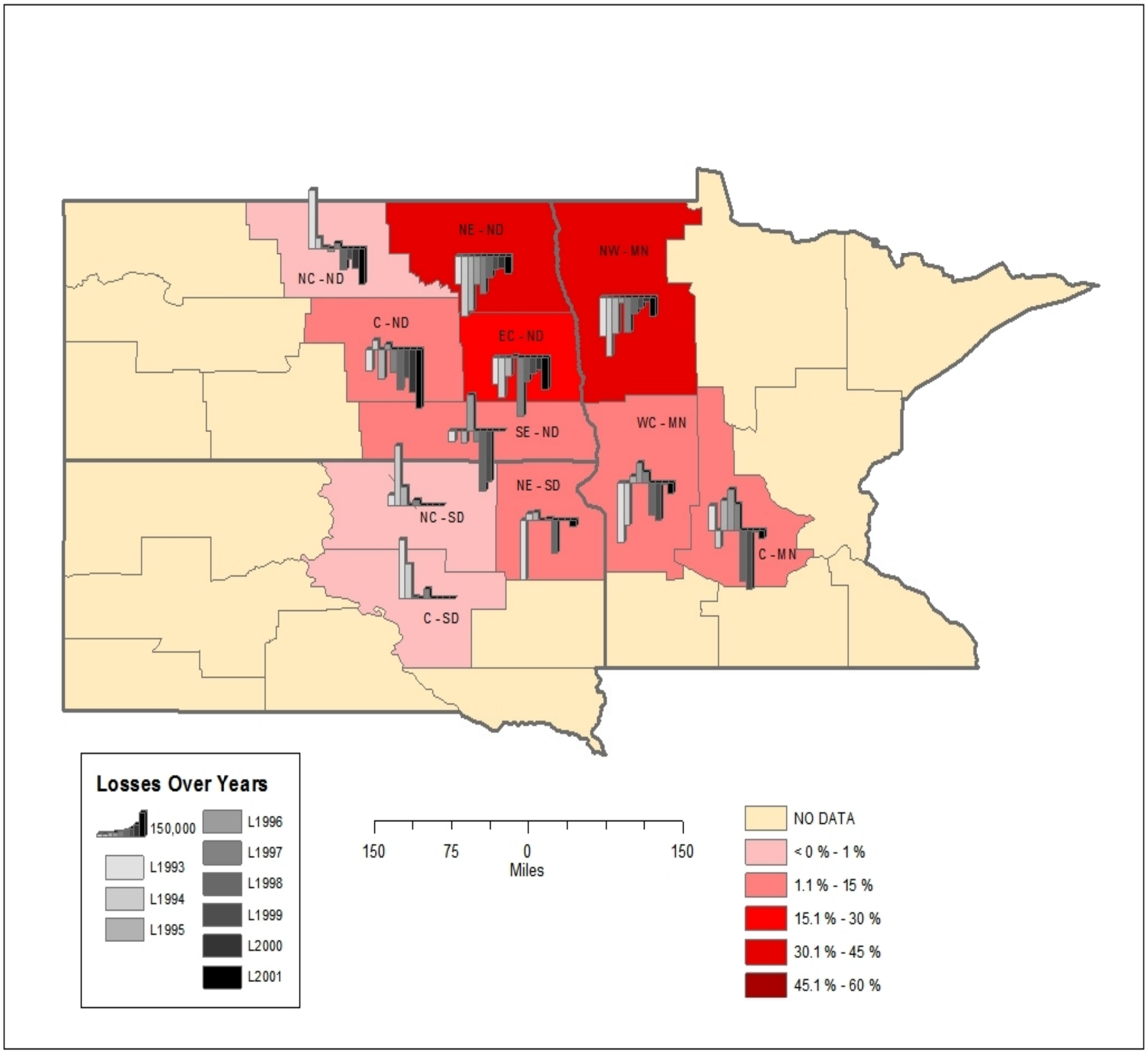

Figure 10. Distribution of Hard Red Spring Wheat Total Production Losses ($) for all Crop Reporting Districts and Years

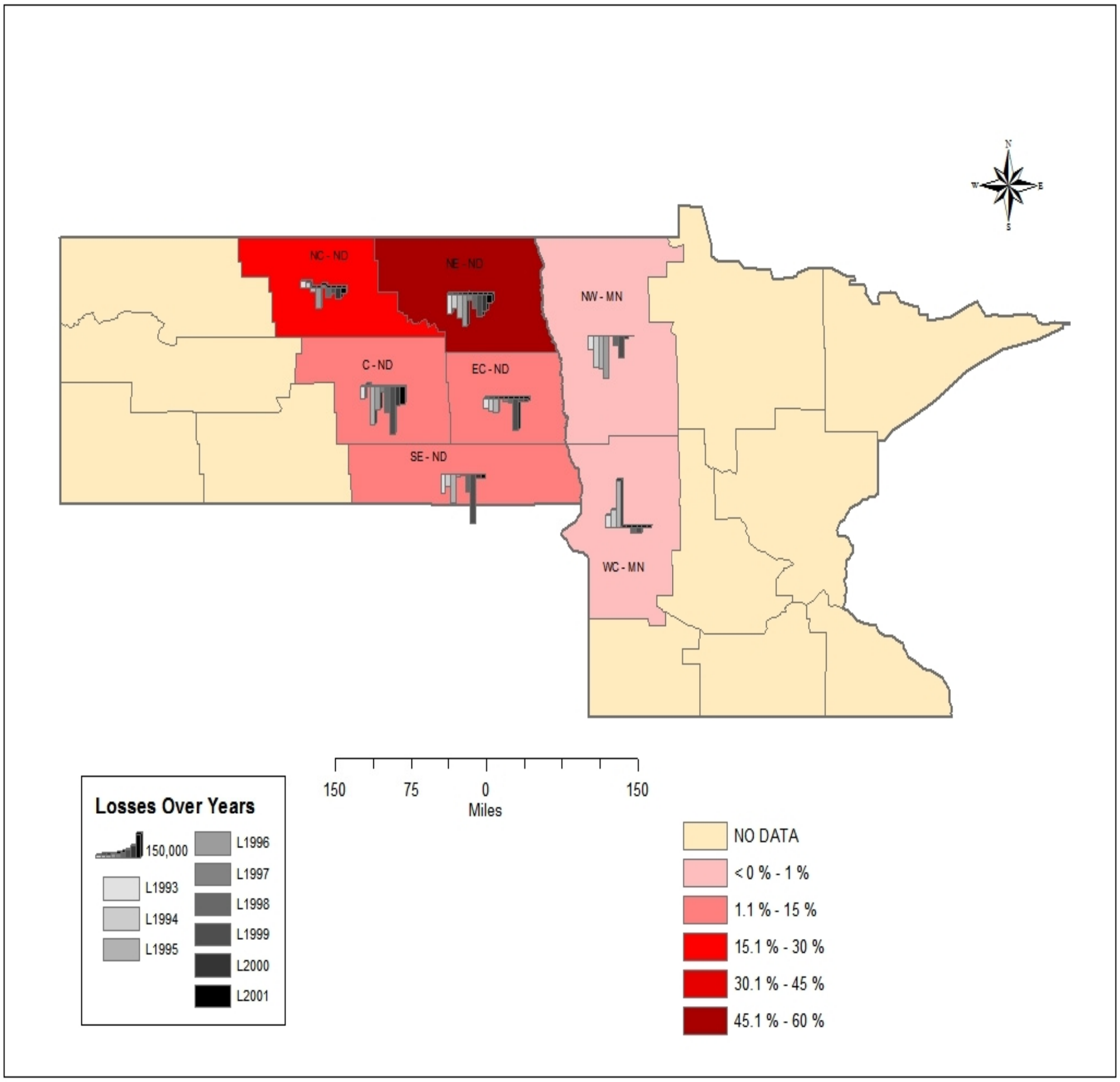

Figure 11. Distribution of Durum Wheat Total Production Losses ($) for all Crop Reporting Districts and Years

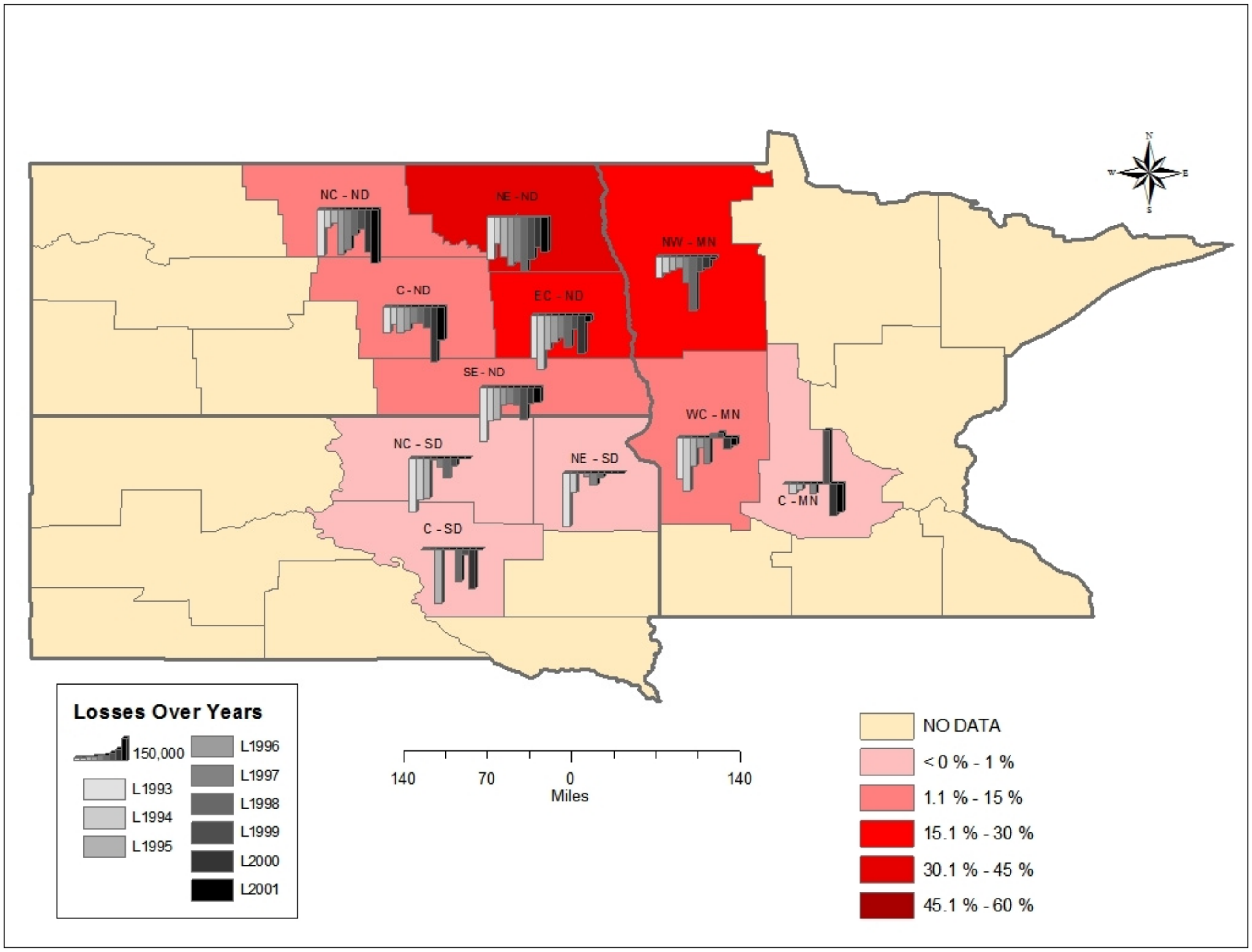

Figure 12. Distribution of Barley Total Production Losses ($) for all Crop Reporting Districts and Years

Table 2. Production Losses Due to Fusarium Head Blight by State, Crop, and Year

State/Crop	Year									
	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
HRS (000 bu)										
ND	58,701.11	40,037.51	25,928.93	16,279.48	34,167.06	4,767.44	2,009.43	5,859.67	12,642.65	200,393.28
MN	47,815.77	47,947.53	20,610.33	7,217.72	28,057.74	3,381.36	3,766.45	3,504.20	14,361.63	176,662.74
SD	13,080.43	2,368.15	505.39	-	1,305.71	242.14	-	-	477.65	17,979.47
Total HRS	119,597.31	90,353.19	47,044.65	23,497.20	65,530.51	8,390.94	5,775.88	9,363.87	27,481.93	
Durum (000 bu)										
ND	10,021.98	3,823.65	6,283.51	8,360.50	4,375.21	706.56	3,942.64	4,556.92	2,885.75	44,956.71
MN	162.70	180.17	143.03	44.76	-	12.14	15.84	1.42	-	560.07
SD	-	-	-	-	-	-	-	-	-	-
Tot Durum	10,184.68	4,003.82	6,426.54	8,405.26	4,375.21	718.70	3,958.48	4,558.34	2,885.75	
SRW (000 bu)										
IL	753.60	-	4,708.93	10,263.03	-	2,111.89	226.99	449.78	630.52	19,144.73
IN	-	-	61.57	1,049.81	-	583.10	189.92	204.49	109.46	2,198.35
KY	20.07	-	20.38	13.43	-	306.52	352.03	725.39	-	1,437.81
MI	-	-	-	3,421.81	-	2,302.22	496.13	656.71	933.30	7,810.17
MO	263.06	-	2,758.99	4,572.69	-	286.64	138.78	599.27	1,059.25	9,678.67
OH	249.86	-	1,299.92	11,499.67	-	1,307.47	109.13	-	673.24	15,139.29
Total SRW	1,286.59	-	8,849.79	30,820.44	-	6,897.84	1,512.98	2,635.64	3,405.77	
All Classes of Wheat (000 bu)										
Total	131,068.58	94,357.01	62,320.98	62,722.90	69,905.72	16,007.48	11,247.34	16,557.85	33,773.45	
Barley (000 bu)										
ND	20,578.51	4,521.67	5,691.49	3,472.36	14,934.29	7,768.18	8,200.92	13,654.22	9,399.00	88,220.63
MN	8,250.82	989.35	82.48	321.64	4,710.11	13,222.84	4,559.74	1,059.88	757.68	33,954.53
SD	848.25	315.50	101.13	29.08	136.61	147.18	75.39	21.61	-	1,674.76
Total Barley	29,677.58	5,826.52	5,875.10	3,823.08	19,781.01	21,138.20	12,836.05	14,735.71	10,156.68	

Price Effect Due to FHB

Tables 3a, 3b, and 3c present estimated price effects, on futures and basis for all wheat classes (for estimated price effects on futures and basis for malting/feed barley, see Table 6). Although FHB caused futures price to increase for wheat (decrease losses), the basis effects were generally negative for all wheat classes and years except for the earlier years (1993 to approximately 1997) for Durum wheat in North Dakota. The aggregate price effects for all wheat classes were generally negative, except, once again, the case of Durum wheat. The occasional positive price effect for all wheat classes draws attention to what may be termed an 'aggregation problem.' The analysis used CRD-level production data and CRD or state-level price data to derive the economic losses suffered by producers. Data at this level of aggregation do not convey the severity of losses for individual producers whose yields and prices were lower than average. Moreover, in some CRDs where producers benefitted (on average) from higher prices, scab-related production losses were fairly small or localized.

Estimates of economic loss are affected, unavoidably, by the inclusion of positive price effects for all crops sold in a CRD–even crops sold by producers who suffered no yield losses. Low impact on futures price may be due partly to imports from Canada that exceed the yield shortfall.

Price impacts on malting barley premiums and feed barley are negative and substantial. Aggregate price effects for barley range from 0 to 80.3 cents/bushel for some CRDs and years. Quality shortfall due to FHB remains a major source of loss for barley producers.

Table 3a. Price Effect for HRS Wheat in Fusarium Head Blight Affected Regions

Price Effect for HRS							
	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	MN	SD
Year	Weighted Futures Price Effect (cents/bu)						
1993	4.10	4.36	4.13	4.16	4.14	2.14	2.36
1994	5.28	6.09	6.07	5.55	6.07	3.27	3.45
1995	6.58	11.22	8.03	9.41	8.65	7.31	5.01
1996	12.93	17.90	14.90	16.91	16.03	14.32	12.83
1997	3.49	6.23	4.01	4.83	4.85	3.76	3.16
1998	1.97	5.28	2.60	4.53	3.33	3.12	2.01
1999	1.04	4.97	2.14	3.80	2.83	3.19	2.00
2000	2.08	6.40	2.75	4.79	3.65	3.79	2.07
2001	2.26	5.93	2.76	4.84	4.16	2.96	2.14
	Weighted Basis Effect (cents/bu)						
1993	71.10	36.36	66.13	7.16	15.14	-13.86	14.36
1994	-27.72	-40.91	-12.93	-17.45	-5.93	-31.73	-2.55
1995	-16.42	-62.78	-22.97	-23.59	-15.35	-25.69	-15.99
1996	-15.07	31.90	-12.10	15.91	5.03	9.32	-9.17
1997	-26.51	-23.77	-25.99	-25.17	-25.15	-20.24	-24.84
1998	-61.03	-43.72	-43.40	-42.47	-70.67	-44.88	-55.99
1999	-53.96	-40.03	-37.86	-38.20	-55.17	-42.81	-57.00
2000	-21.92	-17.60	-21.25	-19.21	-20.35	-10.21	-21.93
2001	-105.61	-47.00	-22.17	-24.09	-32.77	-12.97	-123.79
	Total Price Effect (cents/bu)						
1993	75.20	40.71	70.27	11.31	19.28	-11.73	16.72
1994	-22.45	-34.83	-6.86	-11.90	0.14	-28.46	0.91
1995	-9.85	-51.56	-14.95	-14.19	-6.69	-18.38	-10.97
1996	-2.14	49.80	2.80	32.81	21.07	23.63	3.67
1997	-23.01	-17.54	-21.98	-20.35	-20.30	-16.47	-21.69
1998	-59.06	-38.45	-40.80	-37.95	-67.34	-41.76	-53.97
1999	-52.91	-35.07	-35.72	-34.40	-52.34	-39.63	-55.01
2000	-19.84	-11.20	-18.49	-14.42	-16.70	-6.42	-19.86
2001	-103.35	-41.06	-19.41	-19.24	-28.61	-10.01	-121.64

Table 3b. Price Effect for Durum Wheat in Fusarium Head Blight Affected Regions

Price Effect for Durum							
	ND-NC	ND-NE	ND-C	ND-EC	ND-SE	MN	
Year	Weighted Futures Price Effect (cents/bu)						
1993	30.00	1.30	1.03	0.90	0.89	0.60	
1994	23.00	3.03	2.06	1.78	1.78	1.17	
1995	24.00	5.35	3.95	3.59	3.67	2.37	
1996	6.00	10.21	9.91	9.69	9.71	6.19	
1997	21.00	1.61	1.38	1.26	1.27	0.83	
1998	1.51	1.37	0.60	0.32	0.32	0.17	
1999	0.67	1.43	0.61	0.52	0.29	0.07	
2000	1.20	1.26	0.41	0.30	0.30	0.09	
2001	1.00	1.04	0.99	0.85	0.70	0.54	
	Weighted Basis Effect (cents/bu)						
1993	164.00	79.30	61.03	116.90	116.89	69.94	
1994	125.00	69.03	31.06	151.78	151.78	-2.83	
1995	51.00	17.35	-51.05	33.59	33.67	-8.96	
1996	4.00	-22.79	-14.09	10.69	10.71	8.86	
1997	104.00	124.61	124.38	124.26	124.27	98.16	
1998	-89.49	-69.63	-55.40	-52.68	-52.68	-37.83	
1999	-70.33	-106.57	-15.39	-86.48	-48.71	-63.93	
2000	-42.80	-42.74	-43.59	-43.70	-43.70	-6.24	
2001	-66.93	-66.89	-66.94	-67.08	-67.23	-23.42	
	Total Price Effect (cents/bu)						
1993	194.00	80.59	62.07	117.81	117.78	70.54	
1994	148.00	72.06	33.13	153.56	153.55	-1.66	
1995	75.00	22.70	-47.10	37.18	37.34	-6.59	
1996	10.00	-12.58	-4.19	20.38	20.42	15.06	
1997	125.00	126.22	125.76	125.51	125.55	99.00	
1998	-87.99	-68.23	-54.80	-52.36	-52.36	-37.65	
1999	-69.65	-105.14	-14.79	-85.97	-48.43	-63.86	
2000	-41.60	-41.47	-43.18	-43.40	-43.39	-6.16	
2001	-65.94	-65.85	-65.94	-66.23	-66.54	-22.88	

Table 3c. Price Effect for SRW Wheat in Fusarium Head Blight Affected Regions

Price Effect for SRW							
	IL	IN	KY	MI	MO	OH	
Year	Weighted Futures Price Effect (cents/bu)						
1993	3.05	2.01	2.40	1.88	2.53	2.75	
1994	3.40	2.96	3.60	3.08	3.25	4.22	
1995	7.13	5.77	6.58	6.25	6.43	8.18	
1996	13.16	12.46	13.79	12.50	13.45	13.85	
1997	3.41	2.46	2.91	2.48	2.80	3.76	
1998	1.67	1.08	1.60	1.16	1.63	2.36	
1999	1.74	0.93	1.45	1.36	1.83	2.17	
2000	1.66	1.11	1.52	1.35	2.00	2.52	
2001	3.15	2.10	3.22	2.84	3.49	3.82	
	Weighted Basis Effect (cents/bu)						
1993	4.10	40.01	4.40	54.99	-26.06	-34.05	
1994	-29.25	-58.04	-24.40	4.05	-4.02	-15.47	
1995	0.22	-79.23	1.58	-77.38	-104.93	-94.77	
1996	9.11	-3.54	34.79	10.41	23.41	5.62	
1997	-55.31	34.46	-47.09	-11.81	3.69	-10.57	
1998	-89.88	-91.87	-101.35	-94.79	-110.37	-100.59	
1999	-33.70	-32.51	-25.99	-33.08	-28.21	-43.27	
2000	-0.30	-9.85	-0.44	-9.61	-10.00	-8.97	
2001	-64.78	-99.86	-53.74	-74.07	-116.38	-109.82	
	Total Price Effect (cents/bu)						
1993	7.15	42.01	6.80	56.87	-23.53	-31.30	
1994	-25.85	-55.07	-20.81	7.13	-0.77	-11.25	
1995	7.35	-73.47	8.17	-71.13	-98.50	-86.59	
1996	22.27	8.93	48.58	22.91	36.86	19.47	
1997	-51.90	36.92	-44.58	-9.33	6.50	-6.81	
1998	-88.22	-90.79	-99.74	-93.62	-108.74	-98.23	
1999	-31.97	-31.58	-24.54	-31.72	-26.39	-41.10	
2000	1.37	-8.75	1.08	-8.26	-8.00	-6.45	
2001	-61.63	-97.76	-50.53	-71.23	-112.89	-106.00	

Regional Economic Effects

Economic activity from a project, program, policy, or event can be categorized into direct and secondary impacts. Direct impacts are those changes in output, employment, or income that represent the initial or first-round effects of the activity. Secondary impacts (sometimes further categorized into indirect and induced effects, also known as multiplier effects) result from subsequent rounds of spending and re-spending within an economy.

Direct Economic Impacts

Fusarium Head Blight (FHB) affects small grain producers through price discounts and yield reductions on hard red spring (HRS) wheat, soft red winter (SRW) wheat, durum, and barley. The combined effects of price discounts and yield reductions represent a loss of revenue to small grain producers and also represent direct economic losses to regional economies. These losses may be offset when farmers shift to other crops.

Hard Red Spring Wheat

Yield reductions and price discounts from FHB in HRS wheat were estimated at $1.262 billion in North Dakota, Minnesota, and South Dakota from 1993 through 2001 (Table 4). Total direct losses were greatest in North Dakota ($630 million), followed by Minnesota ($571 million) and South Dakota ($60 million) over the period. Direct losses in the three states were greatest in 1994 and lowest in 1996. Of the total losses over the period, about one-third ($389 million) occurred in 1994 and 1997, with only 25 percent ($310 million) occurring from 1999 through 2001.

Durum

Yield reductions and price discounts from FHB in durum were estimated at $156 million in North Dakota and Minnesota from 1993 through 2001 (Table 5). The economic losses from FHB in durum were limited primarily to North Dakota. Losses in North Dakota represented over 99 percent of the two-state total. Annual direct losses in North Dakota peaked in 1996 ($37.8 million), were lowest in 1997 ($1 million).

Table 4. Direct Economic Impacts from Fusarium Head Blight in Hard Red Spring Wheat in the Northern Great Plains, 1993 through 2001

State	Economic Effect	ND	MN	SD	Total
		------------------- millions $ -------------------			
1993	Production Loss	(205)	(145)	(40)	(390)
	Price Effect	156	38	31	226
	Total	(49)	(107)	(8)	(164)
1994	Production Loss	(129)	(164)	(7)	(300)
	Price Effect	24	15	15	55
	Total	(104)	(149)	9	(245)
1995	Production Loss	(125)	(99)	(2)	(226)
	Price Effect	28	15	6	49
	Total	(96)	(84)	3	(176)
1996	Production Loss	(66)	(30)	0	(97)
	Price Effect	38	22	0	60
	Total	(28)	(8)	0	(37)
1997	Production Loss	(134)	(102)	(4)	(240)
	Price Effect	28	22	5	55
	Total	(107)	(79)	1	(185)
1998	Production Loss	(14)	(10)	(1)	(26)
	Price Effect	(66)	(28)	(24)	(119)
	Total	(81)	(39)	(25)	(144)
1999	Production Loss	(8)	(12)	0	(20)
	Price Effect	(46)	(27)	(25)	(97)
	Total	(53)	(38)	(25)	(117)
2000	Production Loss	(25)	(11)	0	(37)
	Price Effect	(24)	0	(9)	(33)
	Total	(49)	(12)	(9)	(70)
2001	Production Loss	(35)	(43)	0	(78)
	Price Effect	(28)	(12)	(6)	(47)
	Total	(63)	(55)	(6)	(124)
Total	Production Loss	(741)	(617)	(54)	(1,411)
	Price Effect	111	45	(6)	150
	Total	(630)	(572)	(60)	(1,262)

Note: Totals may not equal due to rounding.

Table 5. Direct Economic Impacts from Fusarium Head Blight in Durum Wheat in the Northern Great Plains, 1993 through 2001

State	Economic Effect	ND	MN	Total
		------------------------- millions $	---------------------------	
1993	Production Loss	(39.52)	(0.73)	(40.25)
	Price Effect	32.06	0.76	32.82
	Total	(7.46)	0.03	(7.43)
1994	Production Loss	(16.17)	(0.90)	(17.07)
	Price Effect	12.45	0.85	13.30
	Total	(3.72)	(0.05)	(3.77)
1995	Production Loss	(32.70)	(0.66)	(33.36)
	Price Effect	9.39	0.84	10.23
	Total	(23.31)	0.18	23.13
1996	Production Loss	(36.47)	(0.17)	(36.64)
	Price Effect	(1.47)	0.31	(1.16)
	Total	(37.94)	0.14	(37.80)
1997	Production Loss	(19.46)	0.00	(19.46)
	Price Effect	18.41	0.00	18.41
	Total	(1.05)	0.00	(1.05)
1998	Production Loss	(1.98)	(0.04)	(2.02)
	Price Effect	(18.40)	0.10	(18.50)
	Total	(20.38)	(0.14)	(20.52)
1999	Production Loss	(10.06)	(0.04)	(1.10)
	Price Effect	(18.69)	(0.15)	(18.84)
	Total	(28.74)	(0.19)	(28.94)
2000	Production Loss	(12.53)	(0.01)	(12.54)
	Price Effect	(8.35)	(0.01)	(8.37)
	Total	(20.88)	(0.02)	(20.90)
2001	Production Loss	(7.56)	0.00	(7.56)
	Price Effect	(4.98)	0.00	(4.98)
	Total	(12.54)	0.00	(12.54)
Total	Production Loss	(176.45)	(2.54)	(178.99)
	Price Effect	20.43	2.49	22.92
	Total	(156.02)	(0.05)	(156.07)

Note: Totals may not equal due to rounding.

Barley

Yield reductions and price discounts from FHB in barley were estimated at $484.7 million in North Dakota, Minnesota, and South Dakota from 1993 through 2001 (Table 6). Total direct losses over the period were greatest in North Dakota ($338.9 million), followed by Minnesota ($141.3 million) and South Dakota ($4.5 million). Direct losses in the three states were greatest in 1993 ($121 million), were lowest in 1995 ($27 million), and have averaged $39 million from 1999 through 2001. Of the total losses over the period, about 25 percent occurred in 1993.

Soft Red Winter Wheat

Yield reductions and price discounts from FHB in SRW wheat were estimated at $589 million in Illinois, Indiana, Kentucky, Michigan, Missouri, and Ohio from 1993 through 2001 (Table 7). Total direct losses over the period were greatest in Ohio ($196.8 million), followed by Illinois ($167 million), Missouri ($96.6 million each), Michigan ($63.3 million), Indiana ($43.1 million), and Kentucky ($22.3 million). Direct losses in the SRW wheat producing states were highest in 1998 with $235 million. In 1994 and 1997, no losses due to FHB were reported. Of the total losses over the period, 65 percent ($383.8 million) occurred in two years, 1995 and 1998.

Table 6. Direct Economic Impacts from Fusarium Head Blight in Barley in the Northern Great Plains, 1993 through 2001

State	Economic Effect	ND	MN	SD	Total
		------------------------------------ millions $ ------------------------------------			
1993	Production Loss	(26.66)	(15.10)	(1.50)	(43.26)
	Price Effect	(35.34)	(41.20)	(1.30)	(77.84)
	Total	(62.00)	(56.30)	(2.80)	(121.10)
1994	Production Loss	(12.74)	(1.67)	(0.55)	(14.96)
	Price Effect	(13.26)	(13.30)	(0.05)	(26.61)
	Total	(26.00)	(14.97)	(0.60)	(41.57)
1995	Production Loss	(9.00)	(0.16)	(0.55)	(9.35)
	Price Effect	(11.00)	(6.85)	(0.03)	(17.88)
	Total	(20.00)	(7.01)	(0.22)	(27.23)
1996	Production Loss	(9.50)	(0.77)	0.08	(10.19)
	Price Effect	(15.50)	(3.52)	(0.05)	(19.07)
	Total	(25.00)	(4.29)	0.03	(29.26)
1997	Production Loss	(32.64)	(8.86)	(0.35)	(41.85)
	Price Effect	(35.36)	(4.85)	(0.01)	(40.22)
	Total	(68.00)	(13.71)	(0.36)	(82.07)
1998	Production Loss	(15.94)	(21.42)	(0.33)	(37.69)
	Price Effect	(21.11)	(7.49)	(0.03)	(28.63)
	Total	(38.05)	(28.91)	(0.36)	(66.32)
1999	Production Loss	(13.32)	(7.02)	(0.14)	(20.48)
	Price Effect	(8.39)	(1.43)	0.00	(9.82)
	Total	(21.71)	(8.45)	(0.14)	(30.30)
2000	Production Loss	(23.19)	(1.77)	(0.04)	(25.00)
	Price Effect	(21.71)	(3.77)	0.00	(25.48)
	Total	(44.90)	(5.54)	(0.04)	(50.48)
2001	Production Loss	(15.90)	(1.17)	0.00	(17.07)
	Price Effect	(18.30)	(0.98)	0.00	(19.28)
	Total	(34.20)	(2.15)	0.00	(36.35)
Total	Production Loss	(158.89)	(57.94)	(3.02)	(219.85)
	Price Effect	(179.97)	(83.39)	(1.47)	(264.83)
	Total	(338.86)	(141.33)	(4.48)	(484.67)

Note: Totals may not equal due to rounding.

Table 7. Direct Economic Impacts from Fusarium Head Blight in Soft Red Winter Wheat in Central United States, 1993 through 2001

State	Economic Effect	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
		----------------	----------------	----------------	----------------	----------------	millions $	----------------	----------------	----------------	----------------
IL	Production Loss	(2.180)	0.0	(19.970)	(40.720)	0.0	(4.963)	(0.479)	(0.945)	(0.960)	(70.217)
	Price Effect	(8.820)	0.0	(36.850)	10.710	0.0	(43.665)	(16.979)	0.638	(1.900)	(96.856)
	Total	(11.000)	0.0	(56.820)	(30.010)	0.0	(48.618)	(17.458)	(0.307)	(2.860)	(167.073)
IN	Production Loss	0.0	0.0	(0.270)	(6.290)	0.0	(1.376)	(0.405)	(0.411)	(0.380)	(9.132)
	Price Effect	0.0	0.0	(6.190)	6.020	0.0	(22.400)	(7.576)	(2.182)	(1.690)	(34.013)
	Total	0.0	0.0	(6.460)	(0.270)	0.0	(23.771)	(7.981)	(2.593)	(2.070)	(43.145)
KY	Production Loss	(0.060)	0.0	(0.070)	(0.040)	0.0	(0.693)	(0.771)	(1.523)	(0.980)	(4.137)
	Price Effect	(0.570)	0.0	(4.650)	12.460	0.0	(19.999)	(4.830)	0.203	(0.800)	(18.190)
	Total	(63.000)	0.0	(4.720)	12.420	0.0	(20.692)	(5.605)	(1.320)	(1.780)	(22.327)
MI	Production Loss	0.0	0.0	0.000	(13.040)	0.0	(5.364)	(1.052)	(1.320)	(1.450)	(22.226)
	Price Effect	0.0	0.0	0.000	4.590	0.0	(27.707)	(12.701)	(2.879)	(2.400)	(41.097)
	Total	0.0	0.0	0.000	(8.450)	0.0	(33.071)	(13.753)	(4.199)	(3.850)	(63.323)
MO	Production Loss	(0.720)	0.0	(11.550)	(12.860)	0.0	(0.660)	(0.290)	(1.348)	(2.200)	(29.630)
	Price Effect	(4.660)	0.0	(20.720)	10.750	0.0	(38.150)	(8.440)	(2.649)	(3.100)	(66.969)
	Total	(5.380)	0.0	(32.270)	(2.110)	0.0	(38.812)	(8.730)	(3.997)	(5.300)	(96.599)
OH	Production Loss	(0.890)	0.0	(5.980)	(44.650)	0.0	(2.955)	(0.219)	0.000	(1.600)	(56.194)
	Price Effect	(2.470)	0.0	(42.650)	5.960	0.0	(67.091)	(27.155)	(5.068)	(2.160)	(140.634)
	Total	(3.360)	0.0	(48.530)	(38.690)	0.0	(70.046)	(27.374)	(5.068)	(3.760)	(196.828)
All	Production Loss	(3.850)	0.0	(37.740)	(117.60	0.0	(16.013)	(3.216)	(5.547)	(7.570)	(191.536)
	Price Effect	(16.520)	0.0	(111.06	50.490	0.0	(218.997)	(77.685)	(11.937)	(12.050)	(397.759)
	Total	(20.370)	0.0	(148.80	(67.110)	0.0	(235.010)	(80.901)	(17.484)	(19.620)	(589.295)

Note: Totals may not equal due to rounding.

Total Direct Impacts

The combined effects of price discounts and yield reductions from FHB in HRS wheat, SRW wheat, durum, and barley were estimated at $2.49 billion from 1993 through 2001 (Table 8). Direct economic losses over the period were greatest for HRS wheat ($1.26 billion), followed by SRW wheat ($589 million). Losses for barley and durum were estimated at $485 million and $156 million, respectively. Combined losses with the four crops were greatest in 1998 ($467 million) and were lowest in 2000 ($159 million). Over one-third of the total losses during the nine-year period occurred in 1995 and 1998.

Losses from all crops were summed by state (Table 9). North Dakota, with economic losses from FHB in HRS wheat, barley, and durum incurred the greatest impacts ($1.1 billion) of all affected states from 1993 through 2001. Other states with considerable economic losses over the period included Minnesota ($575 million), South Dakota ($201 million), Ohio ($197 million), and Illinois ($167 million). The remaining four states, largely impacted from FHB in SRW wheat, accounted for 9 percent of economic losses. Losses in North Dakota exceeded $100 million annually over the period, with the exception of 1996, where losses were around $91 million. In other states, the losses were more variable. Losses over the period in Minnesota ranged from $150 million in 1994 to $8 million in 1996. Similarly, losses ranged from $4 million to $64 million in South Dakota. In the SRW wheat producing states, no losses were estimated from FHB in 1994 and 1997. However, total losses were substantial in 1998, exceeding $460 million. Direct economic losses in the tri-state region of North Dakota, Minnesota, and South Dakota accounted for nearly 76 percent of all FHB impacts over the 1993 to 2001 period.

Despite a substantial variation in direct economic losses from FHB during the nine-year period, cumulative economic effects were substantial. The cumulative direct losses of $2.49 billion represent a substantial loss in crop revenue for small grain producers in the affected areas. To put the losses in perspective, consider that the average annual value of all winter wheat production in the United States from 1993 through 2001 was about $5.1 billion. The average losses from FHB over the same period for all crops in this study was estimated at $277 million. Thus, annual losses from FHB represented, on average, 5.4 percent of the total annual value of all US winter wheat production. When compared to the annual value of all wheat (spring, winter, durum, other) production in the US over the same period, annual losses from FHB represented 3.7 percent of the US total.

When losses from FHB in North Dakota, the most affected state, were compared to crop revenues over the period, the effects were more substantial. North Dakota averaged $125.0 million in losses from FHB from 1993 through 2001. The losses represent 11.2, 15.1, and 44.3 percent of the average value of all wheat, spring wheat, and durum production over the period, respectively. The average annual losses from FHB represent 5 percent of the annual average value of all crop production in North Dakota over the period. The losses in ND over the period were substantial, both in terms of overall size and in terms of relative perspective to the value of crop activities in the state.

Table 8. Total Direct Economic Impacts from Fusarium Head Blight, by Crop, in the Northern Great Plains and Central United States, 1993 through 2001

Crop	State	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total	By crop
		000s $										%
HRS	ND	49,000	104,000	96,000	28,000	107,000	81,000	53,000	49,000	63,000	630,000	- - -
	MN	107,000	149,000	84,000	8,000	79,000	39,000	38,000	12,000	55,000	571,000	- - -
	SD	8,000	(9,000)	(3,000)	0	(1,000)	25,000	25,000	9,000	6,000	60,000	- - -
	Total	164,000	244,000	177,000	36,000	185,000	145,000	116,000	70,000	124,000	1,261,000	50.5
Barley	ND	62,000	26,000	20,000	25,000	68,000	37,050	21,710	44,900	34,200	338,860	- - -
	MN	2,800	600	220	(30)	360	360	140	40	0	4,490	- - -
	SD	56,300	14,970	7,010	4,290	13,710	28,910	8,450	5,540	2,150	141,330	- - -
	Total	121,100	41,570	27,230	29,260	82,070	66,320	30,300	50,480	36,350	484,680	19.5
Durum	ND	7,460	3,720	23,310	37,940	1,050	20,380	28,740	20,880	12,540	156,020	- - -
	MN	(30)	50	(180)	(140)	0	140	190	20	0	50	- - -
	Total	7,430	3,770	23,130	37,800	1,050	20,520	28,930	20,900	12,540	156,070	6.3
SRW	IL	11,000	0	56,820	30,010	0	45,618	17,458	307	2,860	167,073	- - -
	IN	0	0	6,460	270	0	23,771	7,981	2,593	2,070	43,145	- - -
	KY	630	0	4,720	(12,420)	0	20,692	5,605	1,320	1,780	22,327	- - -
	MI	0	0	0	8,450	0	33,071	13,753	4,199	3,850	63,323	- - -
	MO	5,380	0	32,270	2,110	0	38,812	8,730	3,997	5,300	96,599	- - -
	OH	3,360	0	48,530	38,690	0	70,046	27,374	5,068	3,760	196,828	- - -
	Total	20,370	0	148,800	67,110	0	235,010	80,901	17,484	19,620	589,295	23.7
All	All	312,900	289,340	376,160	170,170	268,120	466,850	256,131	158,864	192,510	2,491,045	- - -
	%	12.6	11.6	15.1	6.8	10.8	18.7	10.3	6.4	7.7	- - -	- - -

Table 9. Total Direct Economic Impacts from Fusarium Head Blight, by State, in the Northern Great Plains and Central United States, 1993 through 2001

State	Crop	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total	By
		000s $										%
ND	HRS	49,000	104,000	96,000	28,000	107,000	81,000	53,000	49,000	63,000	630,000	
	Duru	7,460	3,720	23,310	37,940	1,050	20,380	28,740	20,880	12,540	156,020	
	Barley	62,000	26,000	20,000	25,000	68,000	37,050	21,710	44,900	34,200	338,860	
	Total	118,460	133,720	139,310	90,940	176,050	138,430	103,450	114,780	109,740	1,124,88	45.2
MN	HRS	107,000	149,000	84,000	8,000	79,000	39,000	38,000	12,000	55,000	571,000	
	Duru	(30)	50	(180)	(140)	0	140	190	20	0	50	
	Barley	2,800	600	220	(30)	360	360	140	40	0	4,490	
	Total	109,770	149,650	84,040	7,830	79,360	39,500	38,330	12,060	55,000	575,540	23.1
SD	HRS	8,000	(9,000)	(3,000)	0	(1,000)	25,000	25,000	9,000	6,000	60,000	
	Barley	56,300	14,970	7,010	4,290	13,710	28,910	8,450	5,540	2,150	141,330	
	Total	64,300	5,970	4,010	4,290	12,710	53,910	33,450	14,540	8,150	201,330	8.1
IL	SRW	11,000	0	56,820	30,010	0	48,618	17,458	307	2,860	167,073	6.7
IN	SRW	0	0	6,460	270	0	23,771	7,981	2,593	2,070	43,145	1.7
KY	SRW	630	0	4,720	(12,420)	0	20,692	5,605	1,320	1,780	22,327	0.9
MI	SRW	0	0	0	8,450	0	33,071	13,753	4,199	3,850	63,323	2.5
MO	SRW	5,380	0	32,270	2,110	0	38,812	8,730	3,997	5,300	96,599	3.9
OH	SRW	3,360	0	48,530	38,690	0	70,046	27,374	5,068	3,760	196,828	7.9

Total Economic Impacts

Economic activity from a project, program, or policy can be categorized into direct and secondary impacts. Direct impacts are those changes in output, employment, or income that represent the initial or first-round effects of the activity. Secondary impacts (sometimes further categorized into indirect and induced effects, also known as multiplier effects) result from subsequent rounds of spending and respending within an economy. The secondary economic effects were estimated using input-output analysis. Input-output (I-O) analysis is a mathematical tool that traces linkages among sectors of an economy and calculates the total business activity resulting from a direct impact in a basic sector (Coon et al. 1985). An economic sector is a group of similar economic units (e.g., communications and public utilities, retail trade, construction).

The North Dakota I-O Model was used to estimate the secondary (multiplier) and total economic effects of Fusarium Head Blight in the affected states. Empirical testing has shown the North Dakota Input-Output Model is sufficiently accurate in estimating economic impacts in neighboring states (Coon and Leistritz 1994; Coon et al. 1984; Leistritz et al. 1990). The model was assumed to also be sufficiently accurate to estimate regional economic losses stemming from FHB in the Central United States.

Fusarium Head Blight affects small grain producers in the northern Great Plains and Central United States through price discounts and yield reductions on hard red spring wheat, durum, barley, and soft red winter wheat. The effects of FHB were assumed to reduce producer net revenues, as the economic linkages and activities associated with crop production (e.g., planting, harvesting) are largely covered through the dispersal of revenues that producers are currently receiving from crop sales. Reductions in producer net revenues were treated as direct economic impacts and allocated to the **Households** sector of the North Dakota I-O Model to estimate the secondary and total economic impacts.

Hard Red Spring Wheat

Direct economic impacts (reductions in producer net revenues) from FHB on HRS wheat totaled $1.26 billion in North Dakota, Minnesota, and South Dakota from 1993 to 2001 (Table 9). Total direct and secondary economic impacts (total economy-wide losses) from FHB on HRS wheat in the three-state region were estimated at $3.88 billion over the period (Table 10). In the case of HRS wheat, North Dakota sustained the greatest level of overall economic loss ($1.94 billion) over the period. Economy-wide losses in Minnesota and South Dakota were estimated at $1.76 billion and $185 million, respectively (Table 10).

Durum

Direct economic impacts of FHB in durum totaled about $156 million in North Dakota and Minnesota from 1993 to 2001. Total direct and secondary economic impacts (total economy-wide losses) from FHB in durum in the two-state region were estimated at $480 million over the period (Table 10). Nearly all (over 99 percent) of the economic losses from FHB in durum occurred in North Dakota. The greatest losses occurred in 1995 and 1996, and 1998 through 2001.

Barley

Direct economic impacts of FHB in barley were estimated at $485 million in North Dakota, Minnesota, and South Dakota from 1993 through 2001. Total direct and secondary economic impacts in the tri-state region were estimated at $1.49 billion over the period (Table 10). About 70 percent or $1 billion of those losses occurred in North Dakota. Over the period, overall economic losses in the three states were greatest in 1993, followed by losses in 1997.

Soft Red Winter Wheat

Direct economic impacts of FHB in SRW wheat were estimated at $589 million in Illinois, Indiana, Kentucky, Michigan, Missouri, and Ohio from 1993 through 2001. Total regional losses (direct and secondary economic impacts) in the affected states were estimated at $1.81 billion over the period (Table 10). About 62 percent of the regional losses occurred in Ohio and Illinois. Of the $1.81 billion in regional economic losses, $606 million occurred in Ohio. Unlike durum and barley, the economic losses from FHB in SRW wheat largely occurred in only four years, 1995, 1996, 1998, and 1999.

Total Direct and Secondary Economic Impacts

Total direct and secondary economic losses from FHB in HRS wheat, barley, durum, and SRW wheat from 1993 to 2001 were estimated at $7.67 billion (Table 11). Overall losses were greatest in 1998, but losses remained mostly consistent over the period, except losses were noticeably lower in 1996, 2000, and 2001. Total economic impacts were greatest for SRW and HRS wheat, which accounted for nearly three-quarters of all losses.

Direct and secondary economic losses for all crops were summed by state (Table 11). Of the $7.67 billion in economic losses associated with FHB, North Dakota had $3.46 billion or about 45 percent of those losses during the 1993 to 2001 period. Losses in the other states were not as large, but substantial losses still occurred Minnesota ($1.77 billion), South Dakota ($620 million, Ohio ($606 million), Illinois ($514 million), and Missouri ($297 million). Relatively lower losses occurred in Michigan ($195 million), Indiana ($133 million), and Kentucky ($69 million).

Table 10. Total (Direct and Secondary) Economic Impacts from Fusarium Head Blight, by Crop and State, in the Northern Great Plains and Central United States, 1993 through 2001

Crop	State	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total	By
		-------	-------	-------	-------	-------	000s $	-------	-------	-------	-------	----
HRS	ND	150,837	320,143	295,517	86,192	329,378	249,342	163,150	150,837	193,933	1,939,329	- - -
	MN	329,378	458,667	258,577	24,626	243,186	120,054	116,975	36,940	169,307	1,757,710	- - -
	SD	24,626	(27,705)	(9,235)	0	(3,078)	76,958	76,958	27,705	18,470	184,699	- - -
	Total	504,841	751,105	544,859	110,818	569,486	446,354	357,083	215,482	381,710	3,881,738	50.5
Barle	ND	190,855	80,036	61,566	76,958	209,324	114,051	66,830	138,216	105,278	1,043,114	- - -
	MN	8,619	1,847	677	(92)	1,108	1,108	431	123	0	13,821	- - -
	SD	173,308	46,082	21,579	13,206	42,203	88,994	26,012	17,054	6,618	435,056	- - -
	Total	372,782	127,965	83,822	90,072	252,635	204,153	93,273	155,393	111,896	1,491,991	19.5
Duru	ND	22,964	11,451	71,755	116,791	3,232	62,736	88,470	64,275	38,602	480,276	- - -
	MN	(92)	154	(554)	(431)	0	431	585	62	0	155	- - -
	Total	22,872	11,605	71,201	116,360	3,232	63,167	89,055	64,337	38,602	480,431	6.3
SRW	IL	33,861	0	174,909	92,380	0	149,661	53,741	945	8,804	514,301	- - -
	IN	0	0	19,886	831	0	73,174	24,568	7,982	6,372	132,813	- - -
	KY	1,939	0	14,530	(38,232)	0	63,696	17,254	4,063	5,479	68,729	- - -
	MI	0	0	0	26,012	0	101,802	42,336	12,926	11,851	194,927	- - -
	MO	16,561	0	99,337	6,495	0	119,475	26,874	12,304	16,315	297,361	- - -
	OH	10,343	0	149,390	119,099	0	215,623	84,265	15,601	11,574	605,895	- - -
	Total	62,704	0	458,052	206,585	0	723,431	249,038	53,821	60,395	1,814,026	23.7
Totals	All	963,199	890,675	1,157,93	523,835	825,353	1,437,10	788,449	489,033	592,603	7,668,186	- - -
	%	12.6	11.6	15.1	6.8	10.8	18.7	10.3	6.4	7.7	- - -	- - -

Table 11. Total (Direct and Secondary) Economic Impacts from Fusarium Head Blight, All Crops, by State, in the Northern Great Plains and Central United States, 1993 through 2001

State	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total	By State
	--					000s $			--		---- % --
ND	364,656	411,630	428,838	279,941	541,934	426,129	318,450	353,328	337,813	3,462,71	45.2
MN	337,905	460,668	258,700	24,103	244,294	121,593	117,991	37,125	169,307	1,771,68	23.1
SD	197,934	18,377	12,344	13,206	39,125	165,952	102,970	44,759	25,088	619,755	8.1
OH	10,343	0	149,390	119,099	0	215,623	84,265	15,601	11,574	605,895	7.9
IL	33,861	0	174,909	92,380	0	149,661	53,741	945	8,804	514,301	6.7
MO	16,561	0	99,337	6,495	0	119,475	26,874	12,304	16,315	297,361	3.9
MI	0	0	0	26,012	0	101,802	42,336	12,926	11,851	194,927	2.5
IN	0	0	19,886	831	0	73,174	24,568	7,982	6,372	132,813	1.7
KY	1,939	0	14,530	(38,232)	0	63,696	17,254	4,063	5,479	68,729	0.9
Total	963,199	890,675	1,157,93	523,835	825,353	1,437,10	788,449	489,033	592,603	7,668,18	- - -

Economic Impacts by Sector

Input-output analysis provides for estimates of the lost business activity by economic sector. The combined effects (direct and secondary) of FHB by economic sector for all affected crops was summed by year for the 1993 to 2001 period (Table 12). The economic sectors of the individual state and regional economies with the greatest loss of business activity during the period were **Households** (which represents economy-wide personal income) ($3.87 billion) and **Retail Trade** ($1.86 billion). Other sectors which incurred substantial loss of economic activity as a result of FHB in small grains included **Finance, Insurance, and Real Estate** ($419 million), **Government** ($269 million), **Communication and Public Utilities** ($263 million) and **Agriculture** ($234 million). Since all effects (direct economic losses) of FHB were allocated to the **Households** sector for each crop and each state, lost business activity by sector within individual states would be in proportion to the aggregate totals for each year (i.e., state-level effects by economic sector would be largely in the same ratio as found in Table 12).

Based on the North Dakota I-O Model, each dollar of direct economic loss or each dollar of lost producer net revenues would result in an additional $2.08 of lost business activity in the state and regional economies. Thus, not only are producers affected by FHB through lost revenues, but numerous sectors of the state and regional economies also are affected.

Table 12. Total (Direct and Secondary) Economic Impacts for Fusarium Head Blight in All Crops, by Economic Sector and Year, Northern Great Plains and Central United States, 1993 through 2001

	Hard Red Spring and Soft Red Winter Wheat, Durum, and Barley									
Economic Sector	1993	1994	1995	1996	1997	1998	1999	2000	2001	Totals
	000s $									
Agriculture	29,412	27,197	35,358	15,996	25,204	42,884	24,075	14,932	18,095	234,153
Construction	28,223	26,099	33,930	15,349	24,185	42,109	23,104	14,331	17,365	224,695
Communication & Public Utilities	33,012	30,524	39,685	17,954	28,287	49,255	27,022	16,761	20,311	262,811
Retail Trade	233,016	215,471	280,126	126,727	199,669	347,662	190,740	118,306	143,364	1,855,081
Finance, Insurance, & Real Estate	52,599	48,637	63,232	28,606	45,073	78,479	43,057	26,706	32,361	418,750
Households	485,746	449,173	583,951	264,172	416,230	724,737	397,617	246,621	298,851	3,867,098
Government	33,791	31,252	40,629	18,372	28,951	50,418	27,662	17,155	20,790	269,020
Other sectors[a]	67,400	62,322	81,023	36,659	57,754	100,561	55,172	34,221	41,466	536,578
Total	963,199	890,675	1,157,934	523,835	825,353	1,437,105	788,449	489,033	592,603	7,668,186
Total Direct Impacts	312,900	289,340	376,160	170,170	268,120	466,850	256,131	158,864	192,510	2,491,045
Total Secondary Impacts	650,299	601,335	781,774	353,665	557,233	970,255	532,318	330,169	400,093	5,177,141

[a] Includes sectors such as business, professional, personal, and social services, transportation, and manufacturing.

Secondary Employment

Secondary employment estimates represent the number of full-time jobs generated based on the volume of business activity created by an industry. Productivity ratios[16] were used with estimates of business activity to obtain secondary employment. The loss of producer revenues from FHB in small grains in the Northern Great Plains and Central United States had substantial effects on secondary employment in the state and regional economies (Table 13). Over the period, secondary employment losses ranged from 4,800 FTE in 2000 to 14,300 FTE in 1998. Other years with substantial employment losses due to FHB included 1995 (12,100 FTE), 1993 (10,000 FTE), and 1994 (9,300 FTE).

Table 13. Secondary Employment Losses from Fusarium Head Blight, All Crops, by State in the Northern Great Plains and Central United States, 1993 through 2001

State	1993	1994	1995	1996	1997	1998	1999	2000	2001
	-- full-time equivalent jobs -------------------------								
ND	3,796	4,287	4,470	2,856	5,445	4,262	3,169	3,507	3,338
MN	3,525	4,807	2,699	246	2,453	1,206	1,170	363	1,677
SD	2,059	192	128	131	394	1,653	1,020	435	238
OH	101	0	1,557	1,217	0	2,161	837	149	109
IL	349	0	1,824	941	0	1,497	531	6	82
MO	168	0	1,035	61	0	1,193	261	116	156
MI	0	0	0	263	0	1,016	418	124	111
IN	0	0	202	4	0	729	239	75	58
KY	15	0	147	(387)[a]	0	635	168	34	49
Total	10,013	9,286	12,062	5,332	8,292	14,352	7,813	4,809	5,818

[a] Indicates an increase in jobs due to positive economic effects from FHB. All other effects represent job losses.

[16]A measure of the amount of economic activity needed in an economic sector to support one full-time job within that sector.

5. Summary and Discussion

This study provides an update of economic losses suffered by wheat and barley producers in scab-affected regions in the United States from 1993 to 2001. Wheat and barley producers in several states have experienced significant yield and price losses due to Fusarium Head Blight (FHB), or scab, since 1993. Yield and price effects of FHB are estimated in this study using change in crop value after accounting for reduced yields, higher abandoned acres, and price impacts on futures and basis, and malting and feed barley prices.

One of the main difficulties in measuring economic losses due to FHB is estimating the price effects. While supply reductions tend to increase the futures price, the effects on average basis (difference between local cash price and futures) are less certain. Shortages of milling-quality grains can induce large price premiums, which favor producers who have high quality wheat or barley to sell. However, many producers in scab-affected regions face quality discounts due to damaged kernels, low test weight, or vomitoxin. The average basis in a region depends on the quality of crop sold by all producers and the premiums and discounts applied by local elevators.

To measure the impact of FHB on basis, deviations from olympic-average basis values were used in years preceding the scab outbreak in the case of wheat. In the case of barley, the malting and feed barley prices were estimated. The actual prices were deducted from the estimated prices to obtain the price effects. An input-output model was used to estimate secondary and total economic impacts of FHB on state economies, individual economic sectors, and secondary employment.

The direct combined effects of price discounts and yield reductions from FHB in HRS wheat, SRW wheat, durum wheat, and barley were estimated at $2.492 billion from 1993 through 2001. Direct economic losses over the period were greatest for HRS wheat ($1.262 billion), followed by SRW wheat ($589 million). Losses for barley and durum wheat were estimated at $484.7 million and $156 million, respectively. Combined losses for the four crops were greatest in 1998, followed by 1995, and 1993, with 2000 losses being the lowest. Losses in 1998 accounted for over 19 percent of the nine-year total.

Cumulative economic losses from FHB over the period 1993 to 2001 were very high. The cumulative direct losses of $2.492 billion represent a substantial loss in crop revenue for small grain producers in the affected areas. To put the losses in perspective, consider that the average annual value of all winter wheat production in the United States from 1993 to 2001 was about $5.1 billion. The average annual losses from FHB over the same period for all crops in this study was estimated at $277 million. Thus, annual losses from FHB over the nine years represent on average 5.4 percent of the total value of all U.S. winter wheat production. When compared to the annual value of all wheat (spring, winter, durum, and other) production in the United States over the same period, annual losses from FHB represented 3.7 percent of the U.S. total.

The combined direct and secondary economic losses for all crops were estimated at $7.7 billion. North Dakota had $3.5 billion or about 45 percent of those losses during the period 1993 to 2001. Losses in the other states were not as large, but substantial losses still occurred in

Minnesota ($1.8 billion), South Dakota ($620 million), Ohio ($606 million), Illinois ($514 million), Missouri ($297 million), Michigan ($195 million), Indiana ($133 million) and Kentucky (69 million).

Johnson et al. (1998) estimated FHB losses for the period 1993 to 1997. The estimates in this study are more comprehensive, and they show that revenue loss due to FHB decreased substantially for wheat in 1993-2001. The most likely reason for the decrease in revenue was the introduction of FHB resistant varieties in North Dakota and Minnesota combined with low precipitation recorded during these periods. However, barley producers continue to suffer significant losses. North Dakota and Minnesota had the largest cumulative yield losses for all wheat classes and barley, followed by Michigan and Illinois.

Scab is still a major economic problem, whether measured in relative terms to other crop sales or measured by overall direct and secondary economic impact. The scab problem is not limited to a narrow geographic region, hurting producers in both the northern Great Plains and central states. Scab continues to effect several classes of wheat and barley, constituting a serious economic problem in several regions of the United States.

Impacts from scab affect not only producers, but other areas of the economy as well. A substantial portion of the impacts affect the businesses that are dependent upon revenues from crop sales (for every $1 dollar of scab losses incurred by the producer, $2.08 in losses are incurred in other areas of rural and state economies). Depressed farm economies are further affected by scab. Scab occurs in many regions of the northern Great Plains that are not only reliant on agriculture, but are predominately dependent upon small grain production. Thus, scab is having an extenuating effect in those areas. Furthermore, income losses from scab are occurring during periods of depressed farm prices and low net farm income. (Net farm income has decreased significantly since 1996.)

The level of impacts (magnitude), the relative impact (comparisons to wheat/other small grain sales), and the geographic size of the problem all suggest that continued research into developing scab resistant varieties of wheat and barley is warranted. Clearly, several million dollars spent on scab research would be easily offset by future benefits of a reduction in scab losses.

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Appendix Tables

Table A1. HRS Wheat Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
ND - NC	94.227	0.32133	-1.4173	0.64874	0.4029	0.2976	21
	(3.305)	(1.685)	(-2.890)	(1.297)			
ND - NE	85.402	0.5673	-1.0613	0.47697	0.3101	0.1883	21
	(2.285)	(2.337)	(-1.698)	(0.7834)			
ND - C	75.725	0.33886	-1.0997	1.0742	0.4323	0.3321	21
	(2.423)	(1.669)	(-2.103)	(2.110)			
ND - EC	93.574	0.63324	-1.2613	0.60845	0.3619	0.2493	21
	(2.415)	(2.590)	(-1.922)	(1.138)			
ND - SE	78.095	0.40425	-1.0025	0.26589	0.2333	0.098	21
	(1.935)	(1.803)	(-1.511)	(0.5233)			
MN - NW	70.111	0.72676	-0.88439	1.0175	0.4083	0.3039	21
	(1.522)	(2.842)	(-1.157)	(1.528)			
MN - WC **	46.37	0.61307	-0.54676	1.2211	0.3581	0.2448	21
	(0.9857)	(2.788)	(-0.7331)	(2.189)			
MN - C **	-26.752	0.20103	0.91152	0.46975	0.1508	0.001	21
	(-0.4797)	(0.6544)	(1.017)	(0.9343)			
SD - NC	79.998	0.36576	-1.134	0.58488	0.3396	0.223	21
	(1.714)	(1.710)	(-1.571)	(0.8920)			
SD - NE **	36.78	0.47997	-0.47984	1.2704	0.3232	0.2037	21
	(0.8842)	(2.576)	(-0.7205)	(2.563)			
SD - C	84.557	0.32151	-1.1035	-0.047464	0.291	0.1659	21
	(-1.702)	(-1.289)	(-1.452)	(-0.079)			

Numbers in the parentheses are t-values.

** Indicates error structure corrected for first order auto-correlation.

Table A2. Durum Wheat Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
ND - NC	98.817	0.32251	-1.4729	0.70589	0.4058	0.3009	21
	(3.332)	(1.625)	(-2.887)	(1.356)			
ND - NE	84.35	0.36631	-1.1761	0.82275	0.3616	0.2489	21
	(2.798)	(1.829)	(-2.275)	(1.475)			
ND - C	82.668	0.46442	-1.2943	1.3865	0.5387	0.4573	21
	(2.616)	(2.263)	(-2.449)	(2.693)			
ND - EC	94.682	0.85496	-1.3889	0.87211	0.4673	0.3733	21
	(2.348)	(3.360)	(-2.033)	(1.567)			
ND - SE	65.407	0.5025	-0.89617	0.83324	0.3908	0.2832	21
	(1.750)	(2.420)	(-1.459)	(1.771)			
MN - NW	61.129	0.6421	-0.82059	1.4907	0.4763	0.3838	21
	(1.416)	(2.678)	(-1.145)	(2.387)			
MN - WC **	35.806	0.42769	-0.39002	1.2589	0.4217	0.3197	21
	(1.044)	(2.674)	(-0.7170)	(3.084)			

Numbers in the parentheses are t-values.

** Indicates error structures corrected for first order auto-correlation.

Table A3. SRW Wheat Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
IL - W	56.233	1.2241	-0.24502	-0.58471	0.6816	0.6179	19
	(1.279)	(4.483)	(-0.3298)	(-1.742)			
IL - WSW	75.505	0.93293	-0.4845	-0.61913	0.6284	0.5541	19
	(1.783)	(3.799)	(-0.6918)	(-1.884)			
IL - ESE	35.662	0.85432	0.21217	-0.73802	0.6479	0.5775	19
	(0.8517)	(3.77)	(0.3069)	(-2.286)			
IL - SW	80.715	0.80986	-0.55467	-0.83165	0.6176	0.5412	19
	(1.86)	(3.643)	(-0.7916)	(-2.814)			
IL - SE	-2.2713	0.79954	0.7623	-0.62178	0.5553	0.4664	19
	(-0.04404)	(3.272)	(0.9269)	(-1.910)			
IN - NE **	70.906	0.89601	-0.57457	-0.17975	0.6339	0.5606	19
	(2.351)	(6.03)	(-1.111)	(-0.4213)			
IN - C **	90.46	1.0548	-0.7959	-0.36563	0.7873	0.7447	19
	(3.339)	(9.376)	(-1.763)	(-1.292)			
IN - SW	29.112	0.76875	0.22551	-0.39652	0.4521	0.3426	19
	(0.5295)	(3.081)	(0.2547)	(-1.101)			
IN - SC **	42.918	0.66552	-0.16107	-0.073021	0.4488	0.3386	19
	(1.015)	(3.651)	(-0.2327)	(-0.2520)			
IN - SE	33.704	0.90967	0.013917	-0.25987	0.6554	0.5864	19
	(0.7634)	(4.818)	(0.01932)	(-0.8592)			
KY - PUR **	4.975	0.74822	0.46648	-0.27356	0.5624	0.4749	19
	(0.0909)	(2.577)	(0.5423)	(-1.060)			
KY - MW	63.983	0.6774	-0.40115	-0.37702	0.4075	0.2889	19
	(0.8769)	(2.169)	(-0.3477)	(-0.8993)			
MI - C	46.362	0.7124	-0.33776	0.51998	0.3094	0.1713	19
	(1.105)	(2.529)	(-0.4099)	(0.9605)			
MI - EC	33.645	1.3381	-0.087447	0.79063	0.6995	0.6394	19
	(0.9666)	(5.78)	(-0.1301)	(1.771)			
MI - SW	57.557	0.88435	-0.52123	0.093666	0.4865	0.3838	19
	(1.543)	(3.208)	(-0.7884)	(0.1458)			
MI - SC	76.68	0.88382	-0.8258	0.013682	0.4688	0.3626	19
	(1.805)	(3.181)	(-1.081)	(0.02038)			
MI - SE	54.808	0.99427	-0.46167	0.36915	0.6047	0.5257	19
	(1.64)	(4.657)	(-0.7414)	(0.6588)			
MO - NE **	76.348	0.74045	-0.58409	-0.51745	0.3673	0.2414	19
	(1.543)	(2.953)	(-0.7318)	(-1.294)			

State / CRD	Intercept	Trend	Temperature	Precipitation	R2	Adj. R2	Sample Size
MO - E	42.048	0.54152	-0.005345	-0.47311	0.4246	0.3095	19
	(0.9438)	(2.516)	(-0.007128)	(-1.783)			
MO - SW	95.491	0.48229	-0.96776	-0.43828	0.4027	0.2832	19
	(2.16)	(2.27)	(-1.333)	(-1.645)			
MO - SC	38.84	0.58563	-0.10129	-0.38543	0.4907	0.3888	19
	(1.002)	(3.128)	(-0.1553)	(-1.670)			
MO - SE **	53.13	0.18257	0.0076974	-0.89689	0.3791	0.255	19
	(1.803)	(0.8101)	(0.01441)	(-2.865)			
OH - NW **	11.227	0.88812	0.42239	0.55772	0.5406	0.4487	19
	(0.258)	(4.883)	(0.5589)	(0.899)			
OH - NC **	14.405	0.95953	0.41396	0.0062829	0.6824	0.6188	19
	(0.4492)	(6.564)	(0.7199)	(0.01602)			
OH - NE **	0.68114	0.88102	0.60395	-0.077001	0.7398	0.6877	19
	(0.0267)	(8.242)	(1.282)	(-0.2230)			
OH - WC **	30.901	0.92016	0.24147	-0.29203	0.6805	0.6166	19
	(0.9204)	(6.548)	(0.4161)	(-0.9234)			
OH - C **	17.405	1.0137	0.4663	-0.5433	0.8358	0.803	19
	(0.6465)	(11.11)	(1.031)	(-2.278)			

Numbers in the parentheses are t-values.

**Indicates error structures corrected for first order auto-correlation.

Table A4. Barley Yield Equation Parameter Estimates, by State

State / CRD	Intercept	Trend	Temperature Deviation	Precipitation Deviation	Precipitation Deviation squared	R2	Adj. R2	Number of Observations
ND - NC**	25.87*	0.72*	-3.89*	4.1*	-2.65*	0.71	0.68	34
	(9.06)	(5.64)	(-3.31)	(3.72)	(-2.47)			
ND - NE	24.43*	1.15*	-3.41*	3.26*	-2.31	0.75	0.72	34
	(8.48)	(9)	(-2.47)	(2.72)	(-1.65)			
ND - C	21.28*	0.93*	-4.56*	5.37*	-1.27	0.69	0.64	34
	(7.73)	(7.02)	(-3.44)	(4.25)	(-1.34)			
ND - EC	27.2*	1.17*	-3.57*	2.96*	-2.27	0.76	0.72	34
	(10.01)	(9.09)	(-2.67)	(2.33)	(-2.14)			
ND - SE	26.43*	0.92*	-2.87*	5.49*	-3.6	0.7	0.66	34
	(9.66)	(7.01)	(-2.07)	(3.56)	(-3.83)			
MN - NW	12.51	0.94	5.15	0.65	-0.44	0.66	0.62	34
	(1.59)	(1.03)	(2.92)	(2.28)	(-5.62)			
MN - WC	19.93	0.76	3.49	1.78	-0.4	0.69	0.65	34
	(2.73)	(3.83)	(4.71)	(1.79)	(-5.3)			
MN - C	21.45	0.37	2.94	1.52	-0.08	0.48	0.4	34
	(3.17)	(3.5)	(3.45)	(1.67)	(-2.79)			
SD - NC	22.5	0.31	1.19	2.03	0.06	0.45	0.37	34
	(2.76)	(2.3)	(0.62)	(0.59)	(2.32)			
SD - NE	11.18	0.68	4.09	0.63	-0.25	0.56	0.5	34
	(1.27)	(1.01)	(2.39)	(1.77)	(-4.23)			
SD - C	18.28	0.5	1.47	0.52	0	0.27	0.17	34
	(1.81)	(0.6)	(0.03)	(0.61)	(2.94)			

Numbers in the parentheses are t-values.

** Indicates error structure corrected for first order auto-correlation.

Table A5. Fraction of HRS, Durum, SRW, and Barley Yield and Area Loss Attributable to Fusarium Head Blight (α_{ijt}), by Crop Reporting District and Year

Year	ND-NC	ND-EC	ND-C	ND-EC	ND-SE	MN-NW	MN-WC	MN-C	SD-NC	SD-EC	SD-C
1998	1.00	0.26	0.81	0.19	1.00	0.13	1.00	*	*	0.16	*
1999	0.04	0.05	0.07	0.04	0.37	0.11	0.63	1.00	*	*	*
2000	0.67	0.15	0.41	0.15	*	0.39	*	*	*	*	*

Fraction of Durum Yield and Area Loss Attributable to FHB (α_{ijt}), by CRD and Year

Year	ND-NC	ND-EC	ND-C	ND-EC	ND-SE	MN-NW	MN-WC
1998	1.00	0.26	0.81	0.19	1.00	0.13	1.00
1999	0.04	0.05	0.07	0.04	0.37	0.11	0.63
2000	0.67	0.15	0.41	0.15	*	0.39	*

Fraction of SRW Yield and Area Loss Attributable to FHB (α_{ijt}), by CRD and Year

Year	IL	IN	KY	MI	MO	OH
1998	0.22	0.13	0.06	0.24	0.05	0.08
1999	0.06	0.02	0.01	0.12	0.09	*
2000	0.15	*	*	*	0.08	*

Fraction of Barley Yield and Area Loss Attributable to FHB (α_{ijt}), by CRD and Year

Year	ND-NC	ND-EC	ND-C	ND-EC	ND-SE	MN-NW	MN-WC	MN-C	SD-NC	SD-EC	SD-C
1998	0.73	0.90	0.47	0.80	0.93	1.00	0.83	*	*	0.75	*
1999	0.35	0.63	0.40	0.60	0.56	0.69	*	*	*	*	*
2000	0.75	0.96	0.81	0.86	0.43	0.90	0.50	*	*	*	*

*Insignificant proportion.
Source: Extension Specialists.

Table A6. Malting Barley Premium Parameter Estimates by Crop Reporting District					
Crop Reporting District	Independent Variable				
	Intercept	Total production (Q_T)	Reg R^2	DW	Observations
ND-NC	0.88** (3.68)	-0.0015** (2.78)	0.20	1.66	34
ND-NE	1.42** (6.16)	-0.0026** (-5.29)	0.47	1.77	34
ND-C	1.07** (4.48)	-0.0018** (3.54)	0.29	1.81	34
ND-EC	2.05** (6.85)	-0.0039** (-6.07)	0.54	1.84	34
ND-SE	1.07** (4.23)	-0.0018** (-3.18)	0.25	2.00	34

Note: Numbers in the parentheses are t-values.
**Indicates parameter is statistically significant at the 0.05 level or higher.

Table A7. Feed Grain Barley Parameter Estimates by Crop Reporting District						
Crop Reporting District	Independent Variable					
	Intercept	Corn price (P_C)	Total production (Q_T)	Reg R^2	DW	Observations
ND-NC	0.24 (1.19)	0.78* (17.75)	-0.0009* (-2.07)	0.91	1.94	34
ND-NE	0.28 (1.48)	0.75* (18.18)	-0.0008* (-2.10)	0.92	1.93	34
ND-C	0.21 (1.19)	077* (19.81)	-0.0007** (2.00)	0.93	1.91	34
ND-EC	0.22 (1.13)	0.75* (17.42)	-0.0006 (-1.39)	0.91	1.87	34
ND-SE	0.21	0.78* (17.49)	-0.0007** (-1.76)	0.91	1.91	34

Note: Numbers in the parentheses are t-values.
*Indicates parameter is statistically significant at the 0.05 level or higher.
**Indicates parameter is statistically significant at the 0.10 level.