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Research: How Is It Done and Why Should You Care?

James W. Pease

"Society needs to negotiate a new contract with the scientific community ... rooted in the pursuit of explicit, long-term societal goals."
--U. S. Representative George Brown Jr. quoted in *The Christian Science Monitor*, February 10, 1993.

Why do university scientists do research? Are researchers interested in information for its own sake or for the sake of long-term goals of society? In fact, the motivation of most university researchers involves both of these purposes, and is influenced by other factors as well. Researchers are drawn to identified research issues by their scientific interest and skills and by funds to support their efforts. Although the availability of funding is an important incentive, researchers do not rush to study just any topic with funds attached. They attempt to link several research projects to address different aspects of an issue.

The applied research conducted by the Rural Economic Analysis Program (REAP) forms an example of the "new contract" suggested by Rep. Brown, in which citizen input frames the issues that researchers investigate. Citizen input to REAP is provided by the REAP Advisory Council, which consists of agricultural and rural leaders. The Advisory Council, in cooperation with the REAP staff at Virginia Tech, identifies the issues that REAP's research projects will address.

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This article describes four phases of the research process and uses a REAP-sponsored project as an illustrative case study. The process described here is most relevant to publicly supported, applied research.

Phase 1: Formulating the Research Topic

In 1988, the REAP Advisory Council identified, as a research "thrust area," the competitive position of traditional agricultural enterprises in Virginia. Within this thrust area, the Council identified a more specific issue: the effects on Virginia farmers of public efforts to protect water quality. The impact on water quality from cropland nutrient use has been a controversial issue. Unfortunately, much of the public debate over this issue has not been based on an objective analysis of the facts, because much of the information needed for such an analysis has not been available.

In response to this need, my colleague Darrell Bosch and I proposed in 1990 a research agenda focused on the farm-level impacts of water-quality protection policies. The general question to be addressed was this: What are the water-quality benefits and associated farm-income effects of policies designed to reduce nutrient applications to cropland? (*Ed. note:* Other REAP-supported research efforts on this topic have been reported in past issues of *Horizons*; these issues are listed in the references for this article.)

Our research goal was to provide objective information that would help citizens and policy makers find reasonable policies to satisfy water-quality objectives and, at the same time, maintain the competitive position of Virginia agriculture. Our research had two specific objectives:

•To obtain accurate estimates of current nutrient applications to crop and pasture land and of related potential impacts on surface and ground water quality;
•To estimate nutrient-application levels and related farm-level income effects of water-quality protection policies.

We did not attempt to estimate potential contamination of water supplies from nutrients applied to cropland. Rather, nutrient application levels recommended by Virginia Cooperative Extension were assumed to represent safe amounts for water quality; in turn, amounts exceeding recommended levels were assumed to pose a potential hazard to water quality.

Researchers can often use existing data from previous field-level surveys or experiments. Such data allow the researcher to construct mathematical models of farms--the "white rats" of this type of scientific inquiry. Using such models, economic researchers can examine the effects of alternative policies on farm income or other variables of interest. In our research, however, few data were available, so it was necessary to collect and analyze farm-level data.

Phase 2 - Primary Data Collection and Analysis

Collecting primary data is expensive. If, however, a research agenda addresses needs of society, funding agencies are usually willing to provide support. In our case, for example, the primary data collection was of interest to, and supported by, the Virginia Water Resources Research Center. Their grant in 1990 supported our work to estimate nutrient applications to cropland in selected Virginia agricultural regions and to study related issues. REAP supported all of the subsequent analyses, which were made possible by the collection of primary data.

Two farming regions of Virginia were investigated. Rockingham County, the leading agricultural county in the state, was selected because of its intensive livestock and poultry production. The second region, consisting of the Northern Neck counties of Lancaster, Northumberland and Westmoreland, was selected because the area's large row-crop farms are close to the Chesapeake Bay. In early 1991, 240 sites (portions of fields) were randomly selected from the Virginia Geographic Information System (VIRGIS) cropland database. Samples were drawn from cropland classified as having either low or high potential to deliver sediment to streams and either low or high potential for nutrients to leach through the root zone. (The sampling procedure is described in detail in Bosch *et al.*, listed in the references.) Interviews with farm operators provided information on 1990 nutrient applications, other cultural practices, and general farm matters.

Within each region, nutrient applications from both chemical fertilizer and manure were compared to Extension's agronomic recommendations for the crop and soil type of each sampled field. Applications relative to recommendations were then estimated for the entire sampled region.

The survey showed that, over all cropland in the Northern Neck, most farmers applied close to recommended amounts of nutrients. A few farmers applied levels well above the recommended amounts. Less than 3 percent of the cropland received nitrogen applications more than 30 pounds per acre over recommended levels (Figure 1), or phosphate applications more than 50 pounds per acre over recommended levels (Figure 2). To put these quantities in perspective, a typical per-acre recommendation for 140-bushel corn production is about 140 pounds of nitrogen and 60 pounds of phosphate.

In Rockingham County, even though a large proportion of cropland received manure applications and sometimes received commercial fertilizer as well, farmers on average still applied nitrogen in amounts below recommended levels (Figure 1). But many Rockingham farmers applied phosphate (primarily from dairy manure and poultry litter) in amounts well above recommended levels (Figure 2). Approximately 1 acre in 5 in Rockingham County received nitrogen applications at least 50 pounds per acre above recommended levels and phosphate applications at least 100 pounds per acre above recommended levels.

Cropland classified as having higher potential to erode or leach nutrients did not receive lower nutrient applications. In Rockingham County, steep slopes and karst limestone structures create a potential for excess nutrients to enter water supplies.

Phase 3: Understanding the Data

Once primary data is in hand, the next phase in a research process is to understand the data--by analysis, interpretation, and examination of the data's implications. More than simply organizing numbers into concise tables or graphs, this phase involves making decisions--aided by statistical tests--about the

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Figure 1. Nitrogen application relative to recommendation (per cropland acre) in two Virginia farming regions, 1990.

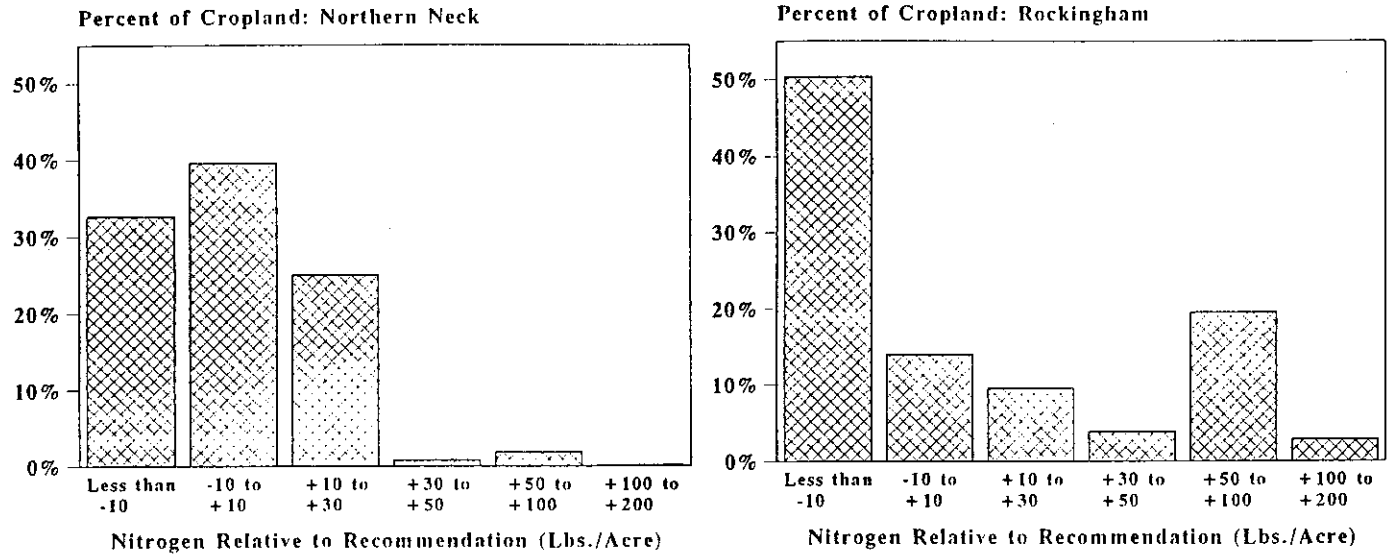
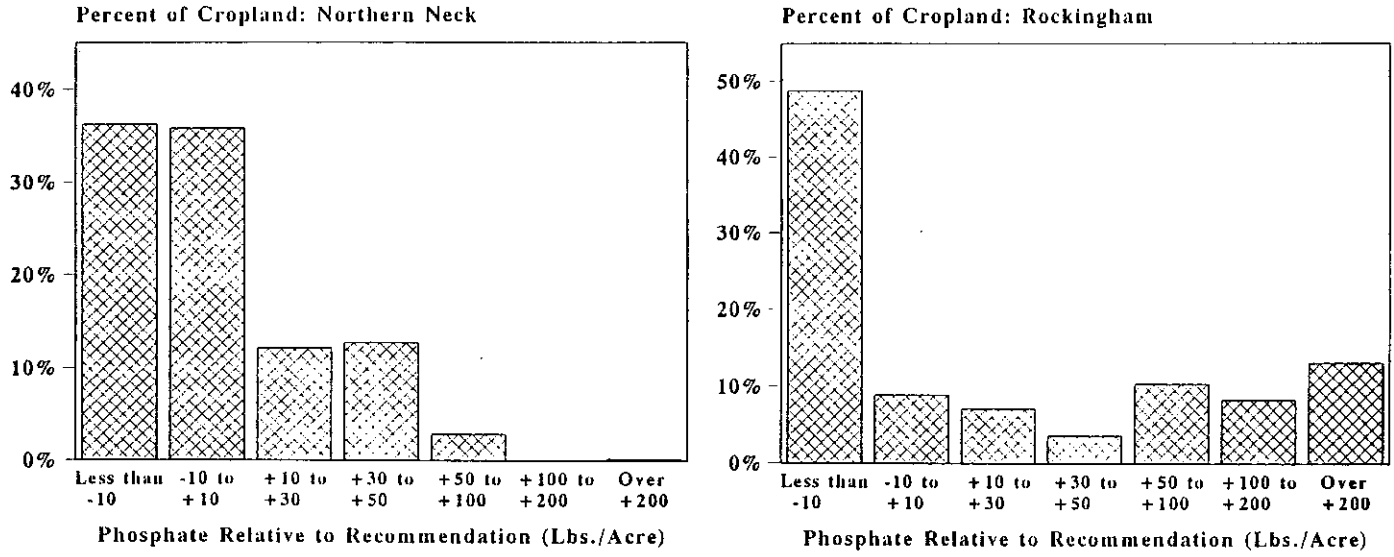


Figure 2. Phosphate application relative to recommendation (per cropland acre) in two Virginia farming regions, 1990.



significance of the information. A researcher is constantly asking, "What questions do the data answer, and what new questions are raised?"

Our primary data had the following implications:

- Educational efforts should be developed to help farmers fully understand the relationships between nutrient applications and water quality.
- To have the most cost-effective impacts on water quality, public policies should target cropland with high potential to erode or to leach nutrients.
- Livestock-intensive farms with small acreage are more likely to apply nutrients in amounts greater than recommended and may deserve more attention in water-quality education and protection efforts.

From this point, our Phase 3 analysis involved organizing the field-level data into farm models and examining the income effects of water-quality protection practices. No attempt was made in Phase 3 to estimate the water-quality benefits of reduced nutrient applications.

As mentioned, nutrient applications on the crop farms of the Northern Neck, were close to recommended levels. If recommended nutrient levels are safe for water quality, then water-quality protection efforts in that region appear to be on the right track.

In Rockingham County, however, relatively high application rates of animal wastes suggested the need

for a closer examination of the potential for water-quality damage through leaching or runoff of excess nutrients. Phase 3 focused, therefore, on farm-income effects of potential water-quality protection measures on Rockingham dairy farms. The question posed by the study was this: If farmers restricted their nutrient applications to recommended levels, what would be the economic impact on the farm? (*Ed. note*: This part of the research will be reported in detail in a forthcoming REAP Report by Bosch and Pease.)

A production and financial model for four 80-cow Rockingham dairy farms (the median capacity in the county) was developed from Phase 2 results and information from other sources. One such representative farm had a small land base (154 acres) and another had a medium-sized land base (241 acres). Two additional representative farms differed from the previous ones only in that the latter two each had 3 broiler houses (capacity slightly less than 1/2 million birds annually).

Baseline economic returns were first estimated for each farm under the assumption that all manure and litter would be applied to crop and pasture land. Then two alternative policies were examined: The first reduced nutrient applications to crop nitrogen requirements, while the second reduced applications according to nitrogen *or* phosphorus requirements, depending on which nutrient was most limiting to total manure/litter application.

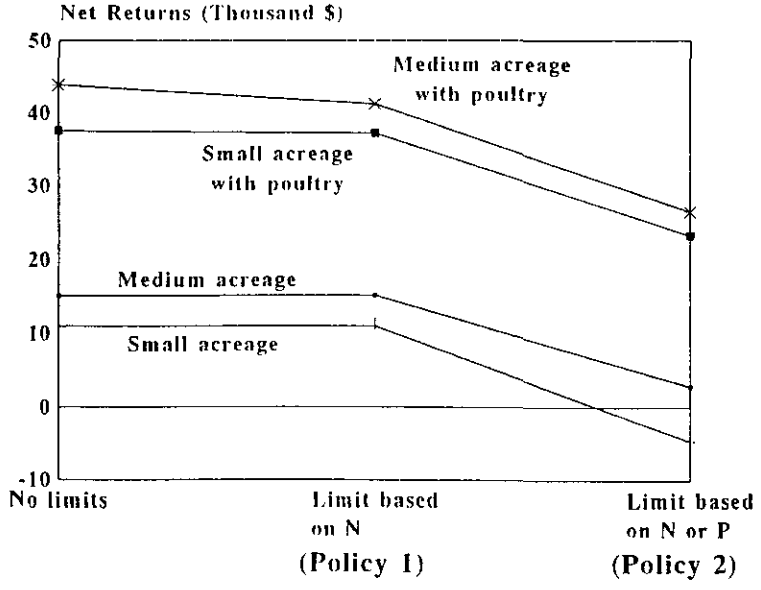
On Rockingham dairy farms, manure and litter substitute for some or all commercial fertilizer requirements. Nutrients in animal waste are present in relatively fixed proportions. For example, dairy manure contains about 92 pounds of nitrogen, 48 pounds of phosphate and 82 pounds of potash per ton of dry matter (these figures were calculated from Rockingham county manure tests and standard formulas). Restricting manure/litter applications to nitrogen or phosphate requirements may limit the substitution for commercial fertilizer because one nutrient requirement may be satisfied with manure/litter while commercial nutrients--at additional cost to the farmer--may be needed to satisfy the other nutrient requirement.

Our analysis was intended as a straightforward, first look at economic impacts of nutrient application policies, so it was assumed that farmers could adjust to the policies only by selection of more nutrient-intensive crops or by a decrease in animal numbers. Also, it was assumed that poultry litter could be shipped off the farm at no cost to the farmer.

Figure 3 shows the predicted effects on returns of the two proposed policies. For the first proposed policy--restricting manure applications to crop requirements for nitrogen--the net income of dairy farms without poultry operations would not be affected. Net income of farms with poultry would be reduced about 1 percent under this policy, because litter applications would be moderately decreased and some commercial nutrients would have to be purchased.

The second proposed policy--restricting manure applications to crop requirements for nitrogen or phosphorus, depending on which most limited the application--would reduce manure/litter applications, force more commercial nutrient purchases, and require cutbacks in cow numbers. Net incomes of farms without poultry enterprises would be virtually eliminated, falling 80 to 120 percent from the baseline incomes shown on the vertical axis. Farms with poultry would suffer approximately 40-percent decreases in net income compared to the baseline.

Figure 3. Estimated net returns for 80-cow dairies in Rockingham County under manure/litter application limits.



This analysis of the primary data has new implications:

- The cost of reducing nutrient applications may be prohibitive for many Rockingham dairy farms if farmers attempt to limit their manure/litter applications to crop and pasture nitrogen/phosphorus requirements.
- Innovative and flexible manure-management policies and cost-sharing arrangements would be required to avoid serious economic effects on the region's livestock industry if policies were implemented to limit nutrient applications.

These implications, and the issues they raise, are the basis for extending the research to a fourth phase, in which both the costs and benefits of possible policies are examined.

Phase 4: Using Results to Examine Policy Options

The research through Phase 3 examined only the farm-level costs of policies limiting manure/litter applications. It did not directly estimate nutrient losses from crop and pasture land or loadings to water supplies, nor did it examine how a wider range of policy alternatives might affect the county's dairy industry and related industries. These broader questions exemplify the fourth phase of research: applying results to issues affecting society and social policies. The final stage of our research has been designed to estimate tradeoffs between costs (from lower farm and related industry incomes) and benefits (from reduced nutrient losses to the environment) of potential nutrient-management policies. This effort is currently in process and will be completed during 1993.

From public policy research in other states, a wide range of potential nutrient-management policy alternatives will be evaluated. Using data from the Phase 2 survey and other sources, more complete production and financial representations o of Rockingham dairy farms will be developed. Field-level nutrient losses and farm-level economic impacts of selected policies will be estimated with computer simulation models. We expect that most proposed policies will result in a tradeoff between lower farm incomes and a reduction in the level of nutrients reaching the environment. Market-based nutrient-management policies can be expected to have the greatest potential to mitigate effects on farm income.

Although this phase of our research is not complete, the research product can be conceptualized by Fig. 4. Any potential policy implies a level of dairy farm income and a level of nutrient losses to the environment. In addition, policy effects on the economy of Rockingham County can be evaluated as impacts multiply through interdependent economic sectors such as poultry processing and dairy feed supply. Analyses such as these provide an objective basis for evaluating the tradeoffs and the overall acceptability of specific nutrient-management policies.

The Research Process is Not Mysterious!

Our goal in this article has been to describe how research issues are identified and investigated, using as an example the specific topic of nutrient applications and water quality. Our main theme is that research, if well-designed and carried out, produces results that permit more cost-effective and equitable public policy choices.

Table 1 summarizes the main activities in each phase of the research process. Although the specific questions addressed in other research projects would be different, the organization of research would be similar to that described here. While research *topics* may be difficult to understand, the *process* of applied, publicly funded research follows a predictable, logical sequence leading, one hopes, to new knowledge that benefits society.

Figure 4. Tradeoffs of farm income vs. nutrient losses (hypothetical).

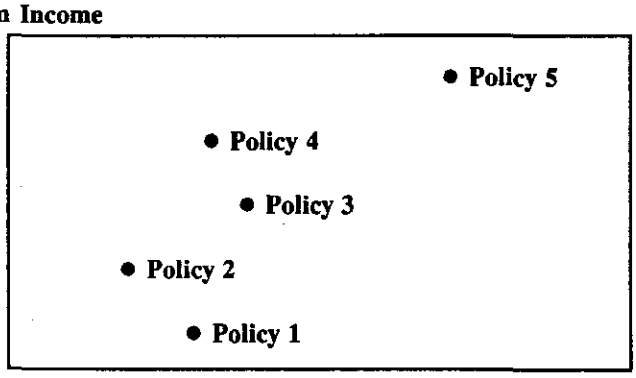


Table 1. Research phases followed in study of economic impacts of water-quality protection policies.

Phase 1--Formulating the issue

Phase 2--Collecting primary data

Phase 3--Understanding the results

Phase 4--Using the results to examine policy options

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NOTICES

*The Center for Economic Education at Virginia Tech will offer a two-week institute "Teaching Environmental Economics: Concepts and Strategies," to be held July 12-23, 1993, in Blacksburg. Designed for K-12 teachers and Extension agents, the course seeks to increase understanding of environmental and economic relationships, and to develop strategies for teaching these concepts to students. The cost for the course is $75 (includes room, board, books, etc.; course limit is 25 participants). For more information, contact Mike Ellerbrock, Dept. Ag. Econ., Virginia Tech, Blacksburg, VA 24061-0401; (703) 231-7513.

*A 10-volume water-management reference has been published by the Virginia Tech Department of Urban Affairs and Planning. The *Sourcebook for Local Water Resources Management* is a valuable tool for local water-management efforts. Copies have been distributed to all Virginia planning district commissions and local governments. A limited number of sets are available for $45 from the Virginia Coal and Energy Research Center, 617 N. Main Street, Blacksburg, VA 24060-3397; (703) 231-5038.

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