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Public Research in Agriculture, Forestry and Home Economics: Its Role, Its Benefits, and Selected Issues

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INTRODUCTION

During the past half century, U.S. agriculture has undergone a transition from a labor-intensive, resource-based industry to a capital-intensive, science based industry. Agricultural productivity has increased substantially as new biological, chemical, and mechanical technologies have been developed, and institutional innovations have encouraged their adoption and mitigated adjustment costs. Extension and formal education have enhanced the impact of new technologies by enabling farmers to efficiently employ new methods over a wide range of physical and economic conditions.

In 1984, inputs into agricultural production; the agricultural production process itself; and the processing, distribution and selling of this production accounted for an estimated $648 Billion of GNP and employed 21.3 million people in the U.S. (Harrington, *et al.*, 1986). The economic activities involved are extremely important to our economy and our physical well being. The amount spent on agricultural research from public and private sources to sustain this activity was a modest one-half of one percent of the value added.

But American agriculture is at a crossroads. Large surpluses exist for several commodities, water quality is an issue of broad concern, many farmers are experiencing financial difficulties, and the competitiveness of U.S. farm products has slipped in international markets. Federal budget deficits create pressures for reduced real (constant dollar) public expenditures on agricultural research. In such an environment, should the United States continue to fund agricultural research at previous or even expanded levels? Who would be the beneficiaries of this research? What should be the mix of public and private financial support for agricultural research? Should public agricultural research focus on basic or applied research? What are the economic consequences of United States support for international agricultural research? These and other questions are the focus of this report. The intent is to address important issues with respect to agricultural research and provide a reasoned response to a set of complex and timely questions.

In addition, questions are raised and answers provided as to the role and benefits of publicly supported research in forestry and home economics.

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WHAT IS THE PAYOFF TO AGRICULTURAL RESEARCH IN THE UNITED STATES?

Agricultural research constitutes an investment aimed at improving society's well-being by raising returns to factors of production through lowering costs or increasing output, by improving product quality or introducing new products, and by reducing farmers' vulnerability to forces beyond their control (Arndt and Ruttan 1977). Innovative farmers obviously benefit from the adoption of new technologies and consumers benefit from agricultural research through increased quantities of high quality food and fiber at lower prices. Agricultural research also helps the United States maintain its competitiveness in world markets thereby increasing foreign exchange earnings.

The gains from agricultural research are realized in other, perhaps more subtle, ways as well. In addition to the direct effects of research-induced productivity growth, there are secondary or multiplier effects on income and employment in the economy as a whole. These benefits stem from changes in the demand for services of input suppliers, marketing and processing firms, and, through them, on the demands of these firms and their employees for industrial and household goods throughout the economy.

Agricultural research has also contributed to improvements in environmental quality. Minimum-tillage farming systems not only conserve energy but reduce erosion and run-off harmful to streams and lakes. Integrated pest management is leading to more timely applications of pesticides which lower pesticide use and costs. But, water pollution from pesticides and fertilizers remains a problem in some areas.

Agricultural research has eased the drudgery and extended the productive worklife of the farmer. Machines, electricity, and herbicides now perform tasks formerly done in a backbreaking manner. Agricultural research has led to reduced resource costs to industry. Efficiency gains resulting from the adoption of new technologies in farming have freed up labor for employment elsewhere in the economy. Lower food prices have facilitated the hiring of that labor by enabling wages to be lower than they would otherwise have been, thus stimulating overall economic growth in the United States. Lower food prices resulting from research also help mitigate inflation.

The United States has recognized the importance of and made a sizable investment in agricultural research. Several studies have attempted to quantify the magnitude of the benefits to that investment. These studies have found that for a wide range of commodities and types of research, the economic returns to public investment in agricultural research have been high compared to other investments available to society. A summary of 21 studies for the United States provided in Table 1 indicates returns in the 30-100% range for most commodities. It is difficult to imagine very many other public activities that would yield as high an annual rate of return on investment.

Few studies have attempted to measure the secondary or multiplier effects of research on income and employment in the economy as a whole. However, one study for Virginia found that an additional $1 million for public agricultural research adds about $9 million to agricultural output but almost $11 million to the gross state product (value-added) and more than 300 man-years (jobs for a year) of employment (Norton and Nichols, 1985).

In summary, the payoffs to agricultural research are multi-faceted. Empirical evidence suggests that the economic returns have been very high indeed.

Table 1. Summary of Agricultural Research and Extension Productivity Studies for the U.S.

Study	Commodity	Time Period		Annual Internal Rate of Return (%)
Griliches, 1958	Hybrid Corn	1940-55	35-40	
Griliches, 1958	Hybrid Sorghum	1940-57	20	
Griliches, 1964	Aggregate	1949-59	35-40	(research & extension)
Latimer, 1964	Aggregate	1949-59	not. sig.	
Peterson, 1967	Poultry	1915-1960	21-25	
Evenson, 1968	Aggregate	1949-59	47	
Schmitz and Seckler, 1970	Tomato Harvester	1958-69	16-28	
Cline, 1975	Aggregate	1939-48	41-50	(research & extension)
(Revised by		1949-58	39-47	"
Knutson and		1959-68	32-39	"
Tweeten, 1979)		1969-72	28-35	"
Bredahl and	Poultry	1969	37	
Peterson, 1976	Dairy	1969	43	
	Livestock	1969	47	
	Cash Grains	1969	36	
Peterson and Fitzharris, 1977	Aggregate	1937-42	50	(research & extension)
		1947-52	51	"
		1957-62	49	"
		1967-72	34	"
Evenson, 1979	Aggregate	1868-1926	65	
	Technology Oriented	1927-50	95	
	Science Oriented	1927-50	110	
	Science Oriented	1948-71	45	
	Technology Oriented (South)	1943-71	130	
	Technology Oriented (North)	1948-71	93	
	Technology Oriented (West)	1948-71	95	
	Farm Management and Agr. Extension	1948-71	110	(research & extension)
Davis, 1979	Aggregate	1949-59	66-100	
		1964-74	37	
White and Havlicek, 1979	Aggregate, South	1929-72	20	(research & extension)
White, Havlicek,	Aggregate	1929-41	54.7	"
and Otto, 1979		1942-57	48.3	"
		1958-77	41.7	"
Norton, 1981	Cash Grains	1969	31-57	
	Dairy	1969	27-50	
	Poultry	1969	30-56	
	Livestock	1969	56-111	
	Cash Grains	1974	44-85	
	Dairy	1974	33-62	
	Livestock	1974	66-132	
Smith, Norton, and Havlicek, 1983	Cash Grains	1978	202	
	Dairy	1978	25	
	Poultry	1978	61	
	Livestock	1978	22	
White and Havlic	Aggregate	1977-81	48	
	By Region	1977-81	23-74	
Braha and Tweeten	Aggregate	1959-82	47	(research & extension)

Source: Adapted from Ruttan (1982).

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WHAT ARE THE BENEFITS TO CONSUMERS FROM AGRICULTURAL RESEARCH?

Consumers of agricultural products in this country as well as elsewhere benefit from agricultural research conducted in the United States in several ways. Most importantly, these benefits include expanded quantities of agricultural products which lower food and fiber prices. Some benefits, such as improved nutrition, appear to be concentrated among low-income groups, because malnutrition is most evident among low-income families (Timmer and Nesheim 1979). Agricultural research that improves the safety of food products is likely to affect consumers in all income categories. The benefits of such research include improved health and longer life.

As reported in Table 2, it is estimated that current annual expenditures for agricultural research result in almost $40 of benefits for the average U.S. family. This figure represents the present value of the benefits that are anticipated to accrue in the future. Impacts of agricultural research differ among consumers by income levels. Estimates of the benefits resulting from agricultural research (discounted to present value), accruing to groups with various income levels in the U.S., ranged from $28 for the lowest income group (less than $10,000 annually) to $56 for the highest income category ($35,000 and over). Although the absolute level of consumer benefits for the highest income group was twice that for the lowest income group, the ratio of benefits to income was four times higher for the lowest income class than for the highest income class--thus agricultural research has the *greatest relative beneficial impact* on low income households.

The major sources of public support for agricultural research are federal and state government appropriations funded by tax revenues. State governments provide approximately 60 percent of these funds while the federal government provides most of the remainder. The analysis of benefits and costs of agricultural research is related to effective tax rates and benefits for income classes. The cost of agricultural research to the average U.S. family is $14.83 per year. And, the benefit-cost ratio ranged from 11.60 to 1 for the lowest income

Table 2. **Relationship of Costs and Benefits of Agricultural Research to Family Income**

Income Class	Average Family Income	Average Benefits Per Family	Taxes for Agricultural Research Per Family	Benefit-Cost Ratio
		Dollars		
Under 10,000	5,926	27.96	2.41	11.60
10,000-14,999	12,416	31.99	6.36	5.03
15,000-19,999	17,444	35.73	9.70	3.68
20,000-24,999	22,422	41.03	11.98	3.43
25,000-34,999	29,902	46.21	16.63	2.78
35,000 and Over	52,077	55.88	41.46	1.35
Average		39.74	14.83	2.68

Source: White, Fred C. *Benefits and Costs to U.S. Consumers in Various Income Categories of Investment in Agricultural Research*. IR-6 Information Report No. 87-1, Agricultural Economics Department, University of Georgia, Athens, GA., June 1987.

households to 1.35 to 1 for the highest income households. Agricultural research thus tends to help families in lower income brackets relatively more than those in higher income brackets.

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WHY CONDUCT AGRICULTURAL RESEARCH IN TIMES OF COMMODITY SURPLUSES?

Agricultural research produces new technologies which generally lower the per unit cost of production but increase output capacity. Today there are large surpluses of many farm products. Therefore, why should we continue to conduct research? The answer to this question requires an understanding of the forces affecting the supply and demand for farm products (Norton, 1987).

Weather, new cost-reducing technologies, market prices, agricultural price supports and other farm policies are the primary forces influencing yields, production costs, input use, and, thus, the aggregate supply of farm products. Population, disposable personal income, food prices, the prices of competing foods from abroad, and exchange rates between the dollar and foreign currencies are the primary forces affecting the demand for U.S. farm products.

New cost-reducing technologies from research increase production but also improve the production efficiency of adopters, lower food prices to consumers, and help maintain U.S. competitiveness in international markets. Agricultural exports provide foreign exchange to help balance the currently large U.S. trade deficit. If those new technologies increase the supply of agricultural products faster than the growth in demand, then prices fall unless they are artificially maintained through government price supports. If prices are allowed to drop, surpluses eventually disappear as a result of increased consumption and decreased production.

However, agricultural price supports have been employed to ease adjustment costs resulting from increased productivity and to stabilize farm income as weather and policies of governments have caused supplies and demands and hence commodity prices both at home and abroad to vary widely. These price supports frequently have been set at levels high enough to stimulate additional production at home and abroad, thereby creating surpluses.

Changes on the demand side have become increasingly important in recent years, particularly changes in foreign demand. In the first half of the 1980s, U.S. macro-economic policies which encouraged large deficits and high interest rates attracted foreign capital into the United States. This, in turn, increased the value of the dollar, reducing export demand for U.S. products and driving down commodity prices. This created pressure to maintain price supports which in turn generated surpluses. In the last two years, the value of the dollar has declined against many currencies. U.S. export volumes have again expanded for many commodities but at a modest rate since competing countries invested heavily in their agricultural sectors when the dollar was high. Furthermore, increased production also has resulted from improved agricultural productivity in less-developed countries such as China, and from price supports in the European Community. At the same time, slower income growth has reduced the rate of consumption growth abroad.

In summary, the U.S. farmer is in a global market. Research to reduce the cost of production makes more sense in that environment than do policies that attempt to artificially raise prices but only generate surpluses. The United States must resist the temptation to react to the current surplus situation in agriculture by suggesting that technological progress be slowed. Public and private research investments today will be responsible for the technologies we see eight to ten years from now and will determine whether the United States maintains its preeminent position in world agriculture. Instead, the United States should get its macro-economic house in order, design farm policies that attempt to stabilize farmers incomes rather than commodity prices and attempt to help stimulate growth and thereby demand for agricultural products in less developed countries. As Ruttan (1986) has pointed out, rather than cutting research on new technologies, additional research is needed to help design more efficient institutions (policies) to protect our production capacity and to assist farmers in adjusting to the integration of U.S. agriculture into world markets.

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HOW IMPORTANT IS MAINTENANCE RESEARCH?

Many types of agricultural research output depreciate in value over time. For example, new plant varieties frequently perform well for several years, but eventually yield less as insects or diseases evolve and attack them. Or, agricultural policies which resulted from research conducted for a certain set of technological and price relationships, do not serve well under new relationships. The result of research depreciation is that a certain proportion of new research must be continually devoted to maintaining productivity, economic efficiency, or other gains realized from past research. This type of research frequently is called maintenance research. Failure to recognize the importance of maintenance research can result in an under-valuation of those types of research for which maintenance is a large component. Agronomic, engineering and economic research designed to reduce soil erosion and maintain soil productivity is an example. Another is plant breeding for insect or disease resistance.

Depreciation is more important in explaining research benefits in agriculture than in other industries. The biological character of agricultural production and the focus of agricultural research on improving productivity in biological production systems are the major causes of depreciation. Many agricultural research activities are directed towards developing direct suppressants of plant and animal pests via insecticides, herbicides, cultural practices, etc. Others emphasize breeding and selecting for crop and animal traits that provide resistance to the pests that are most prevalent and damaging under current field conditions. However, the composition of pest populations is neither constant nor passive to the environment. Farmer adoption of direct suppressants of current pests and of crops and animals having resistance to existing dominant classes of pests alters the environment in which these pests live. Natural selection then comes into play. Those pests which were formerly prevalent recede in numbers. Successor generations will be dominated by those which can survive, or even thrive, in the new environment created by introduction of practices designed to control earlier pest generations. The result is that the initial positive productivity effects of introducing such practices, inputs, and genetic strains can decay over time.

Few studies have attempted to quantify the importance of maintenance research although there are numerous documented cases where research has depreciated and then been replaced by new research based technologies. For example, a new strain of southern corn leaf blight caused a 15% drop in U.S. corn yields in 1970. Researchers developed new hybrids resistant to the blight. A recent article by Plucknett and Smith (1986) details several other examples.

Several recent studies have provided some quantitative evidence of the importance of maintenance research. Heim and Blakeslee (1986) estimated that up to 70% of current research expenditures on wheat production in Washington state are needed to maintain current yields. Blakeslee (1987) estimated that almost 90% of recent agricultural research and extension expenditures in the United States are needed to maintain productivity. These numbers are high compared to estimates by Adusei (1987). Based on a survey of 2400 Agricultural scientists in the U.S., he estimates that maintenance research represents slightly over one-third of the agricultural research aimed at producing biological technologies. While the exact numbers differ between studies, it is clear that a sizable portion of the research budget is needed for maintenance. Furthermore, the importance of maintenance research varies by the type of research and by commodity. For example, replacement wheat varieties are typically needed sooner after the introduction of new varieties than is the case for new soybean varieties.

In summary, available evidence suggests that under recent conditions, the presence of biological decay coupled with major productivity advances due to past research and extension expenditures has produced a situation where the level of expenditure needed to maintain productivity on a continuing basis is high. Thus, significant reductions in research support would not merely halt productivity growth. Actual declines in productivity would occur.

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WHAT SHOULD BE THE MIX OF AGRICULTURAL RESEARCH CONDUCTED BY THE PUBLIC AND PRIVATE SECTORS?

Historically, U.S. Agriculture has been made up of a large number of small firms which had to depend on other institutions (both public and private) to supply most of their needed research and technology. Future agricultural technology will be even more research driven than in the past. And, the knowledge base required for a modernized agriculture requires both very basic and very applied research.

In general, the USDA and State Agricultural Experiment Station (SAES) system have both the incentives and the capabilities to undertake a program of more basic research than do all but the very largest and best financed of the private sector firms. And the comparative advantage of the USDA/State Agricultural Experiment Station (SAES) system lies in its extensive and widely dispersed research base (both professional staff and facilities), its extensive feedback system (particularly with farmers and extension workers) and its training capabilities (particularly at the graduate level). The comparative research advantage of the private sector, on the other hand, lies in its unique profit incentives and in its vast capabilities to develop applied technologies and to market the resulting products.

Over the past decade or so, private sector agricultural R & D in current dollars has grown from about $575 million in 1975 to $2.1 billion in 1985 while the corresponding growth in research budget for the USDA/SAES system has been from about $400 million to $1.2 billion. Thus, there has been both a greater proportional and greater absolute increase in spending by private industry than by the public sector research institutions.

A major portion of this recent increase in R & D expenditure by industry firms has been related to their interest in agricultural chemicals and the emerging biotechnologies and to the possibility they see for proprietary products in these areas. Thus, much R & D by private firms continues to be product related developmental work (Table 3). And, this focus is expected to continue in the future. Historically much of the agricultural research undertaken by the private and public sectors has been complementary rather than competitive in nature. For example, the total plant breeding program of the U.S. is widely recognized as the world's most successful. What is not well known is the fact that much of this record of achievement derives from public research which has been put into application by the private sector industry. While the optimal mix of public and private sector plant breeding work is debatable, there is general concurrence that certain important research in plant breeding will be conducted, in the main, only by public institutions. This includes, for example, improved breeding methodology, use of genetic engineering techniques to better understand plant biology and assurance of the provision of diverse germplasm supplies.

Public agricultural research institutions and private industry do have a history of effective cooperation and complementarity. And, since the future agricultural and food scene promises to be one of increased competition from other countries, a continuing combination of public and private research appears highly desirable. Since the private sector R & D will continue to be guided mainly by a product-related profit motive, it will continue to be the role of the public research system to concentrate on those basic and applied agricultural research areas deemed important to farmers, consumers and the general public but to which private sector R & D investment is not readily attracted.

Finally, one of the reasons why production agriculture in the U.S. still includes a broad base of family-scale farming units is that small and large producers alike have had ready access to new and improved technologies through a public sector system of research and technology transfer. Thus there is a strong case for keeping open access to new technology to all farmers via a continuing strong research program in the USDA/SAES research system.

Table 3. Characteristics of Agricultural Research by Private Industry

	1965 %	1975 %	1985 %
Relevant Basic Research	9	10.2	15
Applied Research	50	29.9	43.5
Engineering and Developmental Research	41	67.3*	41.5

*Includes both developmental and quality assurance related research.

Source: Wilcke, et al., 1967, 1977 and 1985

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WHAT SHOULD BE THE MIX OF BASIC AND APPLIED RESEARCH THAT IS PUBLICLY SUPPORTED?

One of the reasons often cited for the continuance of the U.S. agricultural sector as "world class" is the operation of a comprehensive and effective program of both public and private sector research. Yet, there are critics who feel the public sector research program is too applied and those who feel that it needs to be even more applied than it currently is (Fox, Evenson and Ruttan, 1987). One thing is almost certain, future agricultural technology will be even more science and research driven than in the past.

Research of importance to the U.S. agricultural industry occurs along a continuum from very applied research (with near term farm-level or policy-level applications) to very basic research (in scientific disciplines such as genetics, biochemistry and others). Moreover, both the State Agricultural Experiment Stations (SAES) and USDA have responsibilities to farmers and policy makers to solve problems. Quality of applied research suffers, however, unless there is adequate basic knowledge on which to build.

Evenson (1978) and Fox (1986) have estimated separately the annual rates of return to basic and applied research conducted by the public sector (Table 4). These estimates indicate high rates of return for both types of research which, in turn, implies underinvestments in both types. Moreover, these estimates do not substantiate a need for any major reallocation in the existing balance between basic and applied work. This does not mean, however, that the mix of basic and applied research could not be improved.

Historically, private industry has concentrated on research investments targeted toward applied research and product development. This suggests that if basic research is important to the development of new and improved agricultural technologies, as it is broadly believed to be, the public research sector (including, but not limited to the USDA/SAES system) must play a major role in its provision.

Table 4. Estimated Annual Rates of Return to Basic and Applied Research in U.S. Agriculture (%)

	Evenson (1978)	Fox (1986)
Agricultural Research		
Technology Oriented	95	
Science Oriented	110	
(1927-1950)		
Agricultural Research		
Technology Oriented		
South	130	
North	93	
West	95	
Science Oriented	45	
((1948-1971)		
Livestock Research		
Commodity Specific Research		150
Disciplinary Biological Research		116
(1944-1983)		
Crop Research		
Commodity Specific Research		180
Disciplinary Biological Research		180
(1944-1983)		

Although it may be impossible to pinpoint an optimal mix of basic and applied research by the public sector, this does not mean that the question does not merit continued attention. One effective way to provide such attention is to increase the effective communication among research scientists across the continuum of basic and applied research. Communication which provides effective feedback to other researchers and research administrators can be particularly helpful in guiding the research efforts for "relevant basic" and for "applied" research.

In the final analysis, the question of whether or not the public sector should concentrate on basic or applied research is not one of all or nothing for either type of research. Rather the question is one of finding the appropriate balance. Since much basic research requires large investments in scientists and facilities, some of the better financially endowed states and USDA should probably undertake a relatively heavier proportion of basic research while some of the states with more limited financial resources should probably undertake a relatively heavier proportion of applied research and attempt to capture some of the spillover of benefits from basic research conducted by others.

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WHAT IS THE RELATIONSHIP BETWEEN RESEARCH AND STRUCTURE IN FARMING?

The public sector agricultural research and extension system was established to make farms more efficient and profitable at a time when U.S. agriculture was characterized by a large number of small farms. As technologies resulting from research are disseminated and adopted on particular types or sizes of farms, the competitive position of these farms improves relative to other farms; and hence technological change may lead to changes in farm structure. The impact of the agricultural research and extension system on farm structure can best be understood by considering the separate impacts of research, extension, and technological adoption on farm structure (White, 1986).

Most of the agricultural research presently being conducted by public institutions could be applied to a wide range of farm sizes. Of all production research being conducted at agriculture experiment stations, 78 percent of scientific year (SY) effort was judged to be applicable to all farms, 10 percent primarily useful to small farms, 7 percent primarily useful to moderate-sized farms, and 5 percent primarily useful to large farms (Experiment Station Committee on Policy, 1981). An examination of emerging technologies gives further insight into the role of agricultural research in changing farm structure. The agricultural research system is presently focusing on a number of biological-chemical technologies that are expected to be on line prior to the year 2000 (Lu 1979). Conceptually, most of these emerging technologies could be applied on various sizes of farms.

Some past agricultural research, both private and public, did result in farm technology which was not size neutral. The cotton picker and chemical weed controls, for example, contributed to larger operating units in cotton production in the South. Mechanical innovations such as the tomato harvester (see Schmitz and Seckler 1970) have favored large farms by reducing labor requirements and lowering costs per unit on large farms by spreading a given level of investment cost over more units of production. Priority is now low, however, for public research which is applicable mainly on larger farms.

A major effort of the extension service is to disseminate timely information through public meetings. The topics covered in publications and public meetings is heavily influenced by current research results. A national survey of county agents directed at identifying extension's farm clientele indicated: 46 percent of the farm clients had annual gross sales of under $20,000; 20 percent of the farm clients had annual gross sales of $20,000-$39,999; and 34 percent of the farm clients had annual gross sales of $40,000 and over (U.S. Department of Agriculture, 1980). Even though extension personnel attempt to make information available to all farmers, the ones that make the most use of the research results and extension information can generally be characterized as more innovative, more aggressive, and better managers of larger farms (Paarlberg, 1981).

Even when research and extension activities are structurally neutral, neutrality may not be preserved in the technology adoption process. Adoption of new technology is dependent upon many factors including the potential profitability of the technology, extension and other information on the technology, as well as farmer characteristics such as farmers' schooling and managerial ability. In the case of technologies involving sizable capital investment, adoption is dependent on the amount of financial and natural resources controlled by farmers, as well as the general economic environment in which farmers operate. Many small farmers lack the time, skill, resources, and/or economic incentives to adopt a variety of new technologies.

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DOES THE UNITED STATES HURT ITSELF BY SUPPORTING INTERNATIONAL AGRICULTURAL RESEARCH?

Why is the United States involved in international agricultural research? Isn't the country just hurting itself when it helps improve agricultural productivity in less-developed countries? The answer is no for several reasons. First, the economic well-being of the majority of people in the world depends on improving the agricultural performance in less-developed nations. Approximately 10 million people die of starvation in the world every year and over 500 million are severely malnourished. People in the poorest countries have little or no income to buy food from the developed world. International agricultural research can lead to new technologies, institutions, and trained people to help improve the agricultural and food sectors in many of these countries.

Second, and perhaps less well understood, is the effect of economic growth in less-developed countries on U.S. agricultural exports. Our fastest growing agricultural export markets in the 1970s were in those less-developed countries which experienced the most rapid rates of per capita income growth. Because the agricultural sector is so important in these countries, the rapid growth countries also tended to be the ones that experienced the greatest agricultural productivity growth. Even Brazil which emerged as a strong competitor for some U.S. commodities, especially soybean meal and oil and citrus, increased its imports of U.S. farm products substantially. From 1973 to 1984, Brazil increased its agricultural production by 4% per year. At the same time it *doubled* its cereal imports from 2.5 million metric tons (mostly government-supported) to 5.3 million metric tons (99% commercial), mostly from the United States. Aggregate data for less-developed countries around the world clearly show the same outcome: U.S. farm exports have benefited from increased agricultural productivity in those countries. The reason for this is simple. Increased agricultural productivity increases incomes in low income, agriculturally based countries and when incomes increase, much of every extra dollar, peso, rupee, etc. is spent on food. Furthermore, as incomes increase, people shift their demand to higher quality grains including feed grains for livestock. In 20 to 30 years hence, when less developed countries have higher income levels, the rate of growth in their demand for food imports should decline because they will spend a smaller percentage of any income increases on food. But even then, many countries with little comparative advantage in agriculture will continue to import large amounts of food.

In the U.S. we produce less than one-fifth of the world's food. We also live in an interdependent world with sophisticated international markets for food and other goods and services. Consumers throughout the world with an effective demand for food bid against each other for available supplies. As a consequence, the U.S. consumer cannot expect to continue enjoying the benefits of abundant low cost food unless agricultural systems throughout the world are efficient in the production of food.

Many studies have documented the linkage between income growth and increased demand for imports of food by less-developed countries (Vocke, 1987; Houck, 1987; de Janvry and Sadoulet, 1986; Kellogg, 1987; Christiansen, 1987). The United States has helped low-income countries with their agricultural research since World War II. Increases in agricultural productivity have led to income increases which have saved millions of people from starvation. At the same time, developing countries have steadily increased their imports of food, even in the 1980s when exports to developed countries have declined sharply.

Finally, another reason for wanting to help less-developed countries improve food production is that fostering improved economic conditions in these countries will increase political stability and improve security in the world. Both less-developed countries and the United States benefit from a world of politically and economically sound nations.

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WHAT IS THE CONTRIBUTION OF AGRICULTURAL SOCIAL SCIENCE RESEARCH?

The output of agricultural research is information. In the case of biological, physical, and mechanical research, that information often results in new technologies which are embodied in inputs or products. In the case of agricultural social science research (SSR) that information frequently results in improved management decisions by farmers or is embodied in new or improved institutions or policies. Agricultural SSR can provide farmers and policymakers with much of the knowledge needed to adjust to changing economic conditions. At times, those changing conditions are the result of new biological, physical, and mechanical technologies which have affected input and product markets. Changing economic conditions also result from the increased integration of world product and capital markets.

Agricultural SSR sometimes helps to reduce the cost of institutional innovations. However, it is difficult to quantify the value of those cost reductions. The causality between SSR and institutional change is hard to establish and any particular change may be the result of multiple research studies each of which contributed pieces of information that eventually add up to a useful whole. It is also difficult to capture the complementarity between basic and applied SSR and the interactions among improved human capital, technologies, and institutions. James Bonnen (1983) at Michigan State University has pointed out that it is a major misunderstanding to attribute the entire increment of our increase in agricultural productivity to any one of these three complementary factors. Finally, timing is a critical element affecting the value of agricultural SSR. Attention to the forces that create the demand for institutional change will improve the likelihood of timely information from SSR.

Perhaps because of the above difficulties, few studies have attempted to assess the economic value of agricultural SSR. Studies by Bonnen (1983), Lindner (1987), Norton (1987), Ruttan (1984), and Schultz (1975) provide a conceptual basis for understanding the contributions of social science research. In one of the few empirical attempts to quantify the benefits of SSR, Norton and Schuh (1981) estimated the value of economic outlook research for Minnesota soybeans to be more than $600 thousand in 1978-79. In another study, Adams (1983) carefully documents the role of SSR in the creation of the Cereal Import Facility of the International Monetary Fund. And, the important contribution of SSR in the development of a U.S. Farm Credit System is widely appreciated.

Despite the few formal quantitative evaluations of SSR, it is clear that such research often is used by farm managers and by policymakers or groups of individuals who redefine public policies, property rights, or in more general terms, institutions. Changes in farm programs, environmental regulations, or rural development programs are all examples of institutional changes. These changes in turn lead to actions on the part of producers and consumers which affect economic efficiency and security. These institutional changes also affect the distribution of benefits from technical change and other factors affecting the agricultural sector.

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WHAT ARE THE BENEFITS FROM HOME ECONOMICS RESEARCH?

Home economists have been active in research since the early 1900s. The abiding focus of that research has been the family and home, with an orientation toward the betterment of the lives of individuals and families. Home economics is closely aligned with colleges of agriculture in most state experiment stations, and administrators often desire information on the benefits of home economics as well as agricultural research.

Most previous evaluations of home economics research have recounted the contributions of individual research projects, and analyses have tended to be descriptive rather than quantitative. Volker and Deacon (1982) did conduct benefit-cost analysis of individual projects. For example, they calculated a positive net benefit for a child development project which established a motor-performance test method. However, few studies have attempted to evaluate broad aggregates of home economics research such as nutrition or family resource management, perhaps because of the difficulty of measuring the output of the diverse research activities involved. New approaches are being developed to quantitatively evaluate broad research areas according to the nature of the research output and its potential impact (NCR-133, 1987; Norton and Wall, 1984).

The output of home economics research is information, much of it related to social and economic behavior. This information reaches families through educational programs such as the extension service and through changes in products, programs or practices when used by business and industry, legal and health professionals, and policymakers.

Knowledge generated by a large portion of home economics research can be classified into three major types: household efficiency information, product quality information, and health and safety information. Each type of information affects production and consumption in the household. Efficiency information is helpful to households in selecting and using production inputs and to businesses which supply the household market. As a result, technical efficiency is enhanced through changes in the quantity and quality of inputs. An example is the research on household appliances which leads to greater use of more efficient types. Allocative efficiency is increased through research which develops the combination of inputs required to produce a given level of household services at least cost, as in laundering or meal preparation.

Research in family resource management and human nutrition and foods supplies information which allows consumers to assess product quality more accurately at purchase. The information includes various types of characteristics which affect satisfaction with consumer products. For example, it may concern comfort, aesthetics, physical durability, and care properties of clothing and textiles; physical and chemical characteristics of food as related to storage, preparation, and ingestion; use properties of household machines and implements; and determinants of satisfaction with housing. Product quality information reduces the gap between the satisfaction expected at purchase and that actually realized by consumers.

Research in human nutrition and other areas of home economics results in health and safety information. Improved health is fostered by nutrition research which determines nutrient content and availability in foods, interactions among nutrients and non-nutrients in the diet, and means of assessing nutritional status for use by health professionals. Families and individuals also benefit from research that offers guidance in maintaining healthful diets, such as analyses that yield information on nutrient-conserving food preparation and on dietary factors related to normal growth, development, and activity as well as health risks. Examples in areas other than nutrition include the substantial amount of work on clothing and textile flammability and on pesticide protective apparel; research on non-skid floors and indoor air pollution; and studies on food safety. The information provided is used by policymakers and contributes to legislation or other policies; it also is used by businesses in making products and by consumers in selecting products or taking precautions in product use. The ultimate beneficiaries in each case are households.

Beyond the three types of research above, home economics research addresses the improvement of home and family life through increased understanding of individuals' psychological and social development over the life cycle and of interpersonal relationships. Such understanding benefits families, for example, when adults acquire parenting skills which promote optimum development of children; and when family members gain stress management capabilities and build support systems within family units and in the community. Information provided by research in child and family development is used by families and by human service professionals, as in social agencies, child care centers, and centers for marriage and family therapy.

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WHAT ARE THE BENEFITS FROM PUBLIC SECTOR FORESTRY RESEARCH?

The nation's 1.6 billion acres of forest and associated rangeland produce a great diversity of goods and services essential to the wellbeing of U.S. citizens. Included are wood for housing, furniture, paper and other essential goods; habitat for wildlife and fish; environments for recreation, with more than one half billion visitor-days annually on federal lands alone; and protection of watersheds and regulation of water flows and quality. In addition, the nation's forests provide direct and indirect employment for several million persons, and income generating opportunities through timber sales and fees for use for many of the nine million non-industrial private woodland owners.

Public forestry research-carried out mainly by the USDA Forest Service and the nation's Forestry Schools and State Agricultural Experiment Stations (SAES)-addresses questions relating to all of these benefits from forests. The broad objectives of this research are to sustain and increase the productivity of forests, and to develop ways in which forest resources can more efficiently and effectively serve the needs of people. Many organizations and individuals use the results of this research: Users include about 40 federal agencies, state and county agencies, conservation and recreation organizations, farmers and other woodland owners, forest industry, and the general public. Past forestry research has resulted in benefits such as lower cost wood products for consumers, increased income for rural people through improved management and marketing of wood from small woodlots, expanded employment opportunities, improved water quality and flows, maintenance of ecological diversity, and enhanced recreation experiences through new recreation management techniques. Increased efficiency in the use of all forest resources has resulted from research. In the area of forest products technology, the Congressional Office of Technology Assessment has stated: "As preferred species, sizes, and qualities of wood have become depleted due to increased demand, processing technologies have been adjusted to work with more abundant species and materials previously thought to be unusable." An example is research that led to the development of the structural particle board industry, utilizing what were previously considered "weed" tree species in the Midwest and Northeast.

A number of studies have evaluated the economic payoff to forestry research (Table 5). Results from these studies indicate returns to investment generally in the 20 to 80 percent range, comparable to estimated returns to agricultural research (Hyde, Jakes and Leatherberry, 1986; Risbrudt and Jakes, 1985). Forestry research evaluations to date have measured the gains from research that have increased the productivity of the forest, but they have not captured the gains from productivity sustaining (maintenance) research. An estimated 43 percent of Forest Service research--and probably an equal portion of other forestry research--is aimed at maintaining the existing productivity level, which would decline in the absence of research to deal with disease, pests, fire, and other factors that adversely affect forest productivity. Past evaluations of forestry research have not captured the gains derived outside the marketplace, such as those related to environmental protection and improvement, amenity and recreation values, and so on. Thus, the rates of return shown in Table 5 likely represent a conservative estimate of the payoff to public forestry research.

Table 5. Returns to Investment in Forestry Research

Research Evaluated	Average Return on Investment[a]
Wood Products and Engineering Research	
Timber utilization	14-36
Aggregate limber and wood products	34-40
Softwood plywood	220-410[b]
Structural particleboard	18-22
Wood preservation	15-66/1[c]
Timber Management Research	
Containerized seedlings	37-111
Forest fertilization	9-12
Forest pest management	60-87
Growth and yield model	16/1[b]
Tree improvement research in Michigan	$262 mil. NPW[d]

[a]Unless indicated otherwise, return is measured as an internal-rate-or-return (IRR).

[b]Estimated marginal rates of return.

[c]Benefit/cost ratio.

[d]Net Present Worth

Source: Adapted from Bengston, David and Pamela Jakes (1987).

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WHAT CAN SOCIETY EXPECT FROM AGRICULTURAL RESEARCH IN THE FUTURE?

To predict the future is always a task of considerable uncertainty. This is particularly the case when predicting the future results of human endeavor. But, one can say something about the directions which future agricultural research is expected to take.

Agricultural scientists will almost certainly continue to undertake research to improve agricultural productivity and efficiency but with increased attention to the distributional, environmental, health and safety, and community effects of this research and its expected impacts.

Two facts of economic life serve to make increased productivity (an increase in the ratio of total output to total inputs) a valued goal. First, when a society's resources are being fully utilized, the real income status of both producers and consumers can be improved only through productivity gains. Increased productivity saves resources. Second, in an increasingly competitive world in which excess agricultural production capacity exists, U.S. farmers must realize continued productivity gains if they are to maintain or increase their market share for agricultural commodities. Moreover, if inputs and outputs are appropriately priced vis-a-vis their market and opportunity costs, increased productivity will also result in increased profits for farmers.

In addition to the productivity objectives of future agricultural research, several additional comments can be made about new and emerging agricultural technologies. First, most new technology will be based heavily on the principles, relationships, and techniques developed in the basic sciences. The emerging biotechnologies with their numerous potential applications (for yield increases, disease control, etc.) in plant and animal production are examples. Other new technologies will result from applications of discoveries in chemistry, physics, genetics, physiology, and other fields of science.

Second, many new technologies will include inputs from information and management sciences. Examples are those of computerized information and decision aids for farm management and for inventory control and procurement in food marketing. Another example is the use of space age sensing technologies to monitor plant disease problems. Computerized information and control systems will also play a key role in the development of other new technologies such as robotic devices for use in food processing and manufacturing and a broad range of electronic sensing and control mechanisms.

Third, some new technology will almost certainly be aimed at overcoming perceived problems of human nutrition and food safety. As the adequacy of total food supplies increases, renewed research attention will be directed to improving the quality and safety of food supplies.

Fourth, new and renewed research efforts will be aimed at reducing the use of agricultural chemicals, particularly pesticides, and to impede the movement of these chemicals as pollutants into both ground and surface waters. Increased use of biological methods of pest control and more efficient use of chemicals are among the alternatives being researched.

Fifth, concern about conservation of fossil-source energy in anticipation of higher costs and/or reduced supplies is exemplified by current plant breeding work in corn to reduce the need for energy-intensive grain drying technology. Other research is aimed at conserving energy in irrigation, and improving the efficiency with which crops use fertilizers, particularly nitrogen with its high energy embodiment.

Sixth, land and water conservation will be continuing key objectives in developing such farm production technologies as minimum tillage (soil erosion control) and drip irrigation (water conservation). Efforts will also be made to reduce water requirements in food processing, both through new technologies and through increased recycling of waste water.

Seventh, and finally in this brief and incomplete list of future agricultural research, both an increased adequacy of food supplies and increased demand for environmental amenities will encourage a broad range of research efforts to improve the compatibility between agricultural, recreational and other (multiple) uses of land and water resources.

The above list of future directions for research and technology is not exhaustive but it is suggestive. Much expanded perspective can be found in Dahlberg (1986); Joint Council on Food and Agricultural Sciences (1984); and Sundquist (1983). Clearly, future agricultural research will be many-faceted, it will service the interests of producers, consumers, environmentalists and others, it will be costly to develop, it will involve major R & D efforts by both the public and private sectors, and it will affect everyone in one way or another.

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