LOW INPUT AGRICULTURE:

TRENDS, GOALS AND PROSPECTS FOR INPUT USE

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Low-Input Agriculture:

Trends, Goals and Prospects for Input Use

Low input agriculture (LIA) has reemerged as an issue of the day. It was last a topical issue during the 1970's energy crisis, when the focus was on reducing our reliance on petroleum-based inputs (Klepper, et al.). LIA's current popularity is similarly motivated, but supported by growing evidence of environmental and health risks from agri-chemicals. The drop in commodity prices and farm equity value which occurred between 1981-87 has rekindled interest in developing cost-reducing technologies. Accumulated evidence on groundwater quality effects of nitrogen fertilizer and pesticides (Nielsen and Lee), has triggered numerous State and Federal proposals and administrative actions with respect to agri-chemicals and the environment. Concerns about costs of production and environmental effects are formalized in a recent USDA statement which supports research and education on "alternative farming systems that decrease or optimize the use of purchased inputs and that can increase net cash returns... through decreased costs of production (and) may effectively improve the competitive position of the farmer and decrease the potential for adverse environmental impacts" (USDA).

We question whether widespread employment of systems that concurrently meet these multiple objectives can occur under existing farm policy and economic conditions. Our argument rests on two basic assumptions: profit maximization is a strong motivation for production decisions; and externality issues are the driving force for public encouragement or intervention to selectively reduce purchased input use. We hypothesize that current "high" demand for agri-chemicals coincides with profit maximizing levels of input use. To the extent that empirical evidence supports this hypothesis, the real debate involves the forms of intervention available to internalize externalities.

Low Input Agriculture Goals

Production systems currently referred to as low input systems are typified by enterprise, spatial and temporal diversity, and an implied substitution of land, labor, management, and information for agri-chemicals. The crop systems typically employ rotations of leguminous crops to facilitate soil nutrition and reduce pest populations. Greater emphasis on own-produced inputs in polycultural systems is presumed to lead to lower levels of agri-chemical use while maintaining net revenues at present levels over the long run.

Case studies indicate that, under special circumstances, low input farming can generate net economic returns equivalent to conventional farming in the Corn Belt and semi-arid Northwest regions of the United States (Cacek and Langner). Despite these findings, the systems commonly described as low input are relatively scarce in U.S. agriculture.

On the contrary, a major trend has been the steady rise in consumption of purchased inputs relative to non-purchased inputs. Since 1900, total production expenses have grown from 45 percent to over 80 percent of gross farm income. Concomitantly, the share of value added by a farmer's own and unpaid family labor and owned land has steadily declined. Between 1950 and 1985 alone, manufactured input, interest, and capital consumption expenses as a share of total production cost grew from 22 to 42 percent while labor and farm origin input shares declined from 52 to 34 percent.

Similarly, agri-chemical (fertilizer and pesticide) consumption has grown rapidly (table 1). Since 1960, the percent of acres treated with herbicides has grown dramatically, with over 95 percent of corn and soybean acres and over 60 percent of wheat acres treated by 1987. Nitrogen use has also shown large increases. By the mid-1960's, the value of nitrogen in corn production was well known and its use widely adopted. In 1965, 75 pounds per acre of commercial nitrogen were applied to 88 percent of the corn acreage. By 1987, 132 pounds per acre were applied to 96 percent of the corn acreage. Aggregate nitrogen use has more than tripled since 1960 while pesticide use doubled (table 1).

There are several bases for characterizing current chemical use as excessive. Principal among these is that externalities arising from agri-chemical use imply that privately determined optimal rates of use are higher than their corresponding social optima. Underground and surface water quality, food residues, human health and farmworker safety are the common externalities associated with agri-chemicals. Failure to incorporate these negative-valued outputs underprices agri-chemicals.

Also, evidence provided by agricultural scientists indicates that current rates of fertilizer and pesticide use are greater than the private optimum levels for plant nutrition and protection (Olson, et al.). These results suggest that some producers may be operating under yield maximization rather than profit maximization objective functions, or that ex-ante uncertainty may lead profit maximizing producers to use inputs in excess of what would have been the case under perfect information regarding output price, weather, and pest infestations.

Forces Shaping Current Input Use

At any point in time, the profit-maximizing combination of resources for the production of a commodity depends on relative factor and product prices and the shape of the underlying production function. Over time, changes in technology will alter the shape of the production function. Changes in product demand and factor supply will also change factor and product price ratios. In reality each of these phenomenon is, of course, filtered through a variety of institutions and public policies.

Relative Prices

Historical evidence supports the hypothesis that initial increases in agri-chemicals were fostered by declines in agri-chemical prices relative to crop prices (Heady and Yeh). More recent applied work shows that output prices do, indeed, influence input use levels, through the extent of responsiveness varies by study and approach. Using cross-sectional data, Miranowski obtains partial output price elasticities ranging between 0.11 for fertilizers with respect to cotton price to 3.04 for corn herbicides. Hertel, using a multi-input/multi-output framework, estimated gross input use elasticities with respect to output price of between 0.6 (chemicals w.r.t. oilseeds) and 2.0 (chemicals w.r.t. livestock).

From the early 1950's through 1973, fertilizer prices relative to crop prices decreased almost steadily (fig. 1, panel a). The effect of the energy crises is apparent after 1973, with fertilizer price increases particularly obvious in 1973-74 and 1979-81. More specifically, nitrogen (ammonia) fertilizer prices relative to the corn loan rate remained stable or declined through the early 1970's (fig. 2, panel b). The ammonia/corn loan rate price ratio has been volatile but trending slowly upward since 1973. Similarly, nitrogen fertilizer application rates exhibited a decrease in the rate of increase, a stabilization, and then a decline over the same period.

The extent to which factor price ratios influence agri-chemical use depends upon the degree of competitiveness or complementarity observed between chemicals and other factors. Empirical work in identifying substitution relationships among agricultural inputs has had mixed results. However, most recent studies using post-war data identify agri-chemicals as either strong or weak substitutes for labor, capital and land (Capalbo and Vo). Thus, increasing wage rates, capital cost, and land costs relative to agri-chemical prices provide a plausible explanation for rising agri-chemical use.

Over most of the last 4 decades, farm wage rates rose at a much greater rate than the price of agri-chemicals (fig. 1, panel c). Prices of farm machinery also advanced more than those for agri-chemicals (fig. 4, panel d). As a result, agri-chemicals became relatively less expensive over the entire postwar period preceding the 1970's energy crisis, making fertilizer and pesticides cheap substitutes for competitive inputs and attractive adjuncts to complementary inputs.

Commodity Program Effects

Young and Goldstein suggest that commodity programs pose a constraint to the adoption of "low-input" agricultural systems not only because price supports are limited to a few program crops, but also because payments for these program crops have been tied to historical production. The use of program yields on base acres to determine deficiency payment levels is seen as having provided incentives for farmers to "push the intensity of supported crops in rotations towards their biological limits," and to "fertilize and apply pesticides for near-maximum yields." However, empirical tests do not support the hypothesis that commodity program participants use greater than optimal rates of fertilizers and pesticides for the purpose of maximizing program yield levels (Heady and Yeh; Brandow; Offutt). This apparent lack of responsiveness can be partially explained by changes in average land quality as acreages are reduced in return for commodity program payments (Ash and Lin).

Another issue is the loss of flexibility in cropping patterns imposed by government programs. For example, should changes in relative crop prices encourage the production of a non-program crop, an operator must consider the loss of base in any decision to modify his/her output mix. Glauber has shown that, without government programs, current soybean/corn price ratios favor soybeans. Yet because of the base loss associated with planting soybeans, Corn Belt farmers are unlikely to switch from agri-chemical intensive corn to soybeans.

Technical Change

Technical change represents a shift or change in the shape of the production function. The introduction of hybrid corn seed is a dramatic example of change in the production surface which also led to an increase in fertilizer use, exclusive of relative price effects.

Technical change is not independent of relative prices. The theory of induced innovation (Hayami and Ruttan) suggests that technical change is motivated by the opportunity to use less of relatively higher priced factors of production. This cost reducing effect of technical change is offered as a rationale for the fact that since 1950 developments in U.S. agriculture were labor-saving as wage rates rose relative to other agricultural factor prices. Empirical evidence consistently supports agri-chemical-using and/or labor-saving biases in aggregate U.S. agricultural technology advance (Capalbo and Vo). Decomposition techniques also suggest that technical change has been land-saving with respect to variable inputs (Shoemaker). Hayami and Ruttan attribute land-saving technology to induced innovation, claiming that variations in the fertilizer-land price ratio alone explain more than 90 percent of the variation in fertilizer use between 1880-1980.

<u>Agri-chemical Use and Profit-Maximizing Behavior</u>

It seems clear that agri-chemical use has become "high" in response to rational, profit-maximizing behavior by farmers and the availability of labor saving technology. While producers differ in their response, all of the economic stimuli over the past 40 years would logically induce profit maximizers to increase agri-chemical use. Viewed within the production economics framework, it is really no surprise that agri-chemical use is widespread.

This broad generalization has important qualifications. Our review of aggregate relative prices and technical change ignores simultaneity, masks the dynamics of adoption and interfirm differences, and does not consider institutional factors. As Antle and Capalbo make clear, change in factor cost shares stems not only from factor price changes, but from scale changes, and output level changes as well as biased technical change. Each of these forces acts simultaneously to influence input use levels in a dynamic production process. It is particularly difficult to distinguish factor substitution, output, and technical change effects. Also, anecdotal and empirical evidence suggests that lenders can have a strong influence on input use. Lee and Chambers have shown that factor allocation decisions are linked to credit constraints. And, interfirm differences in enterprise mix and management quality lead to micro-level variation in production functions (Mundlak). This latter point is especially relevant in light of case studies which show that reduced agri-chemical use can lead to the same or higher net revenues.

In light of LIA's advocacy of input substitutability, several hypotheses should be critically, and, eventually, empirically examined. LIA implies that farmers can substitute labor for agri-chemicals while maintaining net revenue. Given farmers' current preference for leisure time and the cost of hired labor, either the relative price of labor must fall or preference for leisure must change before farmers would opt for this substitution. LIA suggests adoption of rotations as a means to reduce agri-chemical inputs (e.g. legumes as a source of nitrogen, which also reduces monoculture cropping, leading to reduced need for commercial pesticides). In essence, land is substituted for agri-chemicals. But either output or input price ratios need to change to make this a rational decision. Finally, management/education/information are suggested as substitutes for agri-chemicals. Examples include timing of agri-chemical applications, adoption of more sophisticated techniques to determine optimal application rates (i.e. soil and tissue testing) and closer monitoring of pest levels. If farmers are not using these management intensive techniques now, they must either be unaware of them, or the effort needed to do so is not perceived to be worthwhile.

Reversing the Trend

While evidence indicates that farmers' current level of agri-chemical use is optimal for maximizing profits, questions of socially optimal levels abound. A number of current and proposed policies are aimed at reducing agri-chemical externalities. If these policies are the driving force behind reduced agri-chemical use, the consistency between their expected outcomes and the goals of LIA warrants some examination.

Taxes/User Fees

The imposition of taxes or user fees on fertilizers and pesticides has been proposed as a means of reducing externalities. But a number of factors limit the feasibility and effectiveness of this approach. Uncertainty, stochasticity, and lack of information on physical and social parameters pose constraints on determining the level of tax that equates social preferences with private use rates (Shortle and Dunn). The spatial, distributional and income aspects of taxes on selected agri-chemicals are also problematical. Furthermore, the demand for agri-chemicals is relatively unresponsive to changes in own price, implying that tax rates would have to be very high in order to stimulate adoption of low input practices. Recent studies of aggregate U.S. agri-chemical use found that demand is inelastic with respect to own price, with published estimates ranging from -0.25 to -0.54 (Capalbo and Vo). This price unresponsiveness may be due to a lack of available substitutes or that substitutability with other inputs is low. In either case, significant price increases would be needed to either induce innovative discovery or make conventional agri-chemical inputs less profitable.

The Pigouvian tax approach is not only uncertain in its effect on reducing agri-chemical use and associated externalities, it is clearly inconsistent with the stated profit and commodity price maintenance goals of LIA. Taxation increases production costs and imposes upward pressure on commodity prices.

Modifying Commodity Programs

The output effect of commodity price support programs on increasing agri-chemical use could be reduced by decoupling farm income support from production levels. Dixon, Dixon, and Miranowski suggest that removal of commodity program-induced effects on crop mix and location of production could greatly reduce aggregate pesticide use.

On the other hand, radical change in commodity programs would also mean discontinuation of the acreage reduction programs that have periodically reduced aggregate use of agri-chemicals. The net effect of commodity program modification rests, in part, on the substitution relationships between land and variable inputs. If land is, in fact, a substitute for agri-chemicals, a discontinuation of commodity programs could also encourage adoption of low input systems through the decapitalization of program benefits from land values.

Miranowski found significant changes in chemical input requirements with a shift in farm program strategy. A free market scenario showed larger environmental gains than longer term land retirement or production quota alternatives, though effects on both farm income and agri-chemical reduction depend upon farmers' expectations and assumptions regarding agricultural export demand. Pursuit of a free market solution can accomplish the same objective as taxation, with less intervention and positive rather than negative effects on farming profitability. While consistent with LIA and environmental goals, commodity program modification has not been a typical approach to externalities reduction.

Research, Extension, and Education

To the extent that uncertainty and imperfect information lead to excessive agri-chemical use, training, education, and extension of new information can be effective in reducing demand for agri-chemicals. Carlson showed the value of weather forecast information in optimizing pesticide use for disease control. Hanneman and Farnsworth found that information was the critical factor affecting California farmers' decisions to adopt IPM. Pingali and Carlson report that training which reduced errors in subjective probabilities regarding pest damage led to a substitution of labor and management for pesticide use in orchards. It is apparent, at least with respect to pesticides, that improvements in human capital can foster the transition to LIA.

New technology could help advance the LIA initiative. Examples include nitrogen fixing grasses, biopesticides, improved carrier material (to keep nutrients near the roots and pesticides near the pests) and crops genetically engineered to attack insects. Physical scientists see these new technologies as answers to environmental quality problems that allow farmers to maintain or increase their productivity. While these new techniques may lower conventional pesticide and fertilizer use, production costs could remain unchanged if these new technologies are as expensive as traditional agri-chemicals. In this case, LIA could lead to higher, not lower costs, with no guarantee for minimization of purchased input use. Futhermore, if the economic signals for inducement of private innovation in these areas are absent, a significant redirection of public research is needed if LIA-consistent technology is to become available.

Regulation

The extent to which regulation can engender a net reduction in externalities also depends upon the opportunities for input substitution (Archibald). Banning or restricting agri-chemicals' use raises the cost of agricultural production, with consequent reductions in consumers' surplus (Taylor and Frohberg). The inelasticity of demand for agricultural goods suggests producers' surplus increases, but distributional consequences may be severe (Osteen and Kuchler). By placing a damper on productivity growth, agri-chemical regulation is unlikely to directly contribute to all the goals of LIA. Regulation could, however, be expected to provide the signals for innovative development of LIA technologies or chemical alternatives.

Conclusions

Examination of the economic forces shaping aggregate input mix goes a long way in explaining current agri-chemical use patterns. Our review of economic circumstances leading to and maintaining current levels of agri-chemical use leads us to conclude that there presently exists little market incentive for private development or adoption of LIA systems. Farmers adopt certain techniques and use certain inputs because it is economically beneficial to do so.

If, because of the externalities associated with present output and input mixes, society places a high value on the switch to LIA, then some form of aggressive public intervention will be needed. However, neither regulation nor other forms of direct intervention to change relative price signals can be expected to induce a change to LIA systems that both maintain profits and lower U.S. commodity prices to stimulate exports. Thus, these options fail to meet all criteria for the advertised advantages of LIA.

A conscious reorientation of public research and extension could, to some extent, offset the effects of the bias towards land-saving and material-using technical change. But the likelihood of public decisions to implement such a long-run strategy for LIA seem closely tied to current economic conditions. Interest in LIA appears to peak in periods when input prices rise relative to output prices. We question whether the present popularity of LIA will survive to significantly influence research direction if commodity export demand and prices return to pre-1981 levels. Should this occur, externalities issues will have to compete against incentives for output increases as the driving force for change in agri-chemical use.

Because of commodity programs' effects on output level and mix, removal or modification of commodity program incentives would likely have the most dramatic short-term influence on the feasibility of LIA systems. Empirical studies suggest that targeted output reduction or decoupling strategies could reduce the demand for agri-chemicals. The magnitude of potential reduction, however, is uncertain.

Additional, updated research is needed on the interaction of factors affecting demand for agri-chemicals. Production economics provides a useful framework for examining aggregate tradeoffs among outputs, inputs, and externalities. However, the complexities of aggregate production make this a challenge. Relative factor and product price relationships alone are insufficient to explain production possibilities. Further work is needed to separate factor substitution in a dynamic environment from output, scale, and technical change effects. Efforts to incorporate externalities into production functions will also be necessary to provide a broad-based rather than case-based rationale and strategy for LIA.

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Table 1--Agri-chemical Input Use: Aggregate and by Major Commodity, 1960-87.

	Acres Treated with Herbicides			Acres Treated with Insecticides			Acres Receiving Nitrogen Fertilizer			Nitrogen Applied Per Acre			Total Consumption	
	-------Percent-------			-------Percent-------			-------Percent-------			-------Pounds--------			Nitrogen	Pesticides
	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat	Corn	Soybeans	Wheat	Mil. Tons	Mil. lbs.[f]
1960	27[a]	NA	20[a]	6[a]	NA	NA	NA	NA	NA	NA	NA	NA	2.7	NA
1965	57[b]	NA	29[b]	33[b]	NA	NA	88	11	48	75	10	31	4.6	335
1970	79[c]	68[c]	41[c]	35[c]	8[c]	7[c]	94	21	61	112	14	39	7.5	430
1975	90[d]	88[d]	38[d]	38[d]	7[d]	14[d]	94	18	63	105	15	46	8.6	625
1980	93	92	42[e]	43	11	3[e]	96	23	67	130	17	58	11.4	846
1985	96	95	44	45	7	5	97	17	77	140	15	60	11.5	861
1986	96	96	53	41	4	7	96	15	79	132	15	60	10.4	820
1987	96	95	61	41	3	7	96	20	80	132	20	62	10.3	NA

Sources: Osteen, C. and P. Smedra. Pesticide Use and Productivity Issues, USDA, Econ. Res. Serv., forthcoming; Vroomen, H. Fertilizer Use and Price Statistics, 1960-85, USDA, Econ. Res. Serv., Stat. Bul. No. 750, Feb. 1987; and Environmental Protection Agency, Office of Pesticide Programs, Pesticide Industry Sales and Usage, 1986 Market Estimates and Previous Years.

NA = not available

[a] 1958.

[b] 1966.

[c] 1976.

[d] 1982.

[e] Active ingredients.

Figure 1 -- Selected product-factor and factor-factor price index ratios