# Chemical Use Reductions in Urban Fringe Agriculture

**Adesoji O. Adelaja, Kevin Sullivan, Yohannes G. Hailu, and Ramu Govindasamy**

Using an augmented profit function framework designed to account for externalities related to chemical use in agriculture, this paper explains the chemical use choices of farmers in an urban fringe farming environment. It further estimates empirical logit models of reduced insecticide, fungicide, herbicide, and fertilizer usage. Results suggest that farmers who perceive their regulatory environment to be strict, who have experienced right-to-farm conflicts, and who have farms larger in size are more likely to reduce their chemical use over time, vis-à-vis other farmers. The results also suggest the importance of other farm structural and business climate factors in determining chemical use reduction choices.

***Key Words:*** chemical use, sustainable agriculture, herbicides, fungicides, fertilizer, pesticides, urban fringe

Following World War II, in an attempt to raise farm productivity and meet growing demands for farm products, agriculture became more dependent upon chemicals. For example, primary nutrient use in agriculture increased from 7.5 million tons in 1960 to 22.1 million tons in 2005, despite the reduction in agricultural land in production (U.S. Department of Agriculture 2005). Chemicals have become important to productivity and competitiveness as farmers use pesticides to control pests, fungicides and herbicides to control diseases and weeds, and fertilizer to replace depleted nutrients in the soil.

By enhancing productivity and reducing output shrinkage, chemicals enhance profitability (Whittaker, Lin, and Vasavada 1995, Dobbs and Smolik 1996, Fernandez-Cornejo, Jans, and Smith 1998). However, farm chemicals also have adverse effects on the farm and non-farm public (Blair and Zahn 1995, Clouser 2005). These adverse effects (or negative externalities) have generated significant public angst and debate in recent years, especially at the urban fringe where farmers are in close proximity to their non-farm neighbors. According to the National Sustainable Agriculture Information Service (2009), more than 40 percent of the calls it receives from the public involve agricultural chemicals. The literature on environmental impacts of farm chemical use provides some evidence that these public concerns are justified. Agricultural chemicals have been reported to contaminate groundwater (Nielson and Lee 1987, Hamilton and Helsel 1995, Kolpin, Thurnman, and Linhart 1998, Barbash et al. 2001). Adverse effects on soil microbial diversity at the DNA level have also been reported (Yang, Hu, and Qi 2000).

Also of growing concern are the adverse human health effects. Farmers, farmworkers, and non-farm neighbors can come into direct contact with agricultural chemicals. Acute poisonings from agricultural chemicals are rare. However, those exposed to chemicals over prolonged periods may have increased risk of cancer of the lymphatic and hematopoietic system, skin cancer, soft tissue

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sarcoma, Blue Baby Syndrome from nitrates, and other diseases (Blair et al. 1992, Blair and Zahn 1995, Knobeloch et al. 2000). Such exposure may also lead to detrimental effects on unborn fetuses and damage to nervous and immune systems (Van Driesche at al. 1987). The growing concern about the impact of farmers' chemical use on the health of workers and the general population has led to increasing regulation of farming and the preclusion by law of some normal farming practices (Bosch, Cook, and Fuglie 1995, Adelaja and Friedman 1999, Henderson 2003). Neighbor concerns have also led to right-to-farm conflicts, especially at the urban fringe where non-farmers and farmers must coexist in close proximity (Adelaja and Friedman 1999).

The growing concerns about chemical use on farms have also raised significant policy questions at the national and state levels about the external costs associated with farming and the sustainability of agriculture. From an agricultural policy perspective, these concerns are difficult to balance against the economic needs of agriculture. Leaders of the farm community, the environmental community, and policymakers are exploring new ways of balancing the needs of farmers with those of the non-farm public. This balance is obviously a delicate one due to the economic, social, environmental, and political dimensions of the agricultural chemical issue.

Many states have introduced Agricultural Management Practices (AMP) or Best Management Practices (BMP) as part of their right-to-farm provisions, their farmland preservation provisions, or their requirements for technical and economic assistance to farmers. For example, in the case of New Jersey, AMPs are a condition for qualifying for the protections offered through the state's right-to-farm legislation, amended in 1998 (New Jersey Statutes Annotated 1998). Offering farmers the opportunity to gain certain benefits by complying with better environmental management practices suggests that policymakers perceive a trade-off between economic performance and environmental performance. However, the lack of concrete scientific evidence of such a trade-off is a hindrance to the development of effective public policies.

At the farm level, chemical usage has direct implications for enhanced productivity and profitability. However, excessive or inappropriate usage may imply not only unnecessary production cost, but also some hazards to farmers themselves. Excessive and inappropriate use of chemicals can also cause negative externalities to farm neighbors (David 2004, Akca, Sayili, and Kurunc 2005), which causes costly nuisance complaints (Dunlap and Beus 1992, Bricker et al. 2004). Such complaints impose legal- and compliance-related costs on agriculture (Adelaja and Friedman 1999). Reducing chemical inputs and seeking new optimal ways to enhance production could reduce external disutilities to non-farmers and make farming more acceptable and sustainable at the urban fringe. For example, a study that evaluated consumers' risk regarding agricultural pesticide residue found that suburban households are more risk-averse toward pesticide residues than are rural households (Govindasamy, Italia, and Adelaja 1998).

Concern about such pesticide residues among consumers could also manifest itself as either increased demand for reduced-chemical agriculture products, or as decreased demand for conventional agricultural products (Weaver, Evans, and Luloff 1992, Park and Lohr 1996, Thomson 1998, Padel 2001, Rigby and Caceres 2001). Hence, there is a connection between chemical use, product price, farm profitability, and long-term sustainability of agriculture (Pacini et al. 2002). In other words, farmers must also be concerned about the market implications of chemical use.

As economic agents, farmers must factor chemical concerns into their decision making process. The right-to-farm regulation and market challenges that could come with excessive chemical use suggests that in addition to typical production costs, farmers must also contend with external costs related to chemicals and the market effects of chemical use. In other words, optimization must imply consideration of costs related to regulation and right-to-farm conflicts, and of the likelihood that neighbors will complain about chemicals, that regulators will penalize them, and that consumers may respond non-favorably.

Many farmers at the urban fringe are already responding to consumers and their neighbors by moving toward alternative farming practices, such as Integrated Pest Management (IPM), Low-Input Sustainable Agriculture (LISA), and organic farming (Govindasamy, Italia, and Adelaja 1998). In New Jersey, for example, 16 percent of the farmers surveyed (as part of the New Jersey FARMS Commission evaluation of agriculture) used conventional methods combined with either IPM or organic practices, 9 percent were fully organic, and 15 percent could be characterized as low-input. The remaining 60 percent were either fully conventional or did not know how to classify themselves. The growing consideration of sustainable farming practices may reflect, in part, a reaction to the backlash from chemical use through neighbor complaints, regulations, right-to-farm conflicts, and market effects.

Several studies have looked at the effects of chemical use on farm performance. Some of these compared the profitability of organic farms and conventional farms. For example, Rendleman (1991) showed that when farms convert to practices involving reduced chemical use, often gross farm income rises but net farm income falls due to rising costs. Painter and Young (1995), who compared conventional cropping systems in southeastern Washington with several alternative systems, also found that some alternative systems had higher net income than even the most profitable conventional systems, while averaging just one-third the soil loss per year. Other studies have suggested that the adoption of organic farming would result in decreased yields, decreased aggregate output, reduced costs, large increases in consumer prices, and increased farm income (Lee 1992). Offermann and Nieberg (2000) similarly compared the performance of conventional and organic farms and found that organic farms have lower yields, higher output prices, and lower costs. Other studies have also argued that reduced chemical use can result in increased output variability and market risk (Serra et al. 2006). It is therefore apparent that there is no real consensus yet as to how chemical reduction affects the profitability of farms, or the nature of the trade-offs or motivations involved in reduced chemical use.

Understanding the trade-off between chemical use and profitability is important to policymakers, farmers, environmentalists, and producers of agricultural chemicals. While these trade-offs are still not very clear, it is possible to gain better understanding of why and how farmers use chemicals and the factors that have led them to reduce their chemical usage over time. Of particular importance is information on how chemical use choices are affected by the regulatory climate, by right-to-farm conflicts arising at the urban fringe, by profitability, and by other factors at the urban fringe that hinder normal farming activities. Policymakers can use such information in designing an incentive system for the adoption of sustainable agricultural practices. Similarly, the information can be useful to chemical producers in targeting their products toward specific farmers.

The objective of this paper is to investigate the economic, socio-demographic, regulatory, and attitudinal factors that contribute to the adoption of reduced use of on-farm chemicals in order to better understand how farmers are responding to growing pressures. The paper conceptualizes the demand for chemicals, primarily focusing on the urban fringe. By incorporating into the profit function of a farm elements of external costs, such as costs associated with regulation and right-to-farm conflict, this paper estimates empirical logit models for reduced insecticides, fungicides, herbicides, and fertilizer use in an urban fringe environment. A unique database based on a survey of New Jersey farmers provided the source of data for this analysis.

## Conceptual Framework

A farmer's production function is used as the starting point for developing a conceptual model of the use of chemical inputs on farms. Following Adelaja, Miller, and Taslim (1998), a farmer produces an agricultural product according to the following production function:

$$(1) \qquad q^i = \theta^i q^i(x^i; m^i),$$

where $q^i$ is the quantity produced by the $i$th farmer, and $\theta^i$ represents the technological or structural parameter of the $i$th farmer. For instance, farm technology (which can shift the input-output relationship) or farm size (which can shift the proportional relationship among inputs) are factors captured by $\theta^i$. Two of the fundamental determinants of farm behavior are the state of technology and the structure of the farm. In the short run, a farmer cannot produce more than is allowed by existing technology and structure. In equation (1), $m^i$ represents the management capability of the $i$th farmer. Several studies have shown that management capabilities (e.g., education and experience) play an important role in the production process. The symbol $x^i$ represents a vector of physical inputs used by the $i$th farmer, including chemicals.

Assume that the production inputs include capital $k^i$, labor $l^i$, chemicals $c^i$, and miscellaneous inputs $r^i$, and that the production function is of the standard neoclassical type, exhibiting decreasing returns to scale. It is assumed that $\partial q^i/\partial x^i > 0$ and $\partial q^i/\partial m^i > 0$. These suggest positive marginal products of inputs, including managerial expertise.

The urban environment invokes additional considerations and possibly additional costs due to the close interaction between farmers and their neighbors and due to local regulation. In other words, in the non-urban environment, where farmers are neighbors with other farmers, the likelihood of right-to-farm conflicts with neighbors will be minimized as farmers represent a more powerful influence block in the community (Lopez, Adelaja, and Andrews 1988). In the urban fringe environment, however, where farmers are more likely to have non-farm neighbors, chemical use potentially imposes costs related to conflicts with neighbors and regulation (Adelaja and Friedman 1999).

To account for such externalities, consider the case where negative externalities are embodied in chemical usage, such that as the level of $c^i$ increases, the level of negative externalities also increases. That is, denote the externalities by $\beta c^i$ such that $\beta$ captures the expected external costs per unit of chemical use by the farmer. A simplifying assumption is made that $\beta$ has an expected constant proportional relationship with pollution, and that chemical use decisions, by type, are independent. Hence, $\beta c^i$ is the expected full cost of eliminating the adverse effects of chemical use on the non-farm public. The expected external costs can be assumed to be an increasing function of the level of chemical use such that $\partial\beta^i/\partial c^i > 0$. For simplicity, further assume that $\partial\beta^{i2}/\partial^2 c^i = 0$. Denote, therefore, the total expected external costs to be borne by farmers by $\alpha(\beta c)$, where $\alpha$ is the expected proportion of the full external cost to society imposed on the farmer via regulation, via the effects of right-to-farm conflicts, and via other policy-induced costs such as fines, fees, and shutdowns. At the urban fringe, we hypothesize that $\alpha$ is more likely to approach one, and at locations away from the urban fringe, that $\alpha$ is likely to approach zero.

The expected external cost expression above accounts for the fact that farmers anticipate some direct and indirect costs from chemical use. These costs range from costs of compliance with regulation, costs associated with complaints by non-farm neighbors, costs of dealing with nuisance suits, etc. That is, while chemical use increases farm productivity, it can also increase indirect production expenses. Farmers must, therefore, choose an optimal level of chemical use consistent with profit maximization, which depends not only on expectations about $\beta$, but also on expectations about $\alpha$, $\alpha\in(0, 1)$. When $\alpha = 0$, farmers expect the regulatory climate and farming environment to be such that they have full property rights or *carte blanche* and will not be required to bear any of the external costs. When $\alpha = 1$, farmers expect to fully bear the external costs. The level of $\alpha$ therefore is related to a whole series of factors, including farmers' understanding of and expectations about the right to farm, the political clout of the farm population, how favorable the farming environment is to farmers, and the nature of the externalities generated from chemical use.

The profit-maximizing farm's decision becomes one of choosing values of the inputs in vector $x$:

(2) $$\begin{aligned}\text{Max}\pi &= p\theta q(x;m) - wx - \alpha\beta(c)\\ &= p\theta q(x;m) - \phi k - \rho l - \tau c - \lambda r - \alpha\beta(c),\end{aligned}$$

where $x = [k, l, c, r]$, $w = [\phi, \rho, \tau, \lambda]$, $\phi$ is the implicit rental value of capital (including farmland), $\rho$ is the wage rate of hired labor, $\tau$ is the price per pound of chemical inputs, and $\lambda$ is the price of miscellaneous inputs. The first-order condition for profit maximization is as follows:

(3) $$\frac{\partial\pi}{\partial k} = p\frac{\partial q}{\partial k} - \phi = 0,$$

(4) $$\frac{\partial\pi}{\partial l} = p\frac{\partial q}{\partial l} - \rho = 0,$$

(5) $$\frac{\partial\pi}{\partial c} = p\frac{\partial q}{\partial c} - \tau - \alpha\beta = 0,$$

(6) $$\frac{\partial\pi}{\partial r} = p\frac{\partial q}{\partial r} - \lambda = 0.$$

These conditions suggest that a profit-maximizing farm will utilize any input up to the point at which its marginal contribution to revenues is equal to its marginal cost. The farm's demand for a specific input, therefore, depends on how productive that input is in terms of quantity produced and on how employing the input affects costs.

Chemical use reduction being the focus of this paper, it is useful to focus on the optimization problem for chemical use [equation (5)]. In the case of chemicals, additional costs over and above the direct input costs are expected to arise from regulation and externalities generated at the urban fringe. In equation (5), since $\alpha\beta$ is not known for certain and probably varies by farmer, there are uncertainties associated with $\alpha\pi/\alpha c$. Farmers will decide how much to produce based on their expectation of $\alpha$ and $\beta$. Since $\alpha$ and $\beta$ are expected values, they depend on farmers' risk attitude and exposure. In other words, the values of $\alpha$ and $\beta$ depend on past experiences ($\overline{\alpha}$ and $\overline{\beta}$), which are mean historical $\alpha$ and $\beta$, as well as the variances of $\alpha$ and $\beta$ ($\sigma_\alpha^2$ and $\sigma_\beta^2$). Therefore, $\alpha$ and $\beta$ are related to the history of right-to-farm, farmers' political clout, the general farming environment, the degree of chemical use, and therefore the degree of externality.

The conditions in expressions (3) through (6) can be solved for the optimal input combination of capital ($k$*), labor ($l$*), chemicals ($c$*), and miscellaneous inputs ($r$*) as functions of the parameters p, $\phi$, $\rho$, $\tau$, $\lambda$, $\theta$, $\alpha$, $\beta$, and $m$:

(7) $$k^* = k^*(p, \phi, \rho, \tau, \lambda, \alpha, \beta; \theta, m),$$

(8) $$l^* = l^*(p, \phi, \rho, \tau, \lambda, \alpha, \beta; \theta, m),$$

(9) $$c^* = c^*(p, \phi, \rho, \tau, \lambda, \alpha, \beta; \theta, m),$$

(10) $$r^* = r^*(p, \phi, \rho, \tau, \lambda, \alpha, \beta; \theta, m).$$

Note that $\partial c^*/\partial\alpha < 0$, suggesting that as the regulatory climate is perceived to be more stringent, chemical use diminishes (*ceteris paribus*). Also note that $\partial c^*/\partial\beta < 0$, suggesting that as the production process is perceived to generate more pollution damage per unit, less chemicals will be used (*ceteris paribus*). The optimal quantity of inputs demanded by the farmer can then be substituted into the production function to derive the optimal quantity produced:

(11) $$q^* = \theta q^*(k^*, l^*, c^*, r^*; m).$$

The implicit function in (9) suggests that the amount of chemicals a farmer uses depends on the following: product price (p), the implicit rental value of capital ($\phi$), the wage rate ($\rho$) of hired labor, the price per pound of chemical inputs ($\tau$), the price of miscellaneous inputs ($\lambda$), and the anticipated regulatory- and conflict-related costs associated with the farming environment (which are affected by history of right-to-farm conflicts, political clout of the farm population, degree of chemical use and externalities, etc). These relationships are subject to technological/structural constraints (size, profitability, regional factors, etc.) and limitations in management capability (education, age, experience, etc.). If output and input prices are held constant, which is the case in the short run or with cross-section data, then chemical use becomes dependent on management capability, technology, structural factors, perceived regulatory climate, expected external costs associated with chemical use, and other farm and farmer characteristics. The empirical goal of this paper is to see how these factors affect chemical use reductions.

## Data, Econometric Models, and Estimation

The dependent variables of interest are the levels of chemical use. Given the purpose of this analysis, it is useful to obtain such information by type of chemical. Farm-level data on specific chemicals is hard to find in conjunction with farm structural, regulatory, and operator characteristics. This necessitated the use of the only existing comprehensive data available in an intensively urban farming environment—data that unfortunately are not recent. The data was based on the Survey of New Jersey Farms (FARMS), a unique survey conducted in 1994 (Adelaja 1995). The FARMS survey involved a re-survey of 216 farmers that had previously participated in the Farm Costs and Returns Survey (FCRS) conducted by the National Agricultural Statistics Service (NASS). U.S. Department of Agriculture and congressional approval was required in order to re-survey these farms and to use the farm cost and returns survey.

The FCRS provides information about aggregate farm expenses and incomes, as well as more detailed information about input use (by commodity category), revenues (by product category), cash expenses, and field operations. For example, information on seed, fertilizer, hired labor, contract labor, family labor, machinery used (by commodity), and machinery operating costs was available. Complete information was available for 206 of the farmers surveyed. The permission granted by the U.S. Congress and NASS allowed the FCRS data to be combined with the FARMS survey data. The combined database was the data source for this study.

In addition to usual data through FCRS, the FARMS survey provided information on chemical use, the structure and location of farms, socio-economic and socio-demographic characteristics, and opinions and attitudes about regulatory, taxation, business climate, land use, marketing, farmland retention, production system, and public policy issues. The FARMS survey also provided information on the extent to which farmers faced right-to-farm conflicts; their perception about land, water, soil, and other regulations; and where in the state they are located. The information on right-to-farm conflicts and farmers' perception about the regulatory climate reflects not only the intensity of conflicts faced by farmers, but also the perceptions about the friendliness of the local environment in which farmers operate.

One of the survey questions asks farmers how their use of chemicals per acre has changed over the previous five years with regard to insecticides, fungicides, herbicides, and fertilizer. The response categories for each of the four chemicals were as follows: 1 = increased, 2 = stayed the same, 3 = decreased, and 4 = do not use. Table 1 provides the distribution of responses to questions about the four chemical types. These responses served as the basis for constructing the dependent variables in this analysis as binary variables, i.e., if a farmer has decreased his/her use of chemicals over the preceding five years, then the choice variable takes on the value of one; otherwise, no decrease and an increase in chemicals takes a value of zero.

Based on the categories of causal factors hypothesized from equation (9) and information available from the data source, the following proxies for the hypothesized determinants of farm chemical usage were identified: (i) farm size, (ii) farm profitability, (iii) primary farming activity, (iv) location or region of the farm, (v) ownership structure, (vi) changes in land use, (vii) regulatory climate, (viii) conflicts with neighbors, (ix) farmer socio-economic and socio-demographic characteristics (e.g., age, farming experience, management capability, and education), (x) degree of innovation and production efficiency, and (xi) exposure to crop and livestock damage. The expected effects of these variables can be deduced from the signs of $\partial c^*/\partial \alpha$ (< 0) and $\partial c^*/\partial \beta$ (< 0). Since $\alpha$ is the farmer's perception of how much he or she will be required to internalize the external costs, the higher the value of $\alpha$, the less the use of a given chemical. Similarly, since $\beta$ is the farmer's perceived per unit cost of addressing externalities, the higher this perceived cost, the lower the level of chemical use.

Farm size can influence adoption of technology and farmer behavior (Feder 1980). Similarly, it is our *a priori* expectation that farmers who operate larger or more profitable farms, vis-à-vis other farmers, may perceive higher externality costs from their large-scale chemical use and higher regulatory risks that could internalize these costs ($\alpha$ and $\beta$), and, therefore, may use less chemicals. Conceivably, small farms may lack the managerial capability and efficiency needed to be optimal in chemical use, or may be less knowledgeable about how to minimize chemical use; or, their activities could be less pronounced. Therefore, such farmers would be expected to use more chemicals.

A more profitable farm is expected to have greater managerial ability and to exhibit greater efficiency and greater cost consciousness (including expected externalities-related regulatory costs), and is thereby expected to be more capable of reducing chemical use. It is therefore our *a priori* expectation that farmers with higher profit per acre would reduce their chemical use due to perceived higher $\alpha$ and $\beta$.

With respect to primary farming activity, chemical needs and utilization should differ for various types of crops. Farmers who grow different products face different challenges in their cultivation practices. For example, the needs of nurseries should differ from those of field crop producers.

**Table 1. Changes in Chemical Use Among New Jersey Farmers in the Past Five Years**

| Chemical Type | Do Not Use | Decreased | Increased | No Change | Total |
|---|---|---|---|---|---|
| Insecticide | 32% | 18% | 6% | 44% | 100% |
| Fungicide | 44% | 15% | 9% | 32% | 100% |
| Herbicide | 20% | 18% | 7% | 55% | 100% |
| Fertilizer | 10% | 16% | 7% | 67% | 100% |

Each farming type is expected to exhibit a different type and degree of chemical use, perhaps leading to different perceptions about (i) the externalities arising from their degree of chemical use, and (ii) perceived regulatory and other responses in their farming environment. This could lead to varying perceptions about $\alpha$ and $\beta$. However, no *a priori* expectation is made with respect to the sign of the coefficients for different farming types.

Regional differences in farming practices should also imply differences in chemical use. New Jersey is a diverse state, containing areas ranging from very urban to very rural. Farms in different areas may face different business circumstances, soil types, external pressures from neighbors to be environmentally considerate, or expected regulatory implications of their chemical use. For example, farmers in the more urbanized counties could conceivably have reduced chemical use more significantly due to the pressure from non-farm neighbors. Hence, location and regional differences are expected in the patterns of chemical dependence and reduction, based on the perceived levels of $\alpha$ and $\beta$. No *a priori* expectations about the signs of regional variables were formed, except for the fact that regions with more stringent regulatory environments were more likely to reduce chemical use.

Owner-operators are expected to be more conservative in chemical use than renters because they would expect a larger long-term cost implication of non-compatibility with their neighbors (see Nkamleu and Adesina 2000). They could also be more sensitive to other long-term cost implications of their externalities and the potential regulatory backlashes. It is, therefore, our *a priori* expectation that farmers who own their land have a higher perception of $\alpha$ and $\beta$, and are often interested in conservation of their land, and, hence, have lower chemical use.

The effect of productive acreage increase or decrease on chemical use helps understand the land use intensity and chemical use relationships. No *a priori* expectation is made about land use change, perceived $\alpha$ and $\beta$, and chemical use decisions.

A more stringent regulatory environment should automatically imply a higher level of $\alpha$, but the type of regulation could mean a lower or higher level of $\beta$, depending on whether it is designed to work in tandem with other incentives that could be cost-saving for farmers (e.g., BMP versus a fine).

Farmers are likely to be more cautious in their use of chemicals when their neighbors have previously challenged them or engaged them in conflicts, which often tend to be expensive. We, therefore, expect that the perception about $\alpha$ and $\beta$ by a farmer who has faced conflicts will be higher than that of a farmer who has not faced such challenges. Our *a priori* expectation is, therefore, that conflict with neighbors induces farmers to reduce their chemical use. Even though it goes beyond the scope of the current paper, we recognize a possible relationship: that responsible chemical use itself could reduce the likelihood of conflicts, or that excessive chemical use can trigger conflicts. For instance, Duke and Malcolm (2003) provide extensive discussion about such endogenous threat effects. Given the cross-section nature of the data, a rigorous test of causality and endogeneity was not possible. Education and experience in farming are likely to influence chemical use (Nkamleu and Adesina 2000). It is our *a priori* expectation that better educated and more experienced managers will perceive higher $\alpha$ and $\beta$, vis-à-vis others, and, therefore, will utilize less chemicals. Educated and experienced managers are less likely to perceive that they have *carte blanche* and are expected to be better exposed to rules and regulations, neighbors concerns, and the penalties associated with non-conformity. They are also likely to have been more exposed to extension programs related to right-to-farm, conflict management, and the potential of the non-farm public to find excessive chemical use to be irksome. Farmers with more education are also potentially more knowledgeable about alternative farming practices, and, therefore, are more likely to reduce chemical use.

Farmers with more experience may have a higher level of management skills necessary to adopt chemical-reducing practices. Older farmers may be more entrenched in their farming practices and, therefore, less likely to reduce chemical use. On the other hand, older farmers generally have more experience, and may be more able to reduce chemical use, especially if they have a higher level of management skills.

Since chemicals are costly, an innovative farmer would be expected to keep chemical use as low as possible and probably use other means to achieve profitability. The perception of $\alpha$ and $\beta$ could also be high due to better understanding of their farming environment.

Farmers facing severe wildlife damage are expected to try to boost productivity by using more chemicals. If the damage from deer significantly outweighs potential perceived costs of $\alpha$ and $\beta$, more chemicals could still be applied. Neighbors in areas exhibiting severe wildlife presence may also be more tolerant to chemical use, as their preoccupation with wildlife may help reduce their focus on farming activities.

To test the hypotheses above, variables from both FCRS and FARMS were included as exogenous variables in a logit chemical use reduction model. Gross farm income (*IGFI*), which is a measure of the sales volume, is used as a proxy for farm size. Net income per acre (*PROFIT*) is used to proxy farm profitability. Five dummy variables were constructed and used as indicators of primary crop produced or commodity group effects. These include nursery crops (*DNURSE*), vegetable crops (*DVEG*), dairy farms (*DDAIRY*), growers of fruit or berry (*DFRUIT*), and poultry, livestock, and horse farms (*DANIMAL*). The base category is cash grain and field crops.

Regional dummy variables were constructed for central (*REG1*), northern (*REG2*), and northeast New Jersey (*REG3*). The base region is southern New Jersey. The southern region (Camden, Gloucester, Atlantic, Salem, Cumberland, and Cape May counties) is relatively rural and agricultural, although Camden County, which is adjacent to Philadelphia, is relatively urban and suburban. The central region (Middlesex, Mercer, Monmouth, Ocean, and Burlington counties) is mostly suburban in nature, with some rural/agricultural areas. The northern region (Morris, Sussex, Warren, Hunterdon, and Somerset counties) is also a mixture of suburban and rural areas. The northeast region (Bergen, Hudson, Passaic, Essex, and Union counties) is highly populated, considered the suburbs of New York City, and is extremely suburban mixed with urban areas such as Newark.

An additional dummy variable is introduced to capture the Pinelands, which is governed by specific regulations related to agricultural production designed to preserve its natural resource base and to enhance environmental quality. Within the Pinelands area, limits are set on specific chemical use and on such activities as spraying. Located in the southern part of New Jersey, the Pinelands occupies 22 percent of New Jersey's total land base. Under the Pinelands Comprehensive Management Plan, the Pinelands Commission regulates all land use in the Pinelands. Farms located in the Pinelands are expected to be more conservative in their use of chemicals due to their perception of regulations in the region. A dummy variable was constructed for farmers located within the Pinelands (*DPINE*). Information was available from the data on farmer attitudes and impressions.

The percentage of total acreage operated that the farmer owns (*ACOWNPCT*) is used as a proxy for ownership. Dummy variables indicating farmers who have increased their productive acreage (*DINCAC*) and farmers who have decreased their acreage (*DDECAC*) are used as proxies for changes in land use and farm size. Surveyed farmers were asked if they have increased production without farming additional land through various techniques such as double cropping, improved irrigation systems, improved fertilizer and herbicide management, etc. Such data is used as the basis for determining land use change.

To capture the regulatory environment, four attitudinal indices showing whether farmers feel that regulations in New Jersey have had negative financial effects on their operations were constructed. The regulatory index (*REGFIN*) is a summary index that measures the financial effect that farmers felt regulations have had on their farm operation. *REGFIN* includes effects from all regulations, including local zoning, water use, waste disposal, taxes, and more. The variables *REGWATER*, *REGSOIL*, and *REGLAND* are similar measures of the financial effect of regulation with regard to water use, soil conservation, and land use, respectively.

To capture the effects of conflicts with neighbors, a dummy variable indicating whether or not a farm has experienced right-to-farm conflicts with nearby residents (*DRTFCON*) is used as a proxy for conflicts with neighbors. Based on survey responses, farmers who indicated experience of right-to-farm conflicts with nearby residents are coded one; if they did not, the data is coded zero. This provided the basis to identify the effect of right-to-farm conflicts on chemical use decisions.

To capture the effects of socio-demographic factors on chemical use choices, operator age (*OPERAGE*), experience (*EXPER*), and education (*OPEDUC*) are included. An innovation variable (*INNOV*) is also constructed and included to test the effects on chemical use. Similarly, a variable constructed to measure how extensively a farmer uses various information sources (*INFOIND*) such as other farmers, the Farm Bureau, extension resources, the New Jersey Department of Agriculture, and the U.S. Department of Agriculture is included. Given the severe deer damage problems faced by New Jersey farmers, the cost that a farmer incurs to reduce deer and wild animal damage (*DAMCOST*) is used as a proxy for prior wildlife damage exposure.

On the basis of equation (11) and the discussion above, the following models were estimated. For each chemical use reduction dependent variable ($C_i$) and a set of independent variables ($x_{ji}$), logit econometric specifications are used. For the logit econometric specifications, the functional form of the model can be given as

$$(12)\qquad P[C_i = 1 \mid x_{1i}, \ldots, x_{ki}] = \frac{1}{1+\exp(-\beta_1 x_{1i} - \ldots - \beta_k x_{ki})} = \frac{1}{1+\exp(-\sum_{j=1}^{k}\beta_j x_{ji})}.$$

The maximum likelihood function for the expression in (12) can be given as

$$(13)\qquad \ln[L(\beta_1, \ldots, \beta_k)] = -\sum_{i=1}^{n}(1-C_i)\sum_{j=1}^{k}\beta_j X_{ji} - \sum_{i=1}^{n}\ln(1+\exp(-\sum_{j=1}^{k}\beta_j x_{ji})).$$

Therefore, each logit specification for chemical use reduction is estimated by a maximum likelihood procedure that generates estimator values by maximizing the log-likelihood function in equation (13), i.e.,

$$\ln[L(\hat{\beta}_1, \ldots, \hat{\beta}_k)] = \max \quad \ln[L(\beta_1, \ldots, \beta_k)].$$

The dependent variables for the four logit models are *FERT*, *INSECT*, *FUNG*, and *HERB* for fertilizer, insecticide, fungicide, and herbicide uses, respectively. For expediency, each chemical use equation is estimated independently.

## Empirical Results

The estimated coefficients for the four logit model estimations are reported in Table 2. Estimated $R^2$'s range from 0.29 for the insecticide equation to 0.48 for the fungicide equation.

### *Fertilizer Utilization*

The McFadden $R^2$ statistic for the fertilizer equation is 0.37. The coefficient for *DINCAC* is significant at the $\alpha = .10$ level. The finding that farmers who increased their acreage experienced reduced fertilizer use per acre indicates that larger or growing farms are better able to reduce their reliance on fertilizer. The use of fertilizer and the associated externality costs are also likely to be noticed by the public, with potential long-term regulatory risks and anticipated pollution-related costs. Therefore, farms that are increasing in size seem to be sensitive to the extent of their fertilizer input use.

The coefficient for *DRTFCON* is significant at the $\alpha = .05$ level and, as expected, the sign is consistent with *a priori* expectations. That is, conflicts from nearby residents induce farmers to reduce fertilizer use. Such conflicts are costly and tend to reduce the viability of farms. Possibly, farmers are reducing chemical use in reaction to these conflicts in order to enhance their sustainability.

**Table 2. Parameter Estimates of Chemical Use Logit Models**

| | Chemical Type | | | | |
|---|---|---|---|---|---|
| Variable | Fertilizer | Insecticide | Fungicide | Herbicide | Description |
| *INTERCEPT* | 2.4926 | 2.0011 | 1.6324 | 2.2688 | Intercept |
| *IGFI* | -1.21E-6 | -3.08E-6* | -5.57E-7 | -2.05E-6 | Gross farm income |
| *PROFIT* | -0.00056 | 0.000011 | -0.0008** | -0.0006** | Net income per acre |
| *DNURSE* | 165.1 | 2.4242** | 7.4083* | 1.8193 | Nursery crops |
| *DVEG* | 0.1372 | 1.9722** | 3.2106** | 2.2301** | Vegetable farm |
| *DDAIRY* | 0.8908 | -0.0831 | 11.7170 | 1.1565 | Dairy farm |
| *DFRUIT* | -0.1921 | 0.0664 | 0.2695 | 1.0965 | Tree fruit and berry farm |
| *DANIMAL* | -0.9628 | 1.7808 | -1.6444 | 1.8577 | Poultry cattle horse farm |
| *REG1* | 0.6677 | 0.3075 | 2.1424** | 1.2398 | Central New Jersey |
| *REG2* | 1.1633 | 0.0747 | 1.1469 | 0.1590 | Northwest New Jersey |
| *REG3* | -154.1 | 9.3629 | 3.9646 | 8.2993 | Northeast New Jersey |
| *ACOWNPCT* | -0.1335 | -0.1024 | -0.0871 | 0.0727 | Acres owned percentage |
| *DINCAC* | -1.5872** | -0.5245 | -2.6737* | -2.2668* | Increased acreage |
| *DDECAC* | -1.0576 | -1.0968 | -1.3002 | -2.0203* | Decreased acreage |
| *DRTFCON* | -2.2811* | -1.5885** | -3.0672* | -0.9791 | Right-to-farm conflicts |
| *DPINE* | -1.1600 | -0.7380 | -2.1219 | -2.5620* | Farm within Pinelands |
| *EXPER* | -0.0500 | 0.00341 | -0.0225 | -0.0121 | Operator experience |
| *OPERAGE* | 0.0160 | -0.00273 | 0.00782 | 0.0182 | Age of operator |
| *OPEDUC* | -0.1699 | -0.4456 | -0.4090 | -0.5133** | Education of operator |
| *INNOV* | -0.1023 | -0.00809 | -0.2285 | -0.0823 | Innovation index |
| *INFOIND* | -0.9540 | -0.4233 | -0.5311 | -1.2653** | Use of information |
| *DAMCOST* | 0.00104 | 0.00103 | 0.00086 | 0.000355 | Animal damage cost |
| *REGFIN* | 0.1007* | 0.0660 | 0.0591 | 0.0612 | Regulation index |
| *REGWATR* | -0.1918 | -0.7758* | -1.4440* | -0.5726 | Regulation—water |
| *REGSOIL* | -0.5421 | 0.1199 | 1.3741** | 0.1638 | Regulation—soil |
| *REGLAND* | 0.1556 | 0.0907 | 0.4399 | 0.0446 | Regulation—land use |
| Chi Square | 45.779 | 33.859 | 45.660 | 40.400 | |
| p-value | 0.0068 | 0.1110 | 0.0070 | 0.0265 | |
| McFadden $R^2$ | 0.37 | 0.29 | 0.48 | 0.33 | |

A single asterisk (*) indicates that the coefficient is significant at the $\alpha = .05$ level. A double asterisk (**) indicates that the coefficient is significant at the $\alpha = .10$ level.

The coefficient of *REGFIN* is significant at the $\alpha = .05$ level and positive. This suggests that farmers who feel that regulations have had negative financial effects on their operations tend to intensify fertilizer use, possibly in an attempt to raise productivity, and hence, to recapture lost profits. As indicated above, the expected sign of *REGFIN* depended on the type of regulation. As Table 2 shows, the marginal effects on the probability of increasing fertilizer use are all zero, except for the marginal effects associated with nursery farms (*DNURSE*). The marginal probability for *DNURSE* is so high because of the 39 nursery farms in the data set, 100 percent have either increased or not changed their fertilizer application over the past year. The insignificance of *DAMCOST* suggests that farmers do not increase fertilizer use in order to make up for lost production from wildlife damage.

The fact that fewer variables are significant in the fertilizer model compared to the other three chemical use models may suggest a structural difference in fertilizer use demand. Fertilizer use is correlated with yield and production. While the other chemicals are also related to yield, they also tend to be utilized on demand when a problem arises. Farm characteristics, farmer socio-demographic and attitudinal characteristics, and other non-market factors seem to play less of a role in determining fertilizer use. One would expect input prices and other pecuniary factors to play a more prominent role in fertilize use.

### *Insecticide Utilization*

The McFadden $R^2$ statistic for the insecticide equation is 0.29. The coefficient of *IGFI* is statistically significant at the $\alpha = .05$ level and negative, again suggesting that larger farms exhibit greater likelihood of reducing insecticide use than do smaller farms. This may reflect the need of large farms to be more chemically conservative because the cost implications of excessive chemical use are more significant for them. It is also consistent with the notion that larger farms at the urban fringe must be more cautious because they are more noticeable and can easily draw the attention of their neighbors.

Nursery farms (*DNURSE*) and vegetable farms (*DVEG*) exhibit a greater likelihood of increasing insecticide use relative to field crop farms. This is consistent with the notion that these higher value crops are more reliant on chemicals because the potential loss due to low productivity is far greater than with lower value crops.

The coefficient of *DRTFCON* is statistically significant at the $\alpha = .10$ level and is negative, suggesting that conflicts from nearby residents induce farmers to reduce insecticide use. This finding further suggests that while these conflicts are costly, they have the tendency to mitigate the adverse environmental impacts of farming. Finally, the coefficient of *REGWATR* is statistically significant at the $\alpha = .05$ level and negative, suggesting that farmers who feel that they are constrained by water use regulations are more likely to have decreased their use of insecticides. In other words, farmers who are reducing water use may be forced to reduce insecticide use to maintain the insecticide/water concentration. The insignificance of *DAMCOST* suggests that farmers do not increase insecticide use in order to make up for lost production from wildlife damage.

### *Fungicide Utilization*

The McFadden $R^2$ statistic for the fungicide equation is 0.48. The results are similar to those of the insecticide model. The coefficient of *PROFIT* is negative and statistically significant at the $\alpha = .10$ level, suggesting that farms that are more profitable have been more successful at reducing their use of fungicides. Consistent with the insecticide model, the coefficients of *DNURSE* and *DVEG* are statistically significant and positive. The coefficient of *REG1* is positive and statistically significant at the $\alpha = .10$ level, suggesting that farms in central New Jersey are more likely to have increased their use of fungicides, relative to farms in southern New Jersey, *ceteris paribus*. This area of New Jersey also tends to be more greenhouse-, nursery-, and vegetable-intensive and has moved rapidly toward high-value agriculture. The coefficient for *DINCAC* is negative and statistically significant at the $\alpha = .05$ level. This suggests that farms that are increasing in size are more likely to have reduced fungicide use. This result is similar to the finding for the fertilizer demand model.

The coefficient of *DRTFCON* is statistically significant and negative, again suggesting the effects of right-to-farm conflicts on the environment. The coefficient of *REGWATR* is statistically significant at the $\alpha = .05$ level and negative, suggesting fungicide effects of concern about water regulation. Finally, the coefficient of *REGSOIL* is significant at the $\alpha = .10$ level and positive. Farmers who feel that land use regulations have had adverse financial effects on their operations appear to have attempted to make up for the loss by increasing fungicide use. The insignificance of *DAMCOST* suggests that farmers do not increase fungicide use in order to make up for lost production from wildlife damage.

*Herbicide Utilization*

The McFadden $R^2$ statistic for the herbicide equation is 0.33. The coefficients for *DINCAC*, *DDECAC*, and *DPINE* are statistically significant at the $\alpha = .05$ level, and the coefficients for *DVEG*, *OPEDUC*, and *INFOIND* are statistically significant at the $\alpha = .10$ level. Farms that are more profitable (*PROFIT*) are more likely to have decreased their use of herbicides. Vegetable farms are more likely to have increased their use of herbicides relative to field crop farms, but unlike with the insecticide and fungicide models, nursery farms are not. This would be expected since weed control is less of an issue with nursery operations vis-à-vis insecticides and fungicides and since such issues are more relevant to vegetable growers. Consistent with the results of the fertilizer and fungicide models, farms that have increased their acreage (*DINCAC*) have been more likely to have reduced their use of herbicide. On the other hand, farms that have decreased their acreage (*DDECAC*) are more likely to have decreased their herbicide use.

Farms that are located within the Pinelands are more likely to have decreased their use of herbicides relative to farms located outside of the Pinelands. The Pinelands is known to have relatively well defined environmental standards. Farmers with higher education levels are more likely to have reduced their use of herbicides. Finally, farmers who utilize available information sources (e.g., extension) are more likely to have reduced their use of herbicides. The finding that better informed farmers have been better able to reduce chemical use is consistent with the notion that better educated farmers are more conservative in chemical use than others.

Some interesting similarities among the four chemical models in Table 2 are worthy of close evaluation. Vegetable growers are more likely than growers of field crops to have increased insecticide, fungicide, and herbicide usage. The coefficient for *DINCAC* is negative and statistically significant except in the case of insecticides. The coefficient for *DRTFCON* is consistently negative and statistically significant, except in the case of herbicides. While *REGFIN* affects fertilizer use only, *REGSOIL* affects fungicide use only, and *REGWATR* affects only fungicide and insecticide uses. The variables *INFOIND* and *OPEDUC* affect herbicide use, but not fertilizer, insecticide, or fungicide uses. One would expect that farmers who make better use of available information from sources such as extension and state departments of agriculture and farmers who are better educated would be more conservative in chemical use. Also, *DPINE* affects only herbicide use. Overall, the results seem to indicate significant consistency in the way farmers make decisions about changes in chemical use. The insignificance of *DAMCOST* suggests that farmers do not increase herbicide use in order to make up for lost production from wildlife damage.

## Summary and Conclusions

On-farm chemical use is an important issue, especially at the urban fringe, where non-farmers are increasingly locating closer to existing farms. Considering the potential problems and costs associated with right-to-farm conflicts and regulation in environments where non-farmer neighbors are more likely to complain, urban fringe farmers are expected to be under pressure to manage their use of chemicals to levels that minimize adverse actions by neighbors while optimizing productivity.

It is shown that chemical use decisions are consistent across chemical types, except in the case of fertilizer. Fertilizer use may be more dependent on market factors than on non-market factors, probably because yield is more correlated with fertilizer use than with other chemicals.

This analysis suggests that while regulatory factors do contribute to changes in chemical use, there also are other factors that influence changes in chemical use that are inherent in farmers and in farms. For example, it is found that profitable farms are more conservative in fungicide and herbicide use and that better educated farmers and those using available information sources are more conservative in chemical use. An important implication of this is that farmer education may be a more relevant tool in promoting less chemical-intensive farming. The impact of regulation is not clear, but appears to depend largely on the type of regulation.

Perhaps the most significant finding in this paper is that farmers who are experiencing conflicts with their neighbors are more likely to have reduced chemical use. That is, not only do right-to-farm conflicts reduce farm viability, but they induce farmers to reduce chemical use as well. The right-to-farm laws on the books in most states may help to temper some of the reductions in farm viability due to right-to-farm conflicts. The trade-off between farm viability and environmental quality is one that policy must obviously be careful to balance at the urban fringe.

The finding that farms with higher gross farm income are more likely to be decreasing their chemical use (relative to farms with lower gross farm income) suggests that larger farms find it easier to conserve chemicals. It may also suggest that excessive chemical use by these farms is more noticeable by their neighbors. This may also imply, however, that minimizing chemical use requires a higher level of management skills, which small-scale farmers typically lack.

Farming at the urban fringe is moving away from large commercial farms toward small, "gentleman" farms (Daniels 1986). It is also moving away from field crops toward chemically dependent, high-value vegetable and nursery crops. In fact, state agricultural economic development policies at the urban fringe have emphasized moving farmers toward high-value intensive agriculture, which also tends to be more chemically dependent. This suggests that a major challenge at the urban fringe may well be in balancing profitability with other non-economic sustainability considerations.

## References


Adelaja, A. 1995. "The 1994 Survey of New Jersey Farms." Mimeograph, the Department of Agricultural Economics and Marketing, Rutgers University, New Brunswick, NJ.

Adelaja, A., and K. Friedman. 1999. "Political Economy of Right-to-Farm." *Agricultural and Applied Economics* 31(3): 565–579.

Adelaja, A., T. Miller, and M. Taslim. 1998. "Land Values, Market Forces, and Declining Herd Size: Evidence from an Urban-Influenced Region." *Agricultural and Resource Economics Review* 27(1): 63–71.

Akca, H., M. Sayili, and A. Kurunc. 2005. "Trade-off Between Multifunctional Agriculture, Externality and Environment." *Journal of Applied Sciences Research* 1(3): 298–301.

Barbash, J.E., G.P. Thelin, D.W. Kolpin, and R.J. Gilliom. 2001. "Major Herbicides in Ground Water: Results from the National Water-Quality Assessment." *Journal of Environmental Quality* 30(3): 831–835.

Blair, A., and S.H. Zahn. 1995. "Agricultural Exposure and Cancer." *Environmental Health Perspectives* 103(Supplement 8): 205–208.

Blair, A., S.H. Zahn, N.E. Pearce, E.F. Heineman, and J.F. Fraumeni. 1992. "Clues to Cancer Etiology from Studies of Farmers." *Scandinavian Journal of Work and Environmental Health* 18(4): 209–215.

Bosch, D.J., Z.L. Cook, and K.O. Fuglie. 1995. "Voluntary versus Mandatory Agricultural Policies to Protect Water Quality: Adoption of Nitrogen Testing in Nebraska." *Review of Agricultural Economics* 1(17): 13–24.

Bricker, J.T., A.G. Martin, C.L. Janssen, and F. Whitford. 2004. "Are All These Rules Necessary? Extension Pesticide Programming with Regulatory Purpose." *Journal of Extension* 42(5): 1.

Clouser, R.L. 2005. "Issues at the Rural-Urban Fringe: Land Use Conflicts." EDIS Document No. FE549, Department of Food and Resource Economics, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

Daniels, T.L. 1986. "Hobby Farming in America: Rural Development or Threat to Commercial Agriculture?" *Journal of Rural Studies* 2(1): 31–40.

David, A. 2004. "Multifunctionality, Agricultural Policy, and Environmental Policy." *Agricultural and Resource Economics Review* 33(1): 8–17.

Dobbs, T.L., and J.D. Smolik. 1996. "Productivity and Profitability of Conventional and Alternative Farming Systems: A Long-Term On-Farm Paired Comparison." *Journal of Sustainable Agriculture* 9(1): 63–79.

Duke, J.M., and S.A. Malcolm. 2003. "Legal Risk in Agriculture: Right-to-Farm Laws and Institutional Change." *Agricultural Systems* 75(2): 295–303.

Dunlap, R.E., and C.E. Beus. 1992. "Understanding Public Concerns About Pesticides: An Empirical Examination." *The Journal of Consumer Affairs* 26(2): 418–438.

Feder, G. 1980. "Farm Size, Risk Aversion and the Adoption of New Technology under Uncertainty." *Oxford Economic Papers, New Series* 32(2): 263–283.

Fernandez-Cornejo, J., S. Jans, and M. Smith. 1998. "Issues in the Economics of Pesticide Use in Agriculture: A Review of the Empirical Evidence." *Review of Agricultural Economics* 20(2): 462–488.

Govindasamy, R., J. Italia, and A. Adelaja. 1998. "Predicting Consumer Risk Aversions to Synthetic Pesticide Residues: A Logistic Analysis." Report No. P-02137-1-98, New Jersey Agricultural Experiment Station, New Brunswick, NJ.

Hamilton, P.A., and D.R. Helsel. 1995. "Effects of Agriculture on Ground-Water Quality in Five Regions of the United States." *Ground Water* 33(2): 217–226.

Henderson, S. 2003. "Regulating Land Use Conflicts on the Urban Fringe: Two Contrasting Case Studies from Australian Poultry Industry." *Australian Geographer* 34(1): 3–17.

Knobeloch, L., B. Salna, A. Hogan, J. Postle, and H. Anderson. 2000. "Blue Babies and Nitrate-Contaminated Well Water." *Environmental Health Perspectives* 7(108): 675–678.

Kolpin, D.W., E.M. Thurman, and S.M. Linhart. 1998. "The Environmental Occurrence of Herbicides: The Importance of Degradates in Ground Water." *Earth and Environmental Science* 35(3): 385–390.

Lee, L.K. 1992. "A Perspective on the Economic Impacts of Reducing Agricultural Chemical Use." *American Journal of Alternative Agriculture* 7(1/2): 82–88.

Lopez, R.A., A.O. Adelaja, and M.S. Andrews. 1988. "The Effects of Suburbanization on Agriculture." *American Journal of Agricultural Economics* 70(2): 346–358.

National Sustainable Agricultural Information Service. 2009. "What Are Typical Questions That Callers Ask?" Available online at http://attra.ncat.org/who.html (accessed August 15, 2007).

New Jersey Statutes Annotated. 1998. New Jersey Right-to-Farm Act, as amended by P.L. 1998, c.48.

Nielson, E.G., and L. Lee. 1987. "The Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals: A National Perspective." Agricultural Economic Report No. 576, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

Nkamleu, G.B., and A.A. Adesina. 2000. "Determinants of Chemical Input Use in Peri-Urban Lowland Systems: Bivariate Probit Analysis in Cameroon." *Agricultural Systems* 63(2): 111–121.

Offermann, F., and H. Nieberg. 2000. "Economic Performance of Organic Farms in Europe." *Organic Farming in Europe: Economics and Policy* 5: 1–198.

Pacini, C., A. Wossink, G. Giesen, C. Vazzana, and R. Huirne. 2002. "Evaluation of Sustainability of Organic, Integrated and Conventional Farming Systems: A Farm and Field-Scale Analysis." *Agriculture, Ecosystems and Environment* 95(1): 273–288.

Padel, S. 2001. "Conversion to Organic Farming: A Typical Example of the Diffusion of an Innovation?" *Sociologia Ruralis* 41(1): 40–61.

Painter, K.M., and D.L. Young. 1995. "Combining Alternative and Conventional Systems for Environmental Gains." *American Journal of Alternative Agriculture* 10(2): 88–96.

Park, T.A., and L. Lohr. 1996. "Supply and Demand Factors for Organic Produce." *American Journal of Agricultural Economics* 78(3): 647–655.

Rendleman, C.M. 1991. "Agrichemical Reduction Policy: Its Effect on Income and Income Distribution." *Journal of Agricultural Economics Research* 43(4): 3–9.

Rigby, D., and D. Caceres. 2001. "Organic Farming and the Sustainability of Agricultural Systems." *Agricultural Systems* 68(1): 21–40.

Serra, T., D. Zilberman, B. Goodwin, and A. Featherstone. 2006. "Effects of Decoupling on the Mean and Variability of Output." *European Review of Agricultural Economics* 33(3): 269–288.

Thomson, G.D. 1998. "Consumer Demand for Organic Foods: What We Know and What We Need to Know." *American Journal of Agricultural Economics* 80(5): 1113–1118.

U.S. Department of Agriculture. 2005. "U.S. Fertilizer Use and Prices." Available at http://www.ers.usda.gov/Data/FertilizerUse/ (accessed August 12, 2007).

Van Driesche, R.G., J. Carlson, D.N. Ferro, and J.M. Clark. 1987. "Pesticides and Suburban Agriculture." In W. Lockeretz, ed., *Sustaining Agriculture Near Cities*. Soil and Water Conservation Society, Ankeny, IA.

Weaver, R., D. Evans, and A.E. Luloff. 1992. "Pesticide Use in Tomato Production: Consumer Concerns and Willingness to Pay." *Agribusiness* 8(2): 22–35.

Whittaker, G., B. Lin, and U. Vasavada. 1995. "Restricting Pesticide Use: The Impact on Profitability by Farm Size." *Journal of Agricultural and Applied Economics* 27(2): 352–362.

Yang, Y.-H., J. Yao, S. Hu, and Y. Qi. 2000. "Effects of Agricultural Chemicals on DNA Sequence Diversity of Soil Microbial Community: A Study with RAPD Marker." *Microbial Ecology* 39(1): 72–79.