OPPORTUNITIES AND IMPEDIMENTS FOR POLLUTION PREVENTION IN CROP PRODUCTION

L. Mark Risse

AUTHOR: Public Service Assistant, Biological and Agricultural Engineering, University of Georgia, Athens, Georgia 30602
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Abstract. Agriculture is one of several industries that face criticism today because of its impact on the environment. Pollution prevention technologies can go a long way toward addressing these concerns. They could also be beneficial to producers as they represent a move toward efficiency. The most common environmental pollutants from crop production are sediment, nutrients, and pesticides. This paper identifies pollution prevention opportunities that are economically viable to the farmer and minimize the impacts of these contaminants. It also lists impediments that limit the adaptation of these practices. Finally, it identifies areas where pollution prevention techniques would be economically viable, technically sound, and environmentally sustainable.

INTRODUCTION

The diversity of agricultural industries presents many obstacles to the adoption of pollution prevention. The Pollution Prevention Assistance Division of the Georgia Department of Natural Resources established an agricultural pollution prevention program (AG P2 program) in cooperation with the University of Georgia Cooperative Extension Service to overcome these obstacles. The primary emphasis of the program is to provide education and technical assistance on pollution prevention to the agricultural community. One of the first projects of this program was to identify the opportunities and impediments to pollution prevention in crop and animal production.

The purpose of this paper is to summarize the findings outlined in "*Pollution Prevention in Agricultural Crop Production*" (Adams and Risse, 1996) and relate that to the AG P2 program.. The original study resulted from an in-depth analysis and review of the literature associated with pollution prevention and crop production practices. Information was gathered from discussions with academicians, extension specialists, and producers to determine current practices and potential waste reduction techniques. By analyzing existing production practices and the concepts behind pollution prevention technologies, many opportunities and impediments have been identified. Pollution prevention in crop production has the potential to reduce environmental degradation and increase the economic return to the producer. This paper can serve as a catalyst for converting this potential to reality.

BACKGROUND

Crop production accounted for $2.05 billion or 40.9% of total agricultural production in Georgia in 1995 (Georgia Agricultural Statistics Service, 1995). Cotton and peanuts are the largest crops in Georgia in terms of value and acreage. These two major crops are followed by corn, tobacco, soybeans, and small grains. In addition, hay production, nursery, greenhouse, and turf production and truck crops including pecans, peaches, apples, grapes, blueberries, and vegetables account for major portions of this income.

While this income alone suggests that crop production is big business, farm expenses amounted to more than $3.6 billion. To achieve production, farmers applied 1,415,047 tons of chemical fertilizers and lime, 105,762 tons of organic fertilizers, and an estimated $171 million of pesticides. Other major expenses included interest, labor, repairs and maintenance materials, rent, fuel and oil, and taxes.

WASTE STREAMS

Most cropping systems produce similar waste streams despite the type of crop being produced as they use common production and cultivation practices. For example, soil, water, nutrient, and pesticide losses occur with runoff and leaching in almost any cropping system. While common principles result in resources being lost, each crop is also unique. The amounts and type of chemicals used, the cultivation technique used, and the tolerance of a plant to stress may be specific to the crop or the location. Since a detailed evaluation of each crop and condition is beyond the scope of this text, this paper will review the common waste streams that are consistent among most crops. A more detailed description of practices and processes specific to individual crops common to Georgia can be found in Adams and Risse, 1996.

Erosion occurring on the State's 8.9 million acres of land produces about 7.6 million tons of sediment each year (USDA et al., 1993). The process of erosion is important because eroded sediment is not only potential pollutant but also carries adsorbed nutrients and chemicals. Soil erosion is detrimental to crop production and causes considerable off-farm damage. The EPA has identified soil erosion as the leading source of impairment to rivers and lakes.

Nutrients are also a major waste stream from crop production since crop fertilization is required on most Georgia farms to sustain crop productivity at the desired yields. In 1995, more than 1,661,885 tons of commercial fertilizers were sold in Georgia (Ga. Ag. Stat. Ser., 1995). Beyond this, an estimated 84,000 tons of nitrogen and 33,000 tons of phosphorus were generated from animal waste and used in crop production. Nationally, the use of fertilizers continues to increase, but this increase corresponds to increases in the amount of nutrients harvested in increased crop yields. Nitrogen and phosphorus compounds are pollutants in water and will exert an oxygen demand, thus reducing the dissolved oxygen content and inducing bacterial and algal growth. The percolation of nitrates is a special problem with human health implications.

Since the 1950's, most growers in the United States have preferred to use synthetic chemical pesticides to control crop pests. The reasons for this include the immediate and dramatic effects on pests, the ability to produce more consistent and higher quality products with synthetic pesticides, and the fact that they require less management and labor than alternative control methods. Since the 1970s, synthetic pesticide use has begun to level off and even decline in some areas (PPRC, 1995). These usage trends have mainly been affected by the development of pest resistant crop varieties and regulatory and legislative action resulting from environmental concerns. Although detailed records on pesticide inventories in Georgia are not kept, in 1994, growers purchased more than $156 million worth of pesticide products (Ga. Ag. Stat. Ser., 1995).

Pesticides and other agrichemicals can enter surface or ground water by direct routes (point sources) or by sustained doses of low concentrations from nonpoint sources. Very small amounts of pesticide can create concentrations in water greater than health standards. Nationally, more than 74 different pesticides have been detected in groundwater in 38 different states. Of these 74 detections, 46 were attributed to normal use and 32 were attributed to point sources or misuse (Ritter, 1990). Pesticides can also contaminate surface water. Typically, annual herbicide losses with water and sediment in runoff from a herbicide treated field are less than 5% of the amount applied (Baker et al., 1995). Losses with subsurface flow are lower, usually less than 1%, and often less than 0.1%. These losses are low from an economic perspective but can result in part-per-billion concentrations of herbicides in groundwater or surface water.

Although it may not be considered a waste stream, Georgia farmers purchased more than $103 million worth of fuel and oil in 1994. If not properly managed, petroleum and oil can cause environmental degradation. Pollution prevention can play a vital role in a farmer's ability to manage petroleum resources. Most farms have shops that can benefit from following pollution prevention practices established for commercial garages. Since fuel is a costly input, substantial efforts have already been made to reduce consumption. Therefore, pollution prevention efforts should focus on improved storage and handling.

Crop residue is the waste left in the field after harvest of the economically valuable portion of the crop. Crop residues help to recycle nutrients back to the soil, thereby diminishing the need for applied nutrients. For example, the 3,900 lb/ac of soybean residue remaining after harvest has an approximate fertilizer value of $12.19 (CAST, 1995). Retention of crop residues on the land where grown is usually the most practical and sound waste management practice.

Much of the material harvested in crop production does not reach the consumer. Post harvest losses can range from 10% to 80% depending on the crop. While losses in the field are usually dispersed or applied to the land, ultimate disposal from offsite packing houses, transport, processing plants, and at the market is usually in landfills. Opportunities to return these wastes to be utilized in the fields, develop new products from the wastes, and define new uses for the wastes need to be considered. When carried out at the field level, these are activities that would reduce post harvest losses at the source.

POLLUTION PREVENTION OPPORTUNITIES

The goals of sustainable agriculture are often similar to those of pollution prevention. Both focus on reducing inputs to protect the environment and increase economic gain. In this section, the pollution prevention technologies with the most promise to crop production are reviewed. For each technology, both the opportunities and impediments are presented and, if possible, strategies for implementation are presented.

Best Management Practices

Best Management Practices (BMPs) refers to a combination of practices determined to be effective economical alternatives to preventing or reducing pollution generated by nonpoint sources. Preventive practices such as these are practical approaches to reducing nonpoint source pollution. For voluntary BMPs to be effective, they must be implemented as systems rather than individual practices, must be site specific and placed in the correct locations, and should be economically sound (Osmond et al., 1995). The main impediments to more widespread use are a lack of capital for implementation, a lack of knowledge concerning the benefits, a lack of willingness to accept responsibility, and a lack of incentives.

As part of an effort to promote voluntary adoption of BMPs, the Georgia State Soil and Water Conservation Commission has published a booklet called *Agricultural Best Management Practices for Protecting Water Quality in Georgia*. This publication is intended to serve as a basic guide for anyone implementing agricultural BMPs and adequately covers most BMPs that would be effective in Georgia. Since BMPs are proven techniques that prevent pollution, they will be the cornerstone of the AG P2 program. A database and library of all BMPs will be established and the program will work closely with other agencies in supplying this information to the agricultural community in both a proactive and reactive technical assistance program. Where necessary, the program will also develop projects to encourage BMP implementation and support applied research to develop new or improved BMPs.

Controlling Runoff and Soil Erosion

Control of soil erosion is a primary opportunity for preventing pollution. Since the dust bowl years of the 1920s and 1930s, both Federal and State efforts have concentrated on reducing or controlling soil erosion. According to the National Resources Inventory, farmers have reduced erosion from an average of 4.5 tons/acre/year in 1982 to less than 3.5 tons/acre/year in 1992. Much of this improvement has been attributed to the move toward conservation tillage systems, the removal of highly erodible land from production, and an increased use of BMPs. The cost of completely preventing rainfall erosion on cropland would be greater than 143 trillion dollars (Porterfield et al., 1995). This is something neither the farmers nor the public could afford. However, through the voluntary implementation of BMPs and pollution prevention techniques, soil erosion and its environmental impact can be substantially reduced.

Many Georgia row crops can be produced using conservation tillage. Conservation tillage systems reduce runoff and soil erosion. Fertilizer and pesticide losses in surface runoff tend to be less than those under conventional tillage (CTIC, 1992). Nationally, conservation tillage has become the norm with an estimated 60% of the crop acreage in some form of conservation tillage. In Georgia, however, adoption rates are much lower. Part of this is due to the crops produced. Peanuts, for example, require some sort of plowing to insure that the subsoil is loose and non-compacted. Soil types also influence the farmer's selection. Conservation tillage, beyond controlling erosion, provides savings of time, fuel, labor, and soil moisture. Usually the savings in fuel and labor can more than offset the cost of additional equipment annually, however, purchasing equipment is a large investment. Equipment must be more readily available if conservation tillage is to be successful in Georgia. Many actions are already underway to increase conservation tillage in Georgia. The Conservation Technology Information Center (CTIC) is a national organization affiliated with the EPA that promotes reduced tillage practices. They are quite active in Georgia and have established programs to rent no-till planters to farmers that cannot afford to purchase the machinery. In addition, the University of Georgia Cooperative Extension Service and Experiment Station have established demonstration plots and outreach programs to show the producers that conservation tillage can be effective in Georgia. The AG P2 program will develop partnerships with these programs to augment them instead of creating additional programs.

A primary problem with conventional tillage is that it buries the organic matter in the surface residue where it is oxidized much faster. This organic matter is essential to soil quality and is an additional reason for the improved productivity of conservation tillage systems. Clearly, soils with high organic matter are more suitable for crop production, yet, organic matter is difficult to maintain using crop residues alone. Green manure or cover crops, proper crop rotations, and organic matter amendments are usually required to maintain high levels of soil organic matter in Georgia. These practices, as well as discouraging crop residue removal, will be advocated by the AG P2 program. The program will also encourage organic matter additions in the form of amendments. Land applying animal manures, yard wastes, compost, sewage sludge and other organic biomass is an attractive disposal method that could relieve landfill pressure. Considerable data in the literature proves that land applied organic matter significantly decreases runoff and soil erosion (Abu-Zreig et al., 1994). Impediments to organic matter additions in Georgia include high decomposition rates, increased labor and management, and a lack of economical sources of organic amendments. To overcome these impediments, the AG P2 program will work with the University of Georgia and local governments throughout the State to develop by-product utilization demonstration sites. These sites will show farmers how they can improve productivity by using organic materials such as biosolids, industrial by-products, composts, and animal manures.

Cropping practices and the selection of crop rotations also affect soil quality, runoff and erosion, and the loss of nutrients and pesticides. By simply changing practices or the sequence of crops grown, a farmer can substantially reduce erosion and improve productivity. Crop rotations can be used to reduce or control nematodes, insects, and diseases and they prevent the buildup of certain weeds associated with the continuous production of one crop. This usually results in less pesticide consumption when rotations are used. When legumes are used in rotation, the nitrogen formed by fixation can reduce the nitrogen supplement required for the subsequent crop. While most farmers realize that crop rotation can increase yields, few take advantage of this fact because they want to get the maximum return every year. To prevent pollution through crop rotation, the AG P2 program will develop educational programs and literature focused on changing the attitude of farmers from making annual decisions to looking at the long term impacts of production decisions.

Crop Fertilization

Since the arrival of chemical fertilizers in the late 1940's and 1950's, progressive farmers have embraced the use of fertilizers as a way to reduce labor costs and increase yields. While the benefits are apparent, when use first began, next to nothing was known about potentially harmful effects of these products. If the costs were not prohibitive, farmers sometimes used higher rates than were essential, often as insurance against low yields or a potential weed or insect infestation. Today, this attitude is changing. Farmers now realize the cost of fertilizers and are aggressively pursuing reductions in use. They are also getting by with less environmental degradation through improved application technologies, better management and planning, and by implementing BMPs to prevent off-site transfer of farm nutrients.

While most chemical fertilizers are no more toxic to the environment than natural or organic sources of nutrients, greater use of alternative fertilizer sources can often cut farm input costs and provide a feasible solution to disposal problems. Organic fertilizers slowly release minerals into the soil (Chan-Muehlbauer and Gunnink, 1994). In contrast, commercial fertilizers are soluble and tend to leach out of the crop root zone. To compensate, these fertilizers are either applied at higher rates or reapplied during crop growth.

Animal manure is the most widely used organic fertilizer in Georgia. Besides manure, there are many other "natural" sources of fertilizer including green manure crops such as legumes, crop residues, food processing and industrial by-products, organic material derived from pulp and paper mills, urban yard waste, sewage sludge, and compost mixes. Most of these do not approach the fertility levels of commercial nutrient sources. Other reasons that organic amendments are not used include: 1) substantial energy and labor costs associated with handling and storage; 2) lack of information on their nutrient values; 3) lack of recognition of economic value; 4) regional availability and high transportation costs; and 5) wide variability in nutrient content. Public perception must also be improved. Hopefully, the AG P2 program can address many of these issues through the development of the by-products utilization program discussed in the previous section.

Nutrient management plans are essential to apply the right amount of nutrients, in the right place, and at the right time. Plans can be formulated by the landowner or farmer, by Extension or other service personnel, or with computer nutrient models. Whatever the approach, the important concept is that nutrient management plans examine all nutrients to minimize losses, to maintain soil quality, and to insure adequate soil fertility to meet the intended crop yield goals. Nutrient management planning has been adopted in Georgia. The University of Georgia ran more than 80,000 soil samples and 3,500 plant samples in 1995. Private labs throughout the State are estimated to run at least that many as well (Plank, Personal Communication, 1996). The farmers that do not use nutrient management planning are either unaware of the benefits or skeptical of the procedures. Costs are usually not an issue since the Extension Service and many fertilizer dealers provide free testing to commercial growers. One impediment that does create some disillusion with producers is the fact that fertilizer recommendations can vary between labs. The AG P2 program will actively work with both the Extension Service and the private sector to encourage more widespread use of nutrient management plans.

Proper and timely application of fertilizers is also important in reducing nutrient losses and pollution potential. Ideally, plant nutrients would be applied in small doses on a frequent basis, however, each pass over the field has an economic consequence. To reduce nutrient losses, the AG P2 program will educate producers on the effects of nutrient application timing, location, and equipment on crop productivity. Certain placement methods, such as subsurface banding and dual placement of N and P below the surface mixing zone, allow reduced rates of nutrients by improving efficiency. Injection systems reduce losses and may be the most efficient application method; however, they are not used extensively because of the difficulty in injecting solid materials. These technologies will continue to improve application efficiency and the machinery costs will continue to decline.

Fertilizers can be manufactured to reduce environmental losses. Nitrification inhibitors are products that control or restrict the conversion of ammonium to nitrate. By keeping N in the ammonium form longer, N losses via leaching and erosion are reduced while the nutrient availability is extended. Slow release fertilizers reduce N losses by resisting biological or chemical breakdown. Prices on these products are often higher. To promote more widespread use of these products, educational efforts need to focus on cost-effectiveness and the potential for yield increases by using these products.

Recently, a considerable amount of research has been conducted on systems to precisely target inputs such as fertilizers and chemicals according to the localized requirement within the field. The systems, described as spatially variable field operations or "precision agriculture," take into account variations in soil quality, nutrient levels, and pests that occur on most arable fields. Application rates of nutrients, pesticides, and other agronomic inputs are not predetermined and constant, but vary continuously based on specific soil and microclimate variations. Precision agriculture should result in more appropriate use of pesticides and fertilizers with an overall reduction in application rates. Equipment with precision farming capabilities is now on the market. The economics of this technology should prove lucrative for the farmer. While widespread use of this technology in Georgia is probably several years away, the technology appears promising and will be an integral part of the AG P2 program.

Pesticides

The incidence of pests, including weeds, insects, disease causing organisms, and nematodes is high in subtropical climates such as Georgia. This makes pest management a paramount concern in these regions as pest management costs comprise a larger portion of the production cost. Insects alone cost Georgians more than $500 million each year in crop loss. Reliance upon chemical solutions to pest problems has been the chief method to exert control. With the awareness of health risks, increasing chemical costs, concerns over drinking water supplies, and awareness of the persistence and toxicity of chemicals, new and innovative approaches to pest management have been developed. These technologies are already reducing pesticide use nationally. From 1982 to 1992, overall pesticide use declined 6% in the United States while production increased almost 20% (Porterfield et al., 1995). The bulk of this reduction is from the application of pollution prevention technologies.

Reductions will continue, however, synthetic pesticides will always be an integral part of crop production.

Ritter (1990) reviews many alternatives available for pesticide pollution control. He supplied the following four categories: 1) Integrated Pest Management (IPM) Systems; 2) Substitution of less biotoxic and less persistent pesticides; 3) Increasing the efficacy of pesticide application technology; and 4) Soil and water conservation practices.

IPM is an interdisciplinary approach to pest control incorporating the judicious application of ecological principles, management techniques, and biological and chemical methods to maintain pest populations at tolerable levels (EPA, 1980). It is a system that anticipates pest population increases and prevents pests from reaching damaging levels by using natural enemies, pest resistant plants, cultural management, pesticides, and other techniques. Extensive IPM evaluation in the early to mid-1980s revealed significant increased net profits to growers who used high levels of IPM, as opposed to non- or low-users. For the most part, Extension programs have been developed to educate growers on the principles of IPM. In 1994, IPM programs involved more than 7,700 Georgia growers with 88% of the cotton and 48% of the peanuts in Georgia grown under IPM management. Since these efforts are already underway and proven to be effective, the AG P2 program will not allocate significant resources to IPM but instead partner with these established programs.

The chemical characteristics of pesticides, especially leachability, persistence, and toxicity, are important considerations when selecting pesticides. These characteristics in conjunction with soil type determine the amount of chemicals lost and their potential for ground water contamination. For users to make informed decisions, they need a thorough understanding of each of these chemical properties and a process or tool to analyze the properties as they relate to their specific soil and environmental conditions. Producers also need to rotate the chemicals to prevent the development of pest resistance. Proper chemical rotation can reduce pesticide application rates by reducing 1) the possibility of applying ineffective pesticides; 2) the need to use higher rates to get equivalent control; and 3) the need for additional applications. While this type of information is available, by limiting the pesticides and soils to those commonly found in Georgia, a more effective pollution prevention tool could be developed to enhance the farmers understanding of these principles. These tools should be developed in fact sheet form for distribution by dealers and also in the Extension Services' *Pest Control Handbook.*

Application of pesticides involves determining the proper rate to apply, calibrating equipment, determining the most effective timing and frequency of application, and selecting the method of application and the appropriate formulation. The Extension service conducts statewide clinics on calibrating pesticide spraying equipment and has several publications available to help growers in this process. Adjuvants are products that can be mixed with pesticides to increase their effectiveness. Since most producers cannot maintain a working knowledge of all of the available products, adjuvant purchases are often based on pesticide dealer recommendations. There is considerable opportunity to provide educational materials that outline specific conditions under which the utilization of adjuvants is worthwhile.

Besides representing a loss of product, pesticide drift can cause environmental problems and yield losses to adjoining fields or neighboring farms. Under most conditions, drift can be reduced or avoided by recognizing the critical factors involved and taking precautions or making modifications. Therefore, educational programs, incorporated in pesticide applicator training programs, would probably be the most effective method of reducing the losses associated with pesticide drift.

Technological advancements in pesticide application equipment will improve application efficiency and reduce pesticide waste. Some studies show that ultra-low volume pesticide application using electrostatic spray nozzles can provide satisfactory insect control at half the rate recommended for conventional spraying (Ozkan and Wilson, 1994). Besides being able to offer the equivalent control using one-half to one third the active ingredient, the electrostatic sprayers have the added advantage of using 10 to 25 times less water carrier than standard hydraulic sprayers. Electrostatic sprayers are commercially available and will probably be the application technology of choice in the future. The largest impediment to more widespread use in crop production is probably cost as the sprayers often list for prices that are three to four times higher than conventional sprayers. Educational materials and demonstration programs will need to be developed to sell current technologies that are cost effective and to track developments and insure that they are implemented.

Industry research has shown that 85% of all applicator pesticide exposure occurs during mixing and loading (Avery, 1995). Chemical handling is becoming safer and more effective by shifting to dry chemical formulations wherever practical. While these changes are all being implemented in the name of safety, they also serve as effective pollution prevention strategies as they are preventing the chance of accidental spills that could lead to losses. Protection for humans in the storing, selling, transporting, mixing, and application of pesticides is regulated under the EPA's Worker Protection Standards. They require that certain individuals that apply pesticides receive certification and annual training. Opportunities for incorporating more pollution prevention principles into these trainings and documents such as those on safety (Delaplane, 1994) and the Georgia Extension Service's annual publication: "*Georgia Pest Control Handbook.*" should be explored.

Pesticide containers are also a waste stream that needs to be dealt with in agricultural crop production. Concentrated pesticide residues leaking from unrinsed, discarded containers can cause environmental contamination and economic loss. Pesticide containers should be recycled whenever possible. In 1995, the equivalent of 171,300 2.5

gallon pesticide containers were recycled in Georgia alone (Tolar, 1996). The Georgia Department of Agriculture and the Cooperative Extension Service are leading these efforts, however the pollution prevention program will assist them in implementation throughout the State.

Agricultural retailers play a vital role promoting pollution prevention both directly and indirectly. They can implement technologies and improved management practices onsite or provide services, counsel, and instruction about the safe use and handling of pesticides and fertilizers. The TVA (Tennessee Valley Authority) has designed a pollution prevention program specifically for agricultural retailers (Rylant, 1996). One of this program's achievements has been the establishment of 69 Research-Demonstration sites at retail facilities in 27 states. These include both "model sites" that demonstrate good environmental stewardship throughout the operation and "individual technology demonstration sites" that focus on one or more specific technologies. This program serves as a great model for development of demonstration facilities in Georgia; however, successful demonstration programs are highly dependent on commitment from the agri-industry involved.

Biotechnology

Since the 1950's genetics and biological advances have been the driving force in improved agricultural crop yields (Avery, 1995). Higher yielding, pest resistant, cold tolerant, higher protein seeds have come from many plant breeding programs worldwide. While biotechnology rarely replaces traditional methods of plant breeding, it often speeds up the process and allows for more precise control. Transgenic plants are often more productive than traditional varieties. Using biofertilizers, scientists have found methods to improve the way plants use nutrients in the soil. Biopesticide products use genetically engineered organisms to control agricultural pests. Such measures, which promise to increase in the future, will likely curb agriculture's reliance on chemical-based pesticides.

Advances in technology do not come easily or inexpensively. For new agricultural products, the time from first discovery to commercialization is often eight to ten years and development costs can be $35 to $50 million. Product registration and regulations are major forces that impede the development of new and improved biotechnologies. Development of resistance is also an impediment. In using these new products, educational efforts should focus on methods of preventing resistance development. Pollution prevention efforts also need to focus on public perception. Many people view biotechnology and genetic engineering as an evil that is no better than the use of toxic chemicals. Since biotechnology does have the potential to alter the environment, development should be controlled and regulated but not impeded. By educating the public of the benefits that biotechnology has provided, many potential problems can be avoided and sustainable development can prosper. Finally, the pollution prevention program should support research that leads to the development of biotechnology that reduces agriculture's dependance on non-renewable resources.

Protection of Water Supplies

Farming accounts for some 70% of global water use. Although Georgia is blessed with an abundance of natural rainfall, most common crops will still benefit from supplemental additions of water. Irrigation requires a high investment of equipment, fuel, maintenance, and labor, but offers a significant potential for reducing the risk associated with dependance on natural rainfall. Since many farmers are also rural residents that are dependent on ground water for drinking purposes, it is imperative that they protect their wellheads from all possible pollutants. The Cooperative Extension Service has several programs and publications to help rural homeowners with wellhead protection. The AG P2 program will supplement this by providing well inspections and well water testing upon request using self assessments such as Farm*A*Syst.

Water conservation can also benefit the land owners directly through fuel or power savings and improved yields or indirectly through a decreased dependance on groundwater resources. Effective irrigation water management reduces the amount of applied water, drainage that requires treatment and/or disposal, leaching of nutrients, pesticides, and other toxics, and runoff. A summary of some practices, using current technology, that farmers can use in water conservation programs are given in Segars, 1995. Irrigation scheduling, Low Energy Precision Application systems, improved calibration for quantity and uniformity, greater use of drip or trickle irrigation, and more use of conservation tillage systems are probably the greatest opportunities. An expanded education program is needed to show to farmers that, there is room for improvement in current irrigation practices, and that there are techniques and technical resources available for this improvement.

Other Opportunities and Impediments

Geographical Information Systems (GIS) can be used to identify and locate intensively farmed areas that may have a greater potential for environmental contamination. This information can then be used to target funding for educational activities. It could also be used by industry in determining suitable sites for expansion. The pollution prevention program should actively seek funding to develop surveys and a database of agricultural resources and wastes. Not only could this information be used to locate areas for potential pilot projects but would also help other State agencies in determining their needs and priorities.

Some farmers choose not to use alternative practices for pollution prevention although they may potentially be more profitable. Much of the problem lies in the farmer's perception of the impact his practices have on the environment. Most farmers feel that they are not responsible for the pollution of their environment and that the use of any corrective measure will come at a cost to them (Conway and Pretty, 1991). Supalla et al., 1995, conducted a study to assess the factors relating to why farmers choose not to use the recommended best management practices. He found that environmentally concerned, well educated, well informed, and younger producers who farmed smaller acreage were more likely to apply nitrogen at recommended rates. In Georgia, most of the farmers are not environmentally concerned, well educated, well informed, and younger producers. The USDA Economic Research Service estimates that 91% of the farms in Georgia are owned by a single family. More than 51% of the farms are less than 100 acres and 77% have sales of less than $50,000. The average age of the farm manager is 55 years and most do not have a college education. Since these older and less prosperous farmers are generally not as receptive to change as younger, college educated farmers, the task of informing them and changing traditional practices is often difficult. Educational efforts to change behavior should address the linkages between management practices and environmental quality. If a farmer understands why he should be concerned and economic alternatives are available, then he will be more likely to use an accepted practice.

Experience has shown that direct contact with farmers is the most effective way to bring about change. Therefore traditional mass contact programs such as descriptive publications, mass-media distribution, newsletters, demonstrations, and educational meetings must be used to reach a broad-based audience. The private sector may provide invaluable assistance in this educational effort through trained and certified consultants. The voluntary Certified Crop Advisors concept being developed by the American Society of Agronomy may provide a possible solution to broad-based recognition of qualified persons in the private sector who can assist farmers. For this to be successful, efforts to train these consultants in pollution prevention should begin immediately. Nationally established Water Quality, Integrated Pest Management, and Sustainable Agriculture initiatives receive substantial amounts of direct federal funding for both research and education. By allying with these programs, the AG P2 program could take advantage of both the funding and the infrastructure already in place.

While the pollution prevention technologies discussed thus far have proven utility, more improved technologies can and will be developed. Pollution prevention is a relatively new concept. However, the concepts of maximizing productivity, conserving soil and water resources, and minimizing environmental degradation have been investigated for many decades. This research has been highly successful returning an average of 1.5 to 5 dollars per dollar invested. Research needs have been identified and are listed in Adams and Risse, 1996. The AG P2 program will now seek funding and capable scientists to see that applied research projects are initiated.

CONCLUSIONS AND RECOMMENDATIONS

Pollution prevention opportunities can be broken down into the waste streams they control; runoff and soil erosion, plant nutrients, pesticides, and agrichemicals. Water quality degradation and soil erosion can often be limited or prevented through the implementation of proven techniques such as best management practices, crop rotation, vegetative buffers, and improved land management. Not only do farmers need to adopt methods of sustaining soil organic matter such as conservation tillage and crop rotation, but organic matter additions need to be investigated. Maintaining or improving soil quality should be the cornerstone of all effective pollution prevention plans. Nutrient management plans and other demonstrated economic techniques should continue to be supported and implemented. IPM and other cultural practices can often be used to both decrease the need for agrichemical inputs and increase their effectiveness. While many improved methods of storing and handling all types of agrichemicals have been developed primarily to address human health and safety issues, they are often based firmly in the principles of reducing risk and are consistent with the goals of pollution prevention.

Economics is often the major impediment of pollution prevention. New sustainable agriculture techniques need to be demonstrated with an emphasis on economic feasibility. Research and demonstration projects should be field oriented and conducted on producers' land. Oversight of these projects should be conducted cooperatively between the researchers and the growers. Financial assistance should be available for those growers willing to risk time and capital on testing and implementing new pollution prevention innovations. There is also a need for continuation of funding for applied pollution prevention research.

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