WHAT WE DON'T KNOW CAN HURT US

adoption of animal waste management strategies

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> Environmental benefits depend on adoption, not just technical feasibility.
> (Lockeretz, 1990)

Researchers in agronomy, animal science, soil science, and agricultural engineering have proposed a number of manure management strategies and technological innovations to reduce air and water quality problems associated with livestock manure. These include buffer strips, improved application technologies, improved information on nutrient content of manure, and feed additives, which reduce nutrient content and odor. However, adoption of the manure management strategies and innovations suggested by scientists has been disappointing. Environmental benefits depend on adoption, not just technical feasibility (Lockeretz, 1990). Increasing voluntary adoption of animal waste management strategies will require improved understanding of the economic and social barriers and constraints that currently limit adoption.

We support using a systems approach. A systems approach looks at the many, and complex interactions that farmers draw on to make a decision to adopt a nutrient management practice. Rogers (1995) and Stoneman (2002) indicate that the following affect adoption rates: different farmer values and goals, previous investments, and the complex interaction of biological and physical factors.

INDUCED INNOVATION THEORY

First, we need technologies and innovations that are adoptable. Much research has addressed manure management strategies in confined animal feeding operations (CAFOs, which are regulated), but smaller farming operations need manure management strategies as well. If technologies and innovations are not addressing the farm that does not qualify as a CAFO, why is this happening? Induced innovation theory is one way to answer this question.

Induced innovation refers to the impact of economic forces on the research, development, and diffusion of new technologies (Hayami and Ruttan, 1971). Market failure can reduce the demand for, and supply of, environmental innovations. If no policies exist to cause smaller farmers to take account of off-site environmental effects, there will be little demand for these innovations. Private firms have an incentive to conduct research that results in a marketable product so they can reap the rewards of their investments. Consequently, there is underinvestment in research for environmental innovations by the private sector because there is little demand for the product. This is in addition to the fact that private firms have little incentive to conduct basic research since they cannot patent the results and capture all the benefits from it (Arrow, 1962).

To remedy this situation, the induced innovation theory can be applied to the creation of policies to reduce negative impacts from intensive livestock operations, by making the negative environmental impacts central to the business' decision-making process. Policies and regulations that affect the pocket book, such as marketable pollution permits and emissions taxes/subsidies, can induce innovation by stimulating demand for new technologies. For example, Honeyman (1995) states that a particular hog production system in Sweden was invented because of the strict regulations in that country.

ADOPTION AND DIFFUSION

For innovations that have been developed, a number of barriers to adoption exist. A review of the adoption and diffusion literatures in economics and sociology shows that perceived characteristics of the innovation, characteristics related to the individual farm and farmer, as well as the social system are important (Feder and Umali, 1993; Rogers, 1995; Stoneman, 2002). Given the variability in farms, farmers, and location-related factors, different barriers will be most limiting and one-size-fits-all technologies and policies will not be appropriate.

To date, the barriers to adoption that have been studied include profitability, cost of equipment, time investment, transportation, uncertainty of potential costs and benefits, and complexity (see sidebar). Complexity implies that there will be costs associated with information acquisition and processing. Rahelizatovo and Gillespie (2003) found that among Louisiana dairy farmers, "need more information" was a more common reason for non-adoption of best management practices than "high cost of implementation." To remedy this, it has been found that increased information availability and trialing of innovations reduces uncertainty (Rogers, 1995; Pannell, 1999; Nowak, 1987). Well-developed communication channels can also reduce information costs (Rogers, 1995).

Adoption occurs in the context of a social system. Formal (e.g. regulations) and informal (e.g. norms of neighborliness) institutions may affect rates of adoption. The structure of the social system may affect who is involved in decision-making (Rogers, 1995). Some researchers have found that environmental empathy affects adoption of conservation practices (Nowak, 1987; Traoré et al., 1998). Discomfort also may affect adoption rates (Rogers, 1995).

Any strategy to increase adoption of manure management technologies must be based on an understanding of the factors that affect adoption. Reducing uncertainty, providing more information, increasing benefits and lowering costs, reducing time constraints, improving access to credit, taking advantage of institutional changes affecting the livestock industry, and recognizing the constraints posed by incompatibility with existing farming systems, will all increase adoption rates. Research on new technologies and practices should build on these factors.

FUTURE NEEDS

So to recap, we know induced innovation theory can help society create needed environmental management innovations, and for our purposes, manure management strategies. We have research that highlights specific barriers to adoption of the manure management strategies we currently have available. Now we ask, Where are the holes? What don't we know that we should know? and How do we get to a place where manure management strategies have a greater adoption record?

Different types of animal operations (e.g. species, size) in different settings (e.g. biophysical, institutional) will have differing needs for manure management technologies and techniques. Rather than seeking universal technical or policy solutions, systems methodology seeks an understanding of the complex, comprehensive, multi-systems at work on the farm. Systems methodology informs us that a more nuanced approach using knowledge about adoption and diffusion is appropriate. Consequently, it is critical to design assessments that integrate biophysical, economic, and social factors to both quantify the need for abatement and identify barriers to adoption.

In the past, manure storage technologies have received ample research. But when analyzing the barriers to adoption, it seems that more research is needed on production systems and application technologies. Production, storage, and application technologies that provide a better nutrient balance and reduce the variability of manure nutrient content (or adjust to that variability), will improve the use of manure as a fertilizer. In some areas, there are already excess nutrients so technologies that produce alternative, valuable products from manure components are required. Production systems are needed that drastically reduce the water content of the manure so it can be more easily transported and incorporated in other production processes (e.g. Koger et al., 2005).

Related to new technologies and new uses, is the concept of the adopting unit. Most new technologies relative to manure management are designed with the expectation that a farm unit will be the target audience. However, little attention has been given to the idea of technologies appropriate to a contiguous or neighboring group of animal operations. For example, technologies could be designed for a "manure cooperative" where manure is collected at a central location and processed to produce a value-added product such as energy, carbon sequestration, or biomass. This would involve large-scale technologies, development of markets, and a form of social organization that would facilitate this type of collective approach.

Social science research that more carefully and systematically identifies constraints to adoption of manure management strategies is needed. There has been almost no research on the discomfort involved with manure affects; how it is managed; and how acceptable it is as a fertilizer substitute (although see Nunez and McCann, 2004). There is also little research on the effect of social pressure on manure management.

Research on policies needs to evaluate how to take advantage of structural changes in the industry and promote technical and institutional innovations. Policy research needs to take into account the factors affect-

additional research on barriers to adopting manure management strategies.

BARRIER	***RESEARCH***
PROFITABILITY, OR LACK OR PROFITABILITY	Contant and Korsching, 1997; Fleming, 1999
STORAGE STRUCTURES AND APPLICATION EQUIPMENT COSTS	Boland et al., 1999; Pfost et al., 2001
CREDIT CONSTRAINTS	Forster, 1997; Sunding and Zilberman, 2001
TIME FACTOR WITH RESPECT TO BOTH LABOR AND MANAGEMENT REQUIREMENTS	Cabot and Nowak, 2005; Karlen et al., 1995
TIMING OF OPERATIONS DURING THE YEAR	Lanyon, 1994
TRANSPORTATION COSTS—A CRITICAL ISSUE AND WILL BECOME MORE SO WITH PHOSPHOROUS-BASED REGULATIONS	Cabot and Nowak, 2005; Jones and D'Sousa, 2001; Ribaudo et al., 2002
UNCERTAINTY REGARDING POTENTIAL COSTS AND BENEFITS	Rogers, 1995; Sunding and Zilberman, 2001

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ing adoption behavior in order to develop policies that are flexible, effective, and that also have low transaction costs.

Solutions to problems associated with manure mismanagement will not be found within one discipline. Development and promotion of manure management technologies and techniques requires an interdisciplinary, systems approach, rather than just a multidisciplinary one. This fact appears obvious, but systems research is scarce in this area.

There are two major challenges associated with conducting systems research that needs to be addressed. First is the lack of a clear methodology on how systems research is to be conducted, especially in regard to environmental or sustainability parameters (Stoorvogel et al., 2004). The second major challenge is associated with the institutional barriers that hinder the interdisciplinary support and collaboration needed for systems research (Nissaini, 1997).

So in conclusion, we know producers have barriers to adoption, we know researchers have barriers to research. And, it may be the information that we currently don't know will be the answer for the future.

Addressing the problem of air and water pollution from livestock operations requires voluntary adoption of manure management strategies by people and firms. Economics and sociology research can help identify barriers to adoption, as well as characteristics of farms, farmers, and situations that are barriers to adoption. State and federal policies affect both the initial development of strategies, as well as their adoption and diffusion. An interdisciplinary, systems approach is needed to find solutions to manure management, but methodological and institutional barriers exist making it difficult to conduct the necessary systems research.

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