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AUTHOR	Stokes, C. Shannon; Brace, Kathy D.
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ABSTRACT

A study of 1,497 nonmetropolitan counties was conducted to test the possible contribution of agricultural chemical use to cancer mortality rates in rural counties. The dependent variables were 20-year age-adjusted mortality rates for 1950 to 1969 for five categories of cancer: genital, urinary, lymphatic, respiratory, and digestive. Because sex and race are both recognized factors in cancer etiology, only rates for white males were used in the analysis. Significant associations were found between agricultural chemical use and four of the five types of cancer examined. Herbicides were positively and significantly associated with genital, lymphatic, and digestive cancer. Insecticides had a strong positive relationship to respiratory cancer. Fertilizer use was largely unrelated to cancer mortality with the exception of a modest negative association with digestive cancer. Of the remaining social, economic, and demographic variables, foreign stock exhibited the largest and most consistent influence and was the strongest predictor of digestive cancer. Income and education were both significant in respiratory and digestive cancer, but of opposite sign. In spite of the limitations of this study, the findings are highly suggestive of the need for additional research on possible links between agricultural chemical use and county cancer mortality. (JHZ)

Agricultural Chemical Use and White Male Cancer Mortality in Selected Rural Farm Counties*

C. Shannon Stokes and Kathy D. Brace

Department of Agricultural Economics
and Rural Sociology
The Pennsylvania State University
University Park, PA 16802

and

Department of Behavioral Sciences
York College of Pennsylvania
York, PA 17404

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Introduction

A recent article in Rural Sociology described rural/urban trends and differentials in cancer mortality between the early 1950s and 1970s (Greenberg, 1984). Rural areas have traditionally had lower total cancer rates and lower rates of most site-specific cancers. During these two decades, historic rural/urban differences in cancer mortality decreased greatly and the trend toward convergence occurred among almost every type of cancer and among the most rural counties. Although several possible explanations for this convergence have been advanced, Greenberg (1984:149) notes that describing ". . . what has happened is easier than explaining why it happened."

The purpose of this study is not to explain the convergence of rural/urban cancer mortality differentials, but to examine the hypothesized impact of factors which may account for variation in cancer mortality within the rural sector. Recent work has begun to focus on the possible effects of agricultural activities, type of farming and the resulting exposure to possible carcinogenic substances as factors in the rural environment (Burmeister, 1983; Clark et al., 1982; Blair and Thomas, 1979).

One of the obvious exposures connected to rural residence is agricultural chemical use. The amount of chemicals used in agriculture continues to increase. U.S.D.A. researchers have documented this trend noting, for example, that in 1952, 11 percent of the corn acreage was treated with herbicides; by 1976, 90 percent of the corn acreage received treatment and in 1982, 95 percent was treated (Eichers et al., 1978; Schaub, 1985). Herbicide use increased from 70.5 million pounds of active ingredient (a.i.) in 1964 to 420.4 million pounds (a.i.) in 1982 (Schaub, 1985:17).

Earlier research has described the short range impact of agricultural chemical use on the health of rural populations. The more immediate deleterious effects of improper exposure to agricultural chemicals has been well documented (Morgan et al., 1980; Swartz, 1978; West, 1964). Reports have indicated a large number of pesticide-related illnesses in fieldworkers (Swartz, 1978; West, 1964), while individual case studies and medical reports illustrate the sometimes fatal results of incorrect exposure during application (West, 1964). Recognition of these hazards has resulted in a ban on certain substances, product labelling, licensing of those prepared to apply chemicals, and the initiation of training sessions by Cooperative Extension personnel in correct handling and application procedures. Additional studies continue to monitor chemically treated fields to determine acceptable re-entry times for workers (Woodrow et al., 1977).

The more immediate effects of these chemicals clearly indicate a need for precautions in application and exposure, but there have also been concerns about the possible long-range effects of exposure since a number of agricultural chemicals have been classified as carcinogenic (Epstein, 1979). What are the long-range effects of these chemicals on the cancer mortality of rural populations? This paper reports the relationship between agricultural chemical use and cancer mortality rates of selected rural farm counties. Agricultural chemical use is examined within an ecological model of county cancer mortality that includes socioeconomic factors implicated in earlier studies.

Background Information

Prior to the convergence in rural and urban cancer mortality rates, total cancer rates among farm residents have been lower than among urban populations, and some reduced site-specific rates have also been documented (Correa and Haenszel, 1978; Fasal et al., 1968; Wan and Wright, 1973). Conversely, some higher site-specific cancer rates have been observed in farm populations and have persisted after factors such as age, sex, race, and socioeconomic status were controlled. Some of these unexpected results revealed increased risks of certain site-specific cancers for farm workers, higher than expected rates among farm residents and higher than expected rates in some rural counties and regions.

Studies of farmers and farm workers in Washington, Oregon, Iowa, Nebraska, and Texas, have all suggested elevated rates for certain types of cancers (Milham, 1971, 1976; Burmeister, 1983; Blair and Thomas, 1979; and Agu et al., 1980). Higher than expected mortality rates include leukemia, myeloma, stomach, pancreas, and prostatic cancers. Elevated rates of leukemia (Fasal et al., 1968) and cancers of the central nervous system (Choi et al., 1970) in farm residents have also been reported. For some farm regions, increased rates of lung cancer (Clark et al., 1977; 1982) and of stomach cancer (Hoover et al., 1975:a,b) have been found. Connections between these cancer patterns and agricultural chemical use have been suggested in some cases, but have not been adequately tested (Burmeister, 1981; Clark et al., 1977; Milham, 1971). Agricultural chemical application on a county level was included in one prostate cancer mortality analysis, but no statistically significant relationship was reported (Blair and Fraumeni, 1978). Other studies have inferred relationships between chemical use and site-specific cancers using crop production patterns as a proxy variable, but little research has attempted to test directly the relationship between use of agricultural chemicals and county cancer mortality (Burmeister et al., 1981; Clark et al., 1982).

Procedures

Sample Counties

To test the possible contribution of agricultural chemical use to cancer mortality rates in rural counties, we attempted to identify a set of counties whose populations would likely be exposed to varying amounts and types of chemicals. The criteria utilized were also designed to reduce the effects of other environmental and technological factors. After reviewing a variety of measures of "rural farm" counties, and estimating the correlations among a series of these measures, three criteria were used to identify counties as "rural farm." Nonmetropolitan counties which met any one of the following criteria were initially included in the analysis: the number of employed persons working in agriculture was equal to or greater than the mean number for all counties; the county had a mean value or greater for land used in farming; the county had a mean value or greater for the dollar value of all agricultural products sold. Eliminating counties with incomplete or unmatched data, 1,497 nonmetropolitan counties met one or more of the criteria and were designated as rural farm.

Measurement of Variables

Twenty-year age-adjusted mortality rates for 1950 to 1969 for five categories of cancer are used as dependent variables (Mason and McKay, 1975). Due to both the small number of cancer deaths and population bases in many rural counties, and the resulting large standard errors associated with their rates, the 20-year mortality rates were grouped into five major categories of related sites (Table 1). In addition to yielding more stable rates, grouping related cancer sites recognizes the possibility of different etiologies. It appears unlikely that agricultural chemicals or other factors would exert the same influence on all types of cancer.

Table 1 about here

Because sex and race are both recognized factors in cancer etiology, only rates for white males are used in this analysis (Cutler and Young, 1975; Epstein, 1979; Greenberg, 1983; Preston, 1976). The small number of nonwhites in most rural counties precluded their inclusion in this study, and the greater occupational exposure of rural males led to the decision to examine female cancer mortality in a subsequent analysis. Finally, to compensate further for the very small number of cancer deaths in some counties, only those counties reporting 50 or more deaths from a given type of cancer were included in the final analysis.

It should be noted that the dependent variables represent average annual age-adjusted mortality rates (per 100,000) for the 1950-1969 period (Mason and McKay, 1975). Subsequent work will examine lagged models in which cancer rates are viewed as dependent upon chemical use in earlier periods. However, the latency period for many types of cancer has been estimated at 20 to 40 years (Greenberg, 1984). Thus data availability limits efforts to test many lagged models, even if the appropriate time interval were known. For example, Census of Agriculture data on county-level chemical use other than fertilizers are not available before 1964, shortly after the midpoint of the period for which the cancer rates are calculated. While earlier measurements on this crucial independent variable would have been desirable, the present models represent a preliminary attempt to test the hypothesized link between chemical use and cancer mortality in an ecological model. Moreover, the consistency of county agricultural production patterns from year to year suggests that these indicators of chemical use would likely be strongly related over time.

Data for the central explanatory variables, agricultural chemical use, were obtained from the 1964 Census of Agriculture. Three categories of chemical use were reported: (1) acres of land treated with dry and liquid fertilizers, (2) acres of crops sprayed for control of insects and diseases (insecticides),[1] and (3) acres of crops or land treated during the year for control of weeds, grass, and brush (herbicides) (U.S. Bureau of Census, 1966). The percentages of the total county farmland acreage treated with each type of chemical (fertilizer, insecticide, herbicide) serve as the measures of agricultural chemical use. While it would have been preferable to have direct measures of the amount of each chemical that was used, such data were not available. Similarly, the number of applications to a given plot was not known. Thus the measures are conservative estimates of chemical use during the period under study.

Although the primary focus of this study is on the influence of agricultural chemical use, other factors have been identified as important in earlier research on cancer. The possible effect of manufacturing industries on cancer rates has been widely noted (e.g., Hoover et al., 1975; Greenberg, 1983). To assess the relative contribution of this variable to county cancer mortality, the proportion of each county's total 1960 employed population that was employed in manufacturing was calculated

(U.S. Bureau of Census, 1962). Similarly, mining has been identified as a high risk occupation for certain site-specific cancers (Hoover et al., 1975; Page et al., 1976). Census data on the proportion of county employees who in 1960 worked in the mining industries were also obtained.

Environmental contaminants previously identified as contributing to explanations of cancer mortality have often been associated with urban locations (Greenberg, 1983). The selection of nonmetropolitan counties controlled part of the possible effects of urban residence. To further control the impact of urban influence, a measure of rurality was constructed using the size of largest place within the county and distance from a metropolitan area. Using 1960 SMSAs, counties were coded from those with most urban influence to those that were most rural. The categories were: (1) adjacent to a metropolitan county and with an urban place of 10,000 or more, (2) adjacent and with an urban place of 2,500-9,999, (3) adjacent but entirely rural, (4) nonadjacent but with a place of 10,000 or more, (5) nonadjacent with an urban place of 2,500-9,999, and (6) nonadjacent and entirely rural.

Other variables frequently included in studies of cancer mortality include socioeconomic status and ethnicity. Socioeconomic status has been identified repeatedly as an important factor in individual-level analyses (Correa and Haenszel, 1978; Cutler and Young, 1975; Graham, 1969; Kitagawa, 1977). A variety of measures of this variable have been used, including occupation, education, and income, as well as indices devised from these characteristics. The potential influence of occupation was included in the manufacturing and mining variables. The impacts of education and income were measured through two separate indicators. Census data on males' median educational levels and median family income (1960) were selected as indicators of county level socioeconomic status.

Finally, several studies have found ethnic background to be associated with certain site-specific cancer rates (Graham, 1969; Hoover et al., 1975b). Consequently, the proportion of the total county population that was foreign stock was included. Foreign stock refers to the proportion of the population that is foreign born plus those who are native-born of foreign parentage.

Multiple regression models are estimated separately for each of the five categories of cancer included. Ordinary least squares equations are estimated using a linear specification in the absence of more complete information as to expected functional form.

Findings

The models estimated in Table 2 support the decision to examine separately cancer deaths at related sites. With the exception of the mining and rurality variables which are positively related to cancer mortality in each case where they are statistically significant, the remaining variables reveal contrasting signs, depending upon the cancer site being examined.

Among the agricultural chemical variables, the percentage of farmland treated with herbicides is the most consistently related to cancer mortality. In four of the five models, herbicide use is significantly related to cancer rates. The standardized partial regression coefficients indicate that herbicide use is the strongest predictor in the genital and lymphatic cancer regressions and the second best predictor in the digestive cancer equation. Herbicide use is positively and significantly related to each of these categories of cancer. Surprisingly, herbicide use is also significantly related to respiratory cancer, but in a negative direction, a finding for which we have no ready explanation. It is interesting to note, however, that in the one equation where this reversal of expected sign occurs, the coefficient for insecticide use is large and positive.

Insecticide use is not only significantly and positively related to respiratory cancer (Beta = .46), it is the best predictor of this type of cancer of the nine variables considered. Use of insecticides is unrelated to urinary, lymphatic or digestive cancers. Genital cancer mortality is negatively related to insecticide use, contrary to expectations. Similar to the respiratory equation in which the anomalous negative effect of one chemical occurred in the presence of a strong positive impact of another, herbicide use emerges as the strongest predictor of genital cancer (Beta = .32). Whether these two findings reflect a particular combination of agricultural practices, types of farming, soil types, or other exposures which may be related to elevated rates of genital or respiratory cancer could not be ascertained. Given the modest correlation between insecticide and herbicide use (.3), this finding does not appear to be a statistical artifact of collinearity in the system.[2]

Fertilizer use was largely unrelated to cancer mortality. It failed to exert a significant impact in four of the five regressions, and in the one case where it was statistically significant (digestive cancer), it was negatively related and of marginal size (Beta = -.09).

Table 2 about here

Manufacturing employment is significantly related in the digestive cancer equation, indicating that increased percentages of the labor force in manufacturing is positively related to this cause of death. It is unrelated in any other regression, perhaps reflecting the small proportion of the labor force employed in manufacturing in this sample of rural counties. Mining, by contrast, was positively related to genital, respiratory and digestive cancer. Its largest impact, as expected, was on respiratory cancer. Notably, however, the impact of mining (Beta = .11) in the respiratory equation was only about one-fourth that of insecticide use (Beta = .46).

The rurality measure was positively related to urinary and lymphatic cancer rates, but not significantly related to the more frequently occurring cancers. The coefficients for income and education are significant in both the respiratory and digestive equations. In each case, their impact is of opposite sign. Education is negatively related to respiratory and digestive cancer, while income exerts a positive impact. Conversely, income reveals a negative coefficient for genital cancer, while education is positively related to lymphatic cancer. Neither variable is significant in the urinary cancer regression.

The coefficients for the percentage of the population classified as foreign stock are substantial and significant in four of the five equations. The impact is particularly noticeable for digestive cancer where foreign stock is the stongest predictor in the equation (Beta = .49) and where the best fitting model is found ($\bar{R}^2$ = .36). This finding again confirms the likely impact of ethnicity on digestive cancer (Hoover et al., 1975). Foreign stock is also significant in the genital, urinary and respiratory regressions. The moderately strong negative coefficient in the respiratory regression contrasts with the positive signs in the other models, again supporting the decision not to examine total cancer mortality rates, but rather to group cancers at related sites. Whether the negative impact of foreign stock on respiratory cancer reflects different patterns of cigarette consumption or other factors cannot be determined from these data, but the findings are suggestive of delimited areas r further research.

Discussion

Significant associations were found between agricultural chemical use and four of the five types of cancer examined. For three of the five models, agricultural chemical use was the best predictor of cancer mortality. Herbicides were positively and significantly associated with genital, lymphatic and digestive cancer. Insecticides had a strong positive relationship to respiratory cancer. In two instances, insecticides in the genital cancer regression and herbicides in the respiratory regression, signs of the coefficients were contrary to expectations. In each of these anomalous cases, a much stronger and positive relationship was exhibited with the other major pesticide. Fertilizer use was largely unrelated to cancer mortality with the exception of a modest negative association with digestive cancer.

Of the remaining social, economic and demographic variables, foreign stock exhibited the largest and most consistent influence. Foreign stock was the strongest predictor of digestive cancer, suggesting that ethnicity was positively related to this cause of death. Similarly, foreign stock exhibited positive impacts on genital and urinary cancer, but negative effects on respiratory cancer.

Income and education were both significant in respiratory and digestive cancer, but of opposite sign. As expected, mining was important to respiratory cancer, but it also was positively related to genital and digestive [redacted] cancer. Manufacturing employment was significant in one instance (digestive cancer), while rurality exhibited positive effects on urinary and lymphatic cancer.

These findings are highly suggestive of the need for additional research on possible links between agricultural chemical use and county cancer mortality. However, several limitations of the study must be recognized. Common to ecological studies, direct links between persons exposed to agricultural chemicals and those who died of cancer cannot be made. Thus, as Clark et al. (1982) note, those who died may not have been involved in farming. Conversely, there are multiple pathways through which chemicals are dispersed in the environment and farm workers are clearly not the only persons exposed to potential risks (Glotfelty, 1985; Severn, 1985; Sieber, 1985). Nonetheless, caution must be exerted in interpreting these results.

A second problem relates to the appropriate time referent for the cancer rates given the long latency periods for most types of cancer. If a 20+ year latency period characterizes the cancer rates examined here, then this analysis may well underestimate the influence of agricultural chemicals. Clark et al. (1982:4) used a 20-year lag because they ". . . thought that . . . was the only time period for which an association with the use of OC (organochlorine) pesticide could be observed." Our results indicate that significant associations may be found within shorter time periods. As data for the 1980-1985 period become available, more appropriately lagged models can be estimated. In the interim, we are currently attempting to estimate lagged models for the 1975-1980 period.

An additional problem of the study is the lack of detailed data on the types, quantities and frequency of chemical applications. In the absence of such data, some investigations have used the proportion of harvested land in a given crop as a surrogate measure of the intensity of chemical use (Clark et al., 1982). Such procedures are several steps removed from the indicators necessary to measure exposure more directly. The finding of significant relationships where the epistemic correlations between concepts and measures are likely to be modest encourages further work. In that regard, the consistency between our findings and those of Clark et al. (1982) indicate that observed relationships are not likely to be simply artifacts of the methods employed.

The contribution of agricultural chemicals to farm production is well established (Schaub, 1985). With one estimate of commodity losses caused by insects in the United States in 1981 at 23 billion dollars (Klassen and Schwartz, 1985:280), their use is likely to continue. While evaluations of the toxicity and possible carcinogenicity of the substances involved is the proper purview of biological and medical researchers (Epstein, 1977), ecological studies involving demographic, socioeconomic and agricultural factors can and should be monitored by social scientists. Environmental sociologists, demographers and rural sociologists would all appear to have a role to play.

Footnotes

1. Although we use the term insecticides to refer to this category of chemicals, a number of other pesticides are also included.
2. In addition to the modest correlation between these two variables, the SAS collinearity diagnostic procedures revealed no collinearity problems involving the chemical variables. Other than the expected correlation between income and education, there was little evidence of harmful or degrading collinearity in the system.

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Table 1. Major Groups of Cancer.

Type of cancer	ICD code[a]
Genital	Prostate (177); testis (178)
Urinary	Kidney (180); bladder (181)
Lymphatic and hematopoietic	Hodgkins's disease (201); lymphosarcoma and reticulosarcoma, other forms of lymphoma (reticulosis) and mycosis fungoides (200,202,205); multiple myeloma (203); leukemia and aleukemia (204)
Respiratory	Nose, nasal cavities, middle ear and accessory sinuses (160); larynx (161); trachea, bronchus and lung specified as primary; and lung and bronchus, unspecified as to whether primary or secondary (162,163)
Digestive	Esophagus (150); stomach (151); large intestine except rectum (153); rectum (154); biliary passages and liver stated as to be primary site (155); pancreas (157)

[a]Source: World Health Organization. Manual of the International Statistical Classification of Diseases, Injuries, and Causes of Death, 6th revision, Adopted 1948, Vol. 1, Geneva, Switzerland.

Table 2. Summary of OLS Regressions of County White Male Cancer Mortality[a] Rates for Specific Types of Cancer on Agricultural Chemical Use and Selected Ecological Variables.

Variable	Genital		Urinary		Lymphatic		Respiratory		Digestive	
	b	β	b	β	b	β	b	β	b	β
Insecticide	-10.129**	-.186	-3.490	-.109	-4.646	-.117	57.488**	.455	3.463	.026
Herbicide	12.630**	.320	-.315	-.012	7.009**	.221	-19.151**	-.178	21.529**	.216
Fertilizer	-1.286	-.057	2.406	.169	-.529	-.030	-4.298	-.072	-5.405*	-.092
Manufacturing	.639	.024	1.080	.066	-1.507	-.072	-5.635	-.075	8.690**	.119
Mining	10.295*	.091	-6.533	-.052	-1.640	-.018	23.610**	.108	12.330*	.054
Rurality	.102	.051	.314**	.225	.223*	.134	.105	.020	.140	.029
Median family income	-.001**	-.237	.001	.174	-.000	-.046	.002**	.283	.001**	.173
Median educational level	.255	.098	.318	.150	.299*	.149	-.168**	-.185	-.719**	-.110
Foreign stock	7.968**	.227	6.612**	.275	1.308	.046	-28.861**	-.298	42.850**	.490
Adjusted R^2	.119		.156		.078		.229		.363	
F-ratio	8.348**		4.055**		4.558**		24.993**		67.673**	

[a]For counties with at least 50 deaths due to specified type of cancer. Mean cancer mortality rates and number of counties include are: genital cancer (19.7, N=489), urinary cancer (11.0, N=150), lymphatic cancer (18.1, N=381), respiratory cancer (33.7, N=727), and digestive cancer (48.7, N=1,055).

*$p = \leq .05$

**$p = \leq .01$