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Impacts of High-efficiency Pesticide Sprayers on Michigan Apple Growers

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Impacts of High-efficiency Pesticide Sprayers on Michigan Apple Growers

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Abstract

This report analyzes the impacts of an MAES-supported innovation — the air-curtain sprayer — that reduces farmer use of pesticides 40 to 50 percent by volume relative to the conventional air-blast sprayer. The specific objectives here are: to generate estimates of the present value of benefits to Michigan apple growers attributable to the development, adoption and use of the air-curtain sprayer; and to determine how adoption patterns, alternative machines and costs of labor displacement affect these benefits. Results indicate that if the sprayer is adopted and used on 90 percent of Michigan apples, pesticide reductions in the range of 200,000 to 800,000 gallons per year are projected; the potential benefit to Michigan apple farmers from adoption and use of the sprayer on 100 percent of orchards would be $8 million per year; and depending on the actual rates of adoption over 20 years and the availability of alternative sprayers, the present value of the benefits to Michigan apple growers is projected to be between $1.3 million and $22 million.

Introduction

The Michigan Agricultural Experiment Station (MAES) has become increasingly interested in economic and environmental impact analysis for a variety of reasons: to help justify research expenditures in times of budget stress, to assist in meeting the requirements of the Government Performance Reporting Act and to provide information relevant to the determination of research priority issues. One area of particular interest is research on pest control techniques. Under current technology, pesticides are critical to the well-being of Michigan specialty crop industries, which provide the highest value per acre in Michigan agriculture and account for one-third of farm sales by value. However, the MAES does not have funds sufficient to support all promising lines of research into improved pest management (Specialty Crop Pesticide Committee [SCPC]). Consequently, information on impacts of MAES investments in pesticide-related research and development (R&D) is of special interest.

This report is an analysis of the impacts of an MAES-supported innovation — the air-curtain sprayer — that reduces farmer use of pesticides 40 to 50 percent by volume relative to the conventional air-blast sprayer. The specific objectives here are: to generate estimates of the present value of benefits to Michigan apple growers attributable to the development, adoption and use of the air-curtain

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sprayer; and to determine how adoption patterns, alternative machines and costs of labor displacement affect these benefits.

The next section of this report is a description of Michigan apple production and the air-curtain technology. The third section addresses methodological issues in quantifying benefits. Results are presented and discussed in the fourth section; the final section then draws conclusions.

Michigan Apple Production

Background

In 1996, Michigan produced 725 million pounds of apples, or 6.9 percent of U.S. production. Despite the lowest yields since 1977 (due largely to unusually cold and dry weather), in 1996 Michigan ranked fourth in state apple production, behind Washington (5.5 billion pounds), New York (1 billion pounds) and California (900 million pounds). Cash receipts from Michigan apples totaled $107 million, more than twice those of the next highest fruit crop (cherries). The state's apple-bearing acreage — 55,000 — is more than twice the 27,300 bearing acres for tart cherries (Michigan Department of Agriculture [MDA], 1997).

Michigan apple production relies on agricultural chemicals for fertilizer and weed, insect and fungus control. At least 37 fungicides, herbicides and insecticides are applied to Michigan apples (Table 1). Apple-growing counties in Michigan have relatively high application rates for pesticides (Hoppin et al, 1997, Figure 2.7), in part because the “per acre intensity of pesticide use is much greater where specialty crops are grown than it is in regions dominated by row-crop, small grain or forage-based systems” (Hoppin et al, p. 17). Application to apples accounts for more than 50 percent (by weight) of total Michigan application of pesticides such as captan, metiram, methomyl and propargite.

Technology

The technical innovation analyzed here is the air-curtain sprayer developed at Michigan State University and marketed under license by BEI Inc. This sprayer, with the trade name CURTEC, combines a number of innovative features to reduce pesticide use. The higher profile of the sprayer (it's 15½ feet tall) provides easier access to tree canopies. Atomizing the pesticide spray into a mist provides better coverage. The construction of the blowers creates a circular or “air-curtain” effect so that the pesticide “rolls” onto the fruit much the way a fog rolls in. The rolling provides better coverage on the back side of the fruit (away from the sprayer), allowing the farmer to spray each row on only one side. The circular motion of the pesticide mist also reduces drift, which is a problem with atomized sprays in conventional blowers because small droplets tend to suspend longer in the air. The sprayer can be pulled faster than conventional sprayers (4 mph vs. 3 mph), resulting in a labor savings. The air-curtain sprayer also contains a number of safety features, such as hydraulic switches designed specifically to prevent misapplication of pesticide in case of power loss.

Characteristics of the air-curtain mechanical sprayer.

Key characteristics:

- 15½ ft high
- atomized spray
- six "air-curtain" blowers
- targets canopy

Spray "rolls" onto fruit as a mist or fog, providing backside coverage and reduced drift.

Purchase price: $75,000, includes 75 hp tractor.

Coverage: 11 acres / hour.

Labor requirements: One hour cleaning and maintenance per spray operation, plus field time.

Pesticide use: 15 gal / acre.

Methods of Analysis

The Counterfactual Situation

When measuring the economic impact of research, counterfactual situations are used to estimate what would have happened in the absence of the innovation. This estimate includes defining the best alternative technique that would have been used. In the case of pesticides, there is considerable discussion about what the best alternative is. At the most basic level, the best alternative may be defined as the practice in place before the introduction of the air-curtain sprayer. A perhaps more realistic but also more complicated counterfactual scenario projects the

Table 1. Agricultural chemical applications: apples, Michigan, 1995.

Agricultural chemical[1]	Area applied	Applications	Rate per application	Rate per crop year	Total applied
	Percent	Number	Pounds per acre	Pounds per acre	1,000 pounds
Fertilizers					
Nitrogen	81	1.8	29	54	2,359
Phosphate	37	2.2	20	43	850
Potash	56	1.9	36	69	2,072
Herbicides					
2,4-D	13	1.1	0.47	0.52	3.7
Diuron	18	1.1	1.07	1.19	11.4
Glyphosate	35	1.2	0.58	0.66	12.4
Paraquat	37	1.1	0.44	0.51	10.0
Simazine	30	1.0	1.19	1.20	19.6
Terbacil	11	1.0	0.49	0.49	2.9
Insecticides					
Azinphos-methyl	93	3.5	0.67	2.32	116.4
Carbaryl	32	1.2	0.89	1.03	17.8
Chlorpyrifos	83	2.5	0.94	2.39	107.5
Clofentezine	34	1.0	0.13	0.13	2.4
Dicofol	2	1.7	1.21	2.05	2.4
Dimethoate	29	1.7	0.79	1.35	21.4
Endosulfan	17	1.4	0.96	1.32	12.3
Esfenvalerate	17	1.3	0.04	0.06	0.5
Fenbutatin-oxide	3	1.0	0.53	0.53	0.8
Formetanate hydro	5	1.4	0.80	1.15	3.2
Methomyl	53	2.0	0.57	1.14	32.8
Methyl parathion	13	2.0	0.45	0.91	6.5
Oxamyl	16	1.3	0.61	0.79	6.9
Permethrin	38	1.1	0.13	0.15	3.1
Petroleum distillate	60	1.1	28.59	31.03	1,005.3
Phosmet	50	1.9	1.32	2.56	68.7
Propargite	36	1.5	1.40	2.09	41.1
Fungicides					
Benomyl	31	2.7	0.26	0.68	11.3
Captan	89	5.8	1.88	10.97	526.9
Copper hydroxide	24	1.2	0.72	0.87	11.5
Copper oxychlosul	23	1.4	2.43	3.34	41.2
Copper sulfate	10	2.1	1.11	2.36	13.1
Fenarimol	58	4.0	0.06	0.23	7.2
Mancozeb	27	2.8	2.61	7.25	103.9
Metiram	64	3.8	2.27	8.58	294.6
Mycolobutanil	47	3.2	0.11	0.36	9.1
Streptomycin	28	2.0	0.22	0.42	6.4
Sulfur	36	3.3	6.72	22.14	433.6
Thiophanate-methyl	11	1.8	0.43	0.79	4.9
Triadimefon	18	2.2	0.08	0.18	1.7
Ziram	25	2.8	2.70	7.64	103.8
Other chemicals					
Cytokinins[2]	4	1.1	0.02	0.02	0.1
Gibberellic acid	5	1.3	0.02	0.02	0.1
NAA	44	1.2	0.02	0.02	0.6

[1] Insufficient reports to publish data for the following agricultural chemicals: ***herbicides*** — Atrazine, Bentazon, Dichlobenil, Napropamide, Norflurazon, Oryzalin, Triclopyr; ***insecticides*** — Bt (Bacillus thur.), Diazinon, Diflubenzuron, Fenthion, Malathion, Methoxychlor, Oxthioquinox, Phosphamidon, Potassium salts; ***fungicides*** — basic copper sulfate, Calcium polysulfide, Chlorothalonil, Copper resignate, Dinocap, Dodine, Ferbam, Maneb Oxytetracycline, Propiconazole; ***other chemicals*** — Allium sativum, Ammonium soap, Ethephon, NAD.

[2] Total applied is less than 50 pounds.

Source: Michigan Agricultural Statistics, 1996-97.

development and use of other sprayers or pest-control techniques as likely to occur over the time period of the analysis, particularly in the absence of the air-curtain sprayer.

There are two realistic choices for the best alternative sprayer. One is the conventional or air-blast sprayer, which sits relatively low to the ground and uses air “blasts” to drive pesticide droplets into the tree canopy and onto the fruit. The second is a tower sprayer with SmartSpray™ electronic (SONAR) sensing, introduced to Michigan in 1993 (Swinton et al., 1997). The sensing-tower sprayer (STS) is also 15 feet tall, allowing better access to the tree canopy. The sensors turn the spray on or off, depending on whether they sense that a tree is in the target area.

The selection of the appropriate alternative sprayer is complex. The R&D phases for the tower sprayer and the air-curtain sprayer occurred simultaneously. The development of the air-curtain sprayer spurred some or all of the R&D underlying the sensing-tower sprayer, so that alternative would not have existed — at least at its current level — without the investment in the air-curtain sprayer. The opposite scenario occurs when public investment in sprayer development drives off or crowds out other private R&D activity — for example, if investors fear that competition from the public sector will diminish any returns to innovation. In this case, sprayer technology might develop just as quickly with no public-sector investment. To suggest which, if either, of these scenarios might contain some truth would be pure speculation. Hence, this report uses both the air-blast and sensing-tower sprayers for comparison.

Present-value Analysis

The impacts of the sprayer are expected to persist over time and change from year to year as adoption increases, so present-value analysis is applied. Present-value analysis translates a time stream of monetary benefits and / or costs into a single number that represents today's value of the time stream. This method is appropriate for analysis of agricultural innovations (Belli, 1996; Robison and Barry, 1996).

Assessment of Pecuniary Impacts

The pecuniary impacts of the air-curtain sprayer are the changes in farm production costs, quantity and quality of product, and price received. The design of the air-curtain sprayer protects fruit from pests at least as well as conventional sprayers (Jones et al., 1996) yet reduces pesticide use by 40 to 50 percent (Swinton et al.). Therefore, it is assumed that the choice of sprayer has no effect on quantity (yield) or quality of fruit, and thus also no effect on price received. The reduction in pesticide costs, along with some labor savings, are the pecuniary benefits of the air-curtain sprayer. The costs of the sprayer are the greater capital investment costs— $75,000 for the air-curtain vs. $56,000 for the conventional air-blast unit (figures include the cost of a 75 hp tractor) — and slightly higher post-spray and annual maintenance costs. Based on a representative farm analysis (200 acres of semi-dwarf apples, 12 sprays per season) and a 10-year life cycle of the machinery, Swinton et al. estimate the annualized (at a 10 percent discount rate) net present cost per acre to be $289 for the air-curtain sprayer vs. $392 for the conventional sprayer and $315 for the tower sprayer with electronic sensors. Swinton et al. provide sensitivity analysis of these figures with respect to various farming scenarios (Table 2).

The maximum potential benefits are achieved if every Michigan apple acre is sprayed using the air-curtain sprayer. Based on 1996 bearing area of 55,000 acres (MDA, 1997), the pecuniary benefits to Michigan apple growers potentially could be $5.7 million annually if the best alternative is the conventional sprayer ($8 million based on non-bearing plus bearing area) and $1.4 million annually if the best alternative is the tower sprayer with electronic sensors. The distribution of these potential benefits across the major apple-growing counties ranges up to $1.6 million annually in Kent County, based on total apple area (Figure 1).

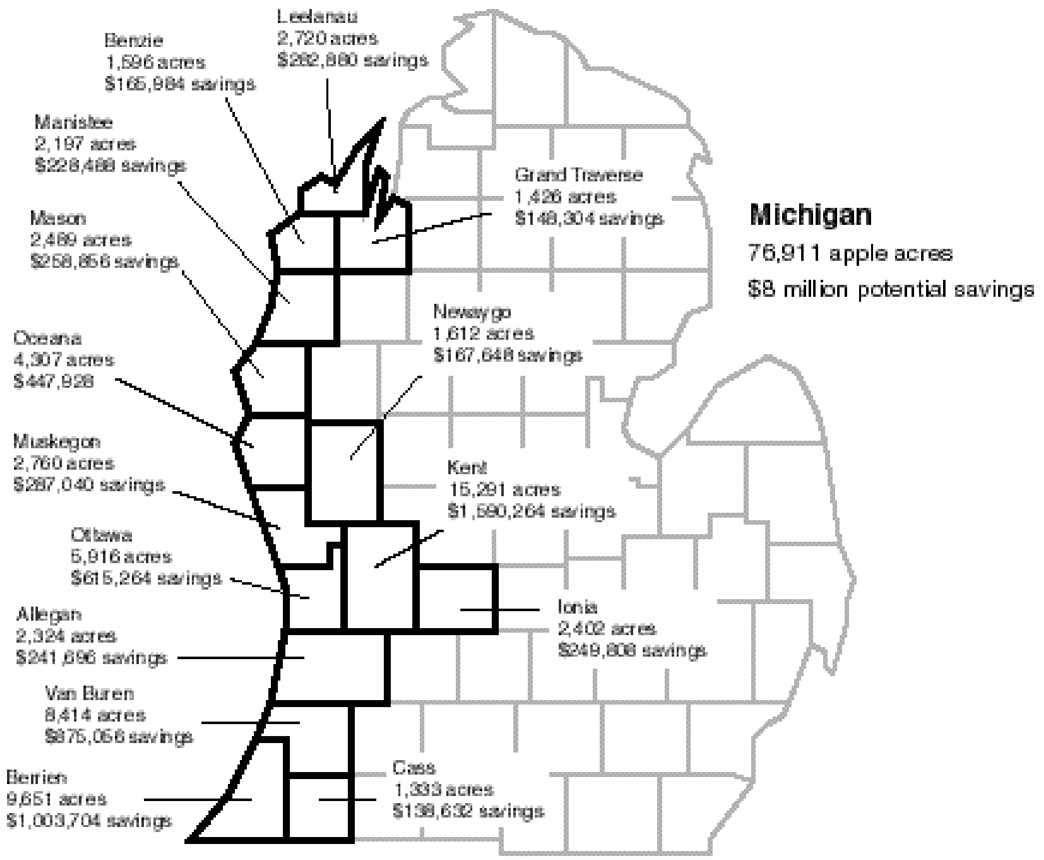
Many factors influence both the level of potential pecuniary benefits and the fraction of these benefits that is actually achieved. The level of potential benefits is affected by the size of the Michigan apple industry, which is relatively stable in area; purchase costs of the sprayer, which are expected to decline; pesticide cost savings, which are expected to increase as pesticide costs increase; and the replacement and obsolescence of the air-curtain sprayer as yet-to-be-invented machines enter the marketplace. The primary determinants of the fraction of the benefits achieved are the ability of the adopting farmer to realize the full pecuniary savings from the sprayer and the level and rates of adoption of the sprayer. As noted

Table 2. Annualized present value of cost of sprayer purchase and use, varying cases, by type of sprayer.

ASSUMPTIONS	Annualized net present cost at 10% of sprayer purchase and use ($/year)			
	Air-blast	Tower boom	Smart spray	Air-curtain
Base case:				
50% borrowed funds	392	347	315	289
10% discount rate				
9.75% loan interest				
200 apple acres				
current pesticide costs				
10 year sprayer life				
Changes in base case:				
12% loan interest	394	349	317	290
150 apple acres	411	367	340	313
Pesticide costs increase 20%	460	401	359	329
Pesticide costs increase 50%	561	482	424	390

Source: Swinton, Assuming-Brempong and van Ee, 1997, Tables A1-A3.

Figure 1. Maximum potential benefits of the air-curtain sprayer, for Michigan and by major apple-producing county.



above, the air-curtain sprayer is somewhat more complicated to use than the conventional sprayer; therefore, it is assumed that farmers achieve only 80 percent of the potential reduction in pesticide use, or a 40 percent reduction in volume relative to the air-blast sprayer.

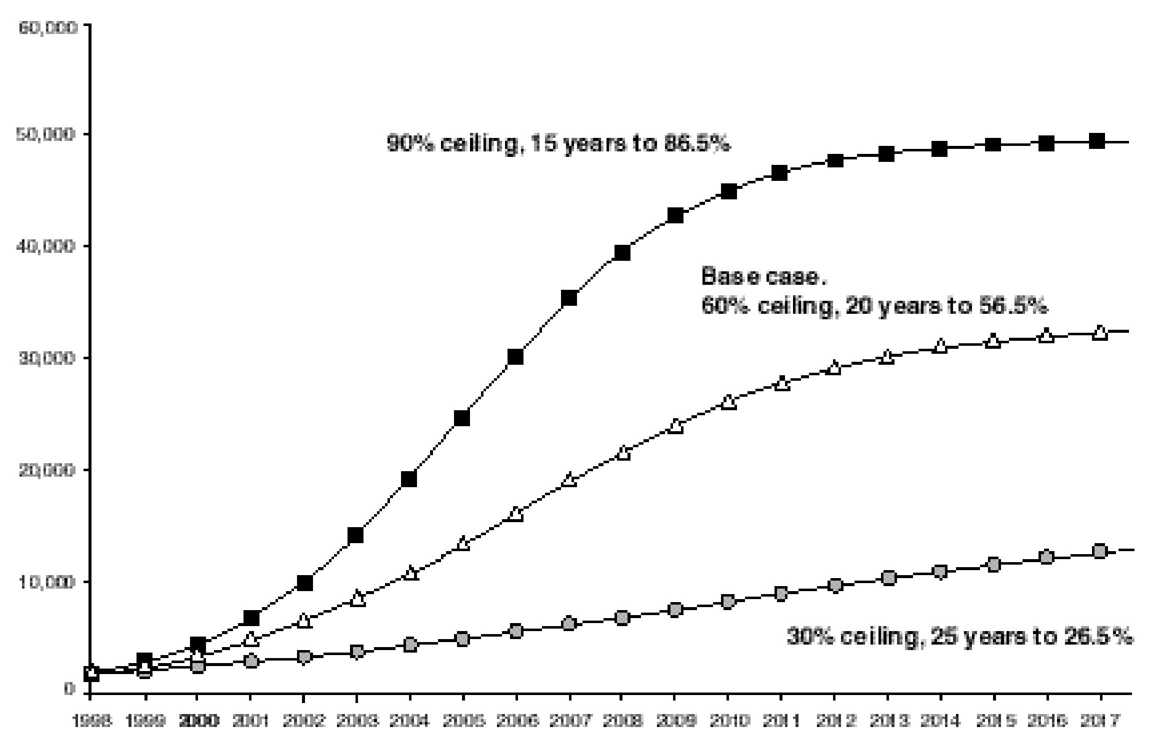
Adoption levels and rates are assumed to follow a logistic adoption path. The logistic curve, first applied to agricultural innovation by Griliches (1957) in his pioneering study on the adoption of hybrid corn, is an S-shaped curve in which the proportion of new adopters in any year is related to the cumulative number of adopters up to that year. The logistic formulation is appropriate and widely used for technology adoption extrapolations.

The logistic curve allows for a wide range of adoption rates and ceilings, so determining the appropriate curve for adoption of an innovation is somewhat subjective. At one extreme, 90 percent of Michigan farmers adopted hybrid corn within a period of about a decade (Griliches); at the other extreme, Michigan farmers have been investing in irrigation for nearly a century, with only about 10 percent of farmers adopting so far (the adoption ceiling is estimated to be 12 percent). To generate a base case, an adoption ceiling of 60 percent of farmers is assumed, with a 20-year time lag to reach an adoption level of 57 percent. This adoption path is approximately that of forage gathering and harvesting machinery (haybines, etc.) in the United States. Application of this adoption path to pesticide sprayers is appropriate because any type of machinery or durable-input investment results in an initial cash outlay that is compensated by decreased costs over the life of the machine. Krause and Black (1995) suggest that this tradeoff of current outlays for diminished future costs is a critical component of the farmer's adoption decision. Hence the base case adoption path is a reasonable projection of adoption of improved mechanical sprayers. Sensitivity analysis is used to generate alternative adoption paths (Figure 2).

Economic Assessment of Indirect Effects

The approach outlined so far focuses on the direct effects of the air-curtain sprayer on farm balance sheets and is used as the base case. However, the improved sprayer may have several indirect effects. This subsection describes the

Figure 2. Adoption paths used for sensitivity analysis.



methods used to calculate scenarios alternative to the base case, where the scenarios account for the costs of farm-labor displacement due to mechanization and reduced farm risk and/or damages from pesticides. In addition, this section addresses the potential impacts of reduced on-farm pesticide use on consumer demand for apples, but information to date is insufficient to quantify these potential impacts on farm balance sheets accurately.

Labor

Measurement of the costs of labor displacement follows the procedure set forth by Schmitz and Seckler (1970), who first introduced the issue of displaced labor into the economic analysis of agricultural mechanization. Schmitz and Seckler use a procedure that, in its simplest form, calculates the social cost of displaced labor to be equal to lost earnings. This approach is applied here, but the lost earnings are restricted to the amount lost in one year. This procedure would result, for example, from the idea that it would take the worker nine months on average to find a comparable job, with relocation costs equal to three months' pay. The shortened time frame also focuses on Michigan apple growers. Though it is unclear what proportion of labor displacement costs will be borne by growers, a scenario in which apple growers bear one year's lost earnings seems both a reasonable estimate of the social costs of displacement and a reasonable upper bound on the cost to growers. Thus, two alternative scenarios are constructed for the costs to growers of labor displacement: one-half year and one full year of lost wages.

The faster coverage by the air-curtain sprayer means that each farmer can cover 200 acres in a little less than two days instead of almost four with the conventional sprayer. It is assumed that the wage rate for skilled labor is $9/hour, including Social Security, Worker's Compensation and other fringes (Kelsey and Schwallier, 1989). The estimated cost of labor displacement in any year is the number of new acres to which the air-curtain sprayer is applied times the hours of displaced labor per acre times the wage rate per hour.

Reduced Pesticide Use

Some of the pesticides applied to apples embody considerable risk to human or animal health. Four pesticides used on Michigan apples — captan, mancozeb, metiram and propargite — are rated by the EPA as probable human carcinogens; another six — benomyl, dicofol, dimethoate, methomyl, permethrin and phosmet — are rated as possible human carcinogens (Hoppin et al.); and there may be evidence of carcinogenicity in others, such as azinphos-methyl (see Watterson, 1988). Many of the pesticides have other negative characteristics, such as mutagenicity; the potential for reproductive and endocrine disruption; high acute toxicity to birds, fish or mammals; bio-accumulation and biomagnification (accumulating in living tissue and increasing in concentration as they move up the food chain, respectively); leaching; runoff; volatility (ability to evaporate easily), etc.

The environmental benefits of reduced pesticide use can be quantified in several ways. The traditional approach to measuring environmental impacts is to quantify the reduction in damages from reduced use (e.g., Belli, 1996). Unfortunately, little is known about the extent of damages. For example, even though the EPA classifies six of the pesticides applied to Michigan apples as possible human carcinogens, potency measures are available for only two of the six. Quantification becomes even less certain for damages to fish and wildlife, and in cases where people or animals may be exposed to a combination of pesticides.

A second approach is to value the pesticide reduction at the cost of replacing the pesticide with the next best alternative. This is frequently done when the issue is the banning of pesticides (see the discussion and references in Pimental and Lehman, 1993, e.g.). In the case of reductions in pesticide use that still maintain the same yield and quality, this approach is inappropriate.

Contingent valuation (CV) methods are the most promising approach for the pesticide reductions discussed in this paper. Contingent valuation essentially asks individuals what they would be willing to pay to have reduced health hazards or improved environmental amenities from reduced pesticide use. This method has two advantages in the current context: first, one can elicit the needed information from farmers, who are the focus of this analysis; second, several CVs of farmer valuation of pesticide reduction have been conducted (though none directly for apple growers). An important part of CV analysis is that it can also focus on reduced risk of health and environmental hazards, rather than specific pesticides. This is both more realistic — not everyone exposed to carcinogens develops cancer, and not all cancers are caused by exposure — and allows for greater flexibility in extrapolating the results of CV analysis from one case to another.

This analysis uses a recently completed CV analysis of farmers' willingness to pay for elimination of carcinogenicity, leaching and fish toxicity from the herbicide atrazine (Owens, 1997) as the basis for the valuation of decreased pesticide use to Michigan apple growers. The CV instrument asked questions on prices that farmers would be willing to pay for this hypothetical atrazine and estimated demand curves and implicit values for eliminating each of the three undesirable attributes. Owens found that farmers were willing to pay $5.77, $5.24 and $3.94 an acre for elimination of carcinogenicity, leaching and fish toxicity, respectively, from 30 acres of corn. These values decline as the acres applied increase, presumably because farmers would apply the hypothetical atrazine to the most sensitive areas first (those nearest wells, ponds or rivers; areas with the highest runoff, etc.).

Adding the valuations for the carcinogenicity, leaching and fish toxicity gives a total value of $14.95 per acre for elimination of all these effects.[2] This figure is within the range found by other studies. For example, Higley and Wintersteen (1992) calculated environmental costs of 32 popular pesticides, including those most commonly used on Michigan apples. The estimated costs ranged from $6.02 / acre to $11.14 / acre (1992 dollars) for a single application. Accounting for multiple applications on Michigan apples would substantially increase the per-acre valuation of pesticide reduction.

The Owens study and the application to Michigan apple growers have several areas of coincidence: the size of the representative apple farm — 200 acres of apple trees — corresponds to the approximate average of 200 acres of corn planted by respondents in the Owens study; both the study and application are in the same state; and apple farmers use significant amounts of pesticides as part of their pest management programs. There are also some significant differences between the study and the application. Dangers of atrazine (and triazine herbicides in general) have perhaps received more attention in the popular news media than hazards of apple pesticides, though fewer than half of the respondents in the Owens study knew that atrazine is toxic to fish and a possible human carcinogen. The dangers of pesticides applied to apples, particularly insecticides, are possibly greater than the risks posed by atrazine. Azinphos-methyl, the most popular apple pesticide by area, is a highly hazardous chemical that is toxic to many life forms, and some studies find evidence of carcinogenicity (Table 3). Methomyl, another popular insecticide, is dangerous to fish. Captan, the most popular fungicide, is harmful to fish and a probable human carcinogen. The greater dangers suggest that farmers may be willing to pay more for elimination of these effects in apple pesticides than in atrazine. Perhaps the major difference between the atrazine findings and this study is that there are no effective apple pesticides without dangerous side effects. The air-curtain sprayer reduces pesticide use, but the pesticides themselves are unchanged. Moreover, the reduction in pesticide use is evenly spread over the entire farm area: the farmer cannot choose to apply 0 percent around the homestead and 100 percent elsewhere.

Despite these caveats, Owens' findings are used to generate values for pesticide reduction in this study. To adjust for the difference between reduced pesticide use due to the air-curtain sprayer and the hypothetical elimination of dangers in the Owens study, one alternative scenario uses per-acre values set at 40 percent of Owens' values, corresponding to the 40 percent decrease in pesticide use relative to the air-blast sprayer. Thus two alternative scenarios are created, based on 40 percent and 100 percent of Owens' values.

Further Considerations

Focusing on impact on growers neglects linkages with other parts of the Michigan economy. This report does not include the economic effects of reduced pesticide purchases on recreation and tourism, does not measure directly the effects on farm worker health or health-care costs, doesn't consider cost savings from potentially longer

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[2] Economic and environmental theory are uncertain whether such figures can be added meaningfully. An individual's declared willingness to pay sometimes changes when multiple events are analyzed. Also, the environmental effects of multiple events — especially multiple pesticide use — may compound as the number of events increases.

Table 3. Comparison of atrazine with selected Michigan apple pesticides: use and health and wildlife effects.

Chemical	**Use and application rate**	**Health and wildlife effects**
Atrazine (herbicide)	Included for comparative purposes — not applied to Michigan apples.	WHO rating: unlikely to present acute hazard in normal use. EPA signal word: "caution". Wildlife effects — as a general precaution, do not contaminate water[a]. EPA carcinogenicity classification: CQ[c].
Azinphos-methyl (organophosphorus insecticide)[a]	Applied to 93% of Michigan apple area at a rate of 2.32 lbs / acre-year[b].	WHO rating: highly hazardous. EPA signal word: "danger: poison". Experimental carcinogen and linked to pancreatic and thyroid tumors (animals). Wildlife effects — dangerous to bees, fish; harmful to livestock, game, wild birds and animals[a].
Methomyl (translocated carbamate insecticide)[a]	Used on aphids and other insect pests on fruit, hops and vegetables[a]. Applied to 53% of Michigan apple area at a rate of 1.14 lbs / acre-year[b].	WHO rating: highly hazardous. Wildlife effects — dangerous to fish, livestock, bees and wildlife (mammals). Banned in Malaysia[a]. EPA carcinogenicity rating: C[c].
Captan (phthalimide fungicide)[a]	Available as a wettable powder or dust[a]. Applied to 89% of Michigan apple area at a rate of 10.97 lbs / acre-year[b].	WHO rating: unlikely to present an acute hazard in normal use. Animal carcinogen. Wildlife effects — harmful to fish[a]. EPA carcinogenicity rating: B2.

Key to EPA Carcinogenicity Ratings: A, known human carcinogen; B2, probable human carcinogen; C possible human carcinogen—no potency estimates; CQ possible human carcinogen—with potency estimates[c].

[a] Watterson, 1988.
[b] Michigan Department of Agriculture, 1997.
[c] Hoppin, Liroff and Miller, 1997.

use of pesticides that otherwise might be banned by the EPA, etc. The overall effect of these additional indirect effects is not expected to be large relative to the direct effects. Moreover, these effects are likely to add to the benefits of the air-curtain sprayer, at least at the social level if not also at the grower level. Consequently, the base case and other scenarios described are expected to provide a very slight undervaluation of the benefits of this MAES activity.

Three additional considerations are important to mention. This report does not quantify increased value to consumers of apples that are grown with fewer pesticides. Van Ravenswaay and Hoehn (1991) and van Ravenswaay et al. (1992) use contingent valuations methods to examine consumer willingness to pay for apples certified and labeled to have different pesticide residue characteristics. These studies unambiguously find that consumers are willing to pay more for apples that are certified residue-free, a finding that could benefit Michigan apple growers. But this finding is not easily generalizable, nor is it easy to discern if the consumers are paying for the pesticide reduction or for a label. Moreover, it is unclear if reduced pesticide applications on the farm really affect residues: “virtually no apples have residues above federal limits” (van Ravenswaay and Hoehn, p. 4). Finally, it is unlikely that consumers know what sprayer or level of spray the farmer used on the apples they are purchasing.

Non-farmers may value reduced pesticide use for ecological or other reasons. Thus, use of the air-curtain sprayer would provide a social benefit to these people. For example, Mullen, Norton and Reaves (1997) combine a Higley and Wintersteen type approach to pesticide risks with a contingent valuation survey of the general U.S. population ("society") to determine the social value of reducing on-farm pesticide applications. In an application to Virginia peanuts, the authors examine a 33 percent reduction in chlorothalonil applications as the result of integrated pest management practices. The social value of this reduction (excluding grower effects) is $884,000 (1992 dollars), or about 1 percent of the value of production (based on data from the Economic Research Service, 1993). It is unclear if extrapolation to Michigan apples is accurate; nonetheless there may be significant social benefits from reduction of pesticide use on Michigan apples. However important the social benefits of pesticide reduction might be, it does not accrue to Michigan apple growers and is not quantified in this report.

Widespread adoption of the air-curtain sprayer could affect the pesticide industry. Michigan apple growers are a significant market for pesticide producers, accounting for the bulk of pesticides (by volume) applied to Michigan fruit. However, of the "Top 25 (by weight) and Other Important Pesticides Used in the Great Lakes Basin" (Hoppin, Liroff and Miller, Table 2.1, p. 14), use on Michigan apples accounts by weight for approximately 3.5 percent of the total (calculated from Hoppin, Liroff and Miller and Michigan Agricultural Statistics, 1996-1997 and 1997-1998). Reducing this figure by one-third over a period of years is unlikely to have a major impact on the pesticide industry. Again, since this does not affect growers, estimates of such an impact are omitted here.

Finally, adoption of the sprayer beyond Michigan could have an impact on apple prices if costs of production are reduced throughout North America. There are still two advantages to Michigan growers of having the MAES invest in sprayer R&D. The air-curtain sprayer is available to Michigan growers before it is available to apple producers in other states. Currently, the technology is licensed exclusively with BEI Inc., which has no plans to distribute the sprayer outside of Michigan. Consequently, for at least the first few years, Michigan growers can reap the cost savings from adoption and use of the sprayer, and the sprayer is likely to have little or no adverse effects on prices (though unrelated factors may influence prices). Moreover, Michigan growers often use higher levels of pesticides than growers in Washington, the top producing state, because of different agroclimatic conditions. Consequently, Michigan growers would expect to have a bigger cost savings due to adoption of the air-curtain sprayer, even if some of these savings are eventually passed on to consumers in the form of lower prices.

Results

The results show that the present value of the benefits to Michigan apple growers attributable to the air-curtain sprayer are positive in every scenario, ranging from $1.3 million in the case of slow adoption when the alternative is the sensing-tower sprayer to $21.9 million when adoption is rapid and the alternative is the air-blast sprayer (Table 4).

Table 4. Present value at a 10% discount rate of the pecuniary benefits of the air-curtain sprayer to Michigan apple growers, by adoption profile and alternative machine, 20-year time horizon.

	Best alternative machine:	
Adoption profile	**Sensing-tower sprayer**	**Conventional sprayer**
Slow adoption	$1,333,810	$5,283,940
Moderate adoption (base case)	$3,345,791	$13,254,479
Rapid adoption	$5,476,600	$21,695,760

In the base case, the present value of benefits is $3.3 million.

A potential negative consequence of the adoption and use of the improved sprayer is the cost of labor displacement. Analysis of these costs indicates they are insignificant relative to the cost savings — they change the present value of sprayer benefits by less than 1 percent (Table 5).

Adoption of the sprayer is projected to decrease pesticide use on Michigan apples by 200,000 to 800,000 gallons per year (Figure 3). The social (non-pecuniary) benefit of risk reduction due to lower pesticide application rates augments the present value of sprayer benefits. If the best alternative is the STS, the results are moderately sensitive to these benefits: the estimated present value rises from about $3.3 million to $3.6 million (using 100 percent of Owens' values), or 7 percent (Table 5). If the best alternative is the conventional air-blast sprayer, these benefits are more important because the pesticide reduction is greater (Figure 3). Valuing these benefits on a par with Owens' values, the risk reduction adds nearly $2 million, or 15 percent, to the present value (Table 5).

The most critical variable determining the level of benefits is the alternative machine. For each scenario, the benefit value when the alternative is the air-blast sprayer is about four times the value when the alternative is the sensing-tower sprayer. The range of overlap between the values for the two alternatives is limited: only for the fast adoption rates when the alternative is the air-blast sprayer do the values exceed those for slow adoption when the alternative is the sensing-tower sprayer. Recalling that the appropriate counterfactual situation depends on whether there was an informal interchange of ideas between the public and private sectors, this suggests that further investigation is warranted into the level and nature of MAES links with agribusiness.

The adoption rates also clearly play an important role in determining the level of benefits. Though their effect is not as large as that of the choice of alternative sprayer, the benefits associated with rapid adoption are generally about four times as large as the benefits associated with slow adoption.

Conclusions

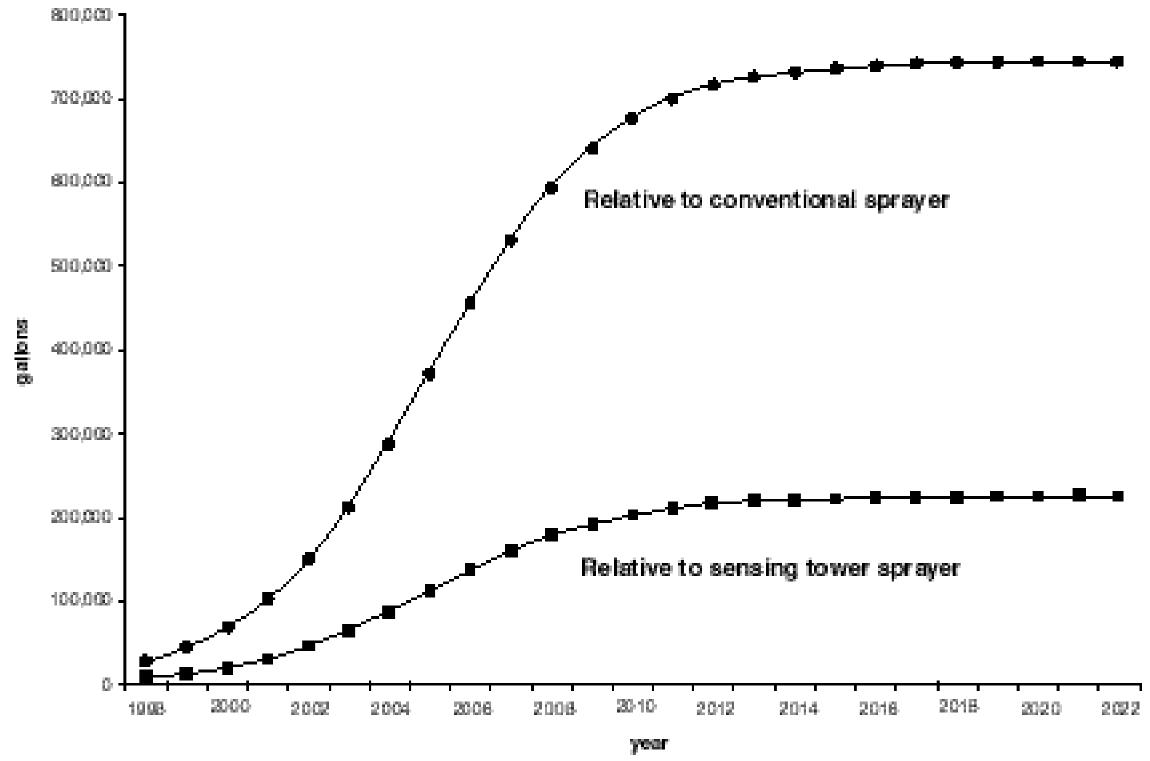
The results indicate that in every scenario, the air-curtain sprayer has a positive present value of benefits. Future benefits are highly uncertain, largely because of limited information on pesticide damages and uncertain projection of sprayer adoption. Sensitivity analysis indicates that direct benefits to Michigan growers are likely to fall in a range from $1.3 million to $21.7 million. It will be important to compare these benefits to investment in the program.

Table 5. Present value of the air-curtain sprayer at moderate adoption rate and a 10% discount rate, including social benefits due to labor compensation and value of pesticide reduction to growers, by best alternative sprayer, 20-year time horizon.

	Including potential labor compensation		
Best alternative sprayer	**1 year**	**½ year**	**none (base case)**
Sensing-tower sprayer	$3,336,147	$3,339,808	$3,345,791
Conventional air-blast sprayer	$13,115,849	$13,185,164	$13,254,479

	Including value of pesticide reduction to growers		
	At 100% of CV values	**At 40% of CV values**	**Zero value (base case)**
Sensing-tower sprayer	$3,586,270	$3,441,982	$3,345,791
Conventional air-blast sprayer	$15,178,309	$14,024,011	$13,254,479

Figure 3. Annual pesticide reduction due to use of air-curtain sprayer, relative to conventional and sensing-tower sprayers.



Increasing control of pesticides, high registration and re-registration costs, and R&D expenses suggest that the pesticide choices available to farmers may decline and / or prices may increase in the future. These forces are not in the sensitivity analysis but could affect the results replacement of pesticides by other forms of pest management would tend to decrease the value of the sprayer; higher pesticide prices would tend to increase its value. Consequently, the projections and results of this study should be interpreted as preliminary only. Verification of results as sprayers are produced, adopted and used will provide additional useful information.

This study has focused exclusively on the impacts of the air-curtain sprayer on Michigan apple growers. The sprayer has broader applications, both for other areas and other commodities. For example, adaptations are currently being field tested on Michigan blueberries, cherries and grapes, and Texas and Georgia pecans. Additionally, the non-farm public's willingness to pay for pesticide reduction has not been included in this study. Pesticides may also have important effects on other industries that are not examined in this paper. For example, much of Michigan's $12 billion tourist industry is based on natural resources, including visits to U-pick fruit farms and vineyards, and tourism based on fishing, hunting or other Great Lakes Basin water and wildlife resources. Expanding the current study to address these areas would be an important contribution to our knowledge of pesticide impacts.

The focus on Michigan apple growers also neglects general equilibrium considerations, particularly price changes. Historical evidence is sufficient to conclude that important agricultural innovations that reduce production costs eventually reduce output prices, so that most of the gain from these innovations accrues to consumers in the form of lower prices. For apple sprayers, this suggests that if major apple-producing states such as Washington adopt the sprayer, then farm prices will fall by an amount approximately equal to the per unit cost savings (at 7 to 10 percent of output, lower costs only in Michigan may not be sufficient to affect prices). The major advantage to Michigan farmers is thus the advantage from adopting the sprayer early, before price changes (though adoption is beneficial at any realistic apple price). This has implications for the role of the MAES and MAES research targets. MAES research on innovations for Michigan may provide Michigan industries an early adopter advantage that lasts until these innovations are adapted for use in the other major producing states.

Despite these caveats, the clear lesson that emerges from this study is that the air-curtain sprayer has significant potential benefits for Michigan apple growers. The present value of these benefits, accrued over the next 25 years, could exceed $20 million. Moreover, this is a situation in which farmers, consumers and the environment are all likely to emerge as winners.

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