Chapter 12

Impacts on Agricultural Research and Extension

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Much of the success of American agriculture is attributable to the creation of the Nation's agricultural research and extension system (Ruttan, 1982; Cochrane, 1958). For well over a century this system has contributed to a plentiful, low-cost supply of food and fiber, and to the positive U.S. balance of agricultural trade, through the system's research on new agricultural technologies and practices and through its transfer of technology to farmers and other members of the agricultural community. The technological innovations brought about by agricultural research and extension increased agricultural output in 1945 through 1979 by 85 percent, with no change in the level of agricultural inputs (USDA, 1980).

The public has invested substantial sums of money (currently about $3 billion annually) in agricultural research and extension at Federal and State levels. This investment has been no accident. Several important events have helped make the agricultural research and extension system an integral and long-standing part of U.S. agricultural policy—the first Federal appropriations to agricultural research in 1856, the establishment of the U.S. Department of Agriculture (USDA] and land-grant university system in 1862, the funding of a State agricultural experiment station system in 1887, and the creation of the Federal-State-local extension partnership in 1914,

However, agriculture's entrance into the era of biotechnology and information technology raises several questions about the impact of technical advances on the performance of the research and extension system and about how that performance will ultimately affect the structure of agriculture. For example, in the past, public research was the driving force for agricultural production. Now, with the private sector becoming more involved, the public sector is emphasizing more basic research while the private sector is focusing on certain areas of applied research and development,

This situation leaves open the question of who will do other aspects of applied research in the public sector. Although the public sector has allocated resources to research in biotechnology and information technology, extension has done little to make information about these technologies available to farmers. Extension must thus decide what its mission will be, for extension policy will determine how effective moderate farmers will be in gaining access to new technology. without such access moderate farms will disappear even faster.

The role of extension raises additional questions:

- who gains and who loses from the process of technological change in agriculture?
- Is agricultural research and extension structurally neutral, or does it favor the growth of large industrialized farms?
- what are the roles of the various components of the agricultural research and extension system as they relate to technological change in the biotechnology and information technology era?
- What are the implications of increased private sector involvement in agricultural research?
- what are the implications of patents being conferred on biotechnology and information technology discoveries, that is, for the social contract under which the agricultural research system was created?
- How is a proper balance to be struck between public and private sector components of the agricultural research and extension system?

These major questions will be addressed in this chapter. The answers to the questions are based on previous OTA studies, on an extensive body of literature on the impact of technology on agriculture, and on papers commissioned by OTA regarding the status of the agricultural research and extension system as it relates to developments in biotechnology and information technology.[1]

[1]The OTA papers were prepared by George Hyatt, Roy Lovvorn, Ronald Knutson, and Fred White. The findings from these papers were integrated into this chapter by Ronald Knutson.

THE FUNCTIONS AND CHALLENGES OF RESEARCH AND EXTENSION

Increasing demands are being placed on the agricultural research and extension system. These demands result largely from pressures to increase food and fiber production in the face of an ever-expanding world population, the goal of eliminating hunger and malnutrition, higher levels of consumer income, agriculture's impact on the environment and worker safety, policies designed to expand exports, the desire for a safer food supply, and reduced availability of water for irrigation.

Technological change is necessary for solving each of the problems implied by these public concerns, The process of achieving technological change in agriculture involves three basic steps, each a function of the research and extension system:

1. basic research—discovery of new ideas, concepts, and relationships;
2. applied and developmental research:
   - development of ideas, concepts, and relationships into products (where a product is the output of technology);
   - adaptation of new technologies to as many agro-ecosystems as possible; and
   - maintaining newly achieved productivity from evolving pests, disease, decline in soil fertility, and other factors (sometimes referred to as maintenance research); and
3. adoption of products (transfer of technology).

Discovery is primarily the function of basic research. Most basic research has traditionally been done in the public sector. There appears to be a general assumption that the private sector will not support sufficient amounts of high-risk basic agricultural research because that research is unlikely to yield a near-term payoff. However, this assumption is now being challenged by large private sector investments in biotechnology and information technology,

Developmental and applied research is conducted by both the public and private sectors. The marked increase in the quantity of applied private sector research has resulted in suggestions that public sector support for agricultural research might logically be reduced, Such a suggestion, however, is overly simplistic. Research policy decisions like this require an understanding of the relative payoffs from various types of research, the interrelationships between basic and applied research, and the types of research undertaken by the public and private sectors (White, 1984). Most of the applied research conducted by the private sector is development of ideas, concepts, and relationships into products. Very little private sector applied research is allocated to the adoption of new technologies to a specific agro-ecosystem or to defense of newly achieved productivity from enemies of the agro-ecosystem (maintenance research). This responsibility falls to the public sector.

The function of encouraging technology adoption has traditionally been shared by the public and private sectors, In the public sector, extension educators at the Federal, State, and county level work directly with farmers to test and demonstrate the usefulness of new products flowing out of both sectors. Private firms tend to concentrate their adoption strategies on more conventional promotion and advertising strategies.

Over time, the effort and resources required to achieve a technological breakthrough, as a general rule, increase, This is true because the simpler problems naturally tend to be solved first. More difficult problems require more complex tools of analysis and thus a larger research commitment in time, effort, and resources. The entry of agriculture into the contemporary biotechnology era illustrates this increased complexity. For years, agriculture has depended on chemicals to control pests, diseases, and weeds. These chemicals have been applied without a full knowledge of either precisely how they work or how they affect the environment. This practice has increasingly been questioned as chemical residues have become more associated with environmental contamination and safety concerns. Moreover, biotechnology research has increased the understanding of the specific effects of chemicals, such as atrazine on weeds. As a result of such research, it is becoming possible to develop chemical control agents for specific needs. Potentially, all agricultural plants could, for example, be made resistant to "Roundup" herbicide. With all cultivated plants resistant to the herbicide and all undesirable grasses susceptible to it, the potential exists for nearly complete control of grassy weeds on a farm. Higher output and/or reduced inputs would result from improved weed control, In addition, fewer and safer chemicals, and chemicals in smaller quantities, could be used. The result could be a safer food supply and environment, less use of valuable resources, and a higher level of output.

To achieve these benefits, large investments must be made in basic research. Much of this research uses techniques not common to agriculture. New scientists having modern biotechnology research skills must be trained for agricultural research, and existing scientists must be retrained. Laboratories and related equipment will be more complex and expensive. The educational levels of the producer clientele will have to be improved to adopt and use effectively the more complex new technologies,

Such needs will not be accomplished overnight. Research and education are, of necessity, long-term processes, Interruptions in research and education create gaps in the flow of technology into agriculture that are of a considerably longer duration than the interruption itself. For example, if a line of research designed to pinpoint molecular defects in genes that make poultry and cattle vulnerable to leukosis (a form of cancer) were interrupted, it could increase the time required for discovery, development, and adoption of leukosis control methods by several years.

Agricultural research and extension educational programs compete with other demands for both public and private funds, In the private sector, support for research depends on overall firm profitability and the potential for near-term cost recovery and contribution to profits. When firm profits fall, research funds are traditionally among the first to be cut. This variability yin private sector research investment increases the need for stability of funding by the public sector. It also increases the need for policy makers to evaluate the comparative payoff from various forms of Government expenditures—recognizing that all requests for Government assistance cannot be satisfied. Weighing the payoffs from the many alternative demands on the public treasury may be the most complex task facing policy makers (Knutson, 1984).

COMPONENTS OF THE AGRICULTURAL RESEARCH AND EXTENSION SYSTEM

The U.S. agricultural research and extension education system contains many research and education agencies, grouped in the following five categories:

- U.S. Department of Agriculture (USDA);
- other Federal agencies;
- land-grant universities;
- non-land-grant universities; and
- private firms, individuals, and foundations.

The agencies can be viewed both from the perspective of the sources of funds and from the perspective of the performers of research and educational activities (users of funds) (figure 12-1). Each of the components of the agricultural research and extension system has its unique role, although all components are interrelated and tied to the central objective of technology discovery and transfer for the benefit of farmers and of society as a whole.

USDA

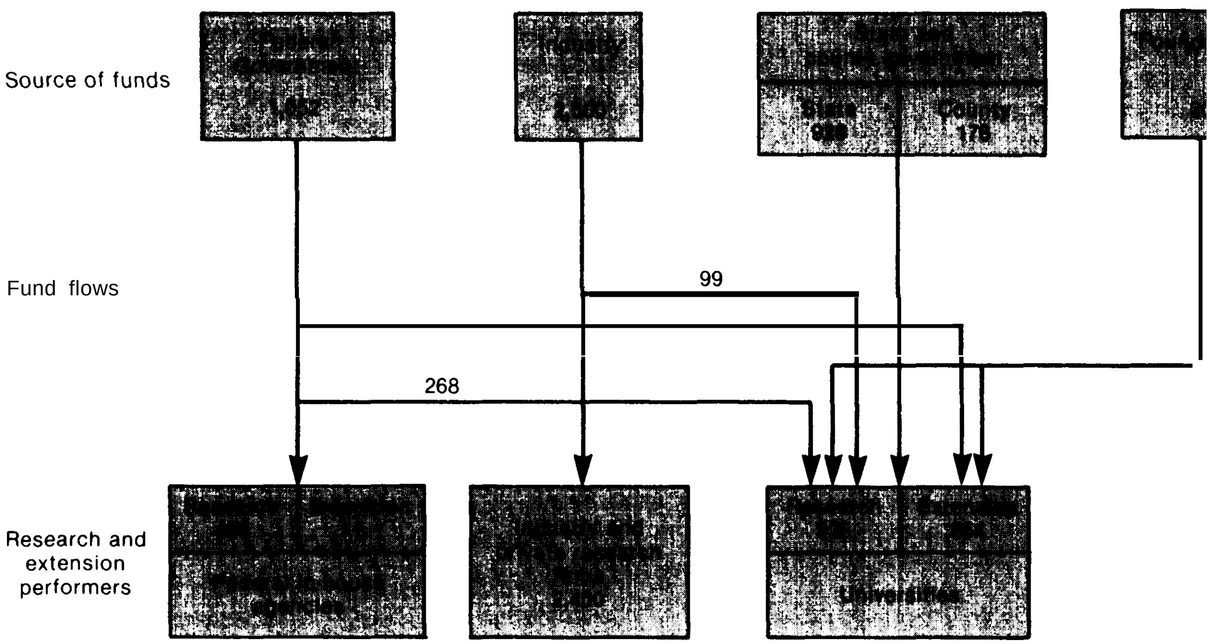
The 1977 farm bill designated USDA as the lead Federal agency for research, extension education, and teaching in the food and agricultural sciences. This action confirmed by law what had been true since before the turn of the century. It did not, however, mean for USDA to provide a majority of the funds for these functions. In fact, the proportion of funds provided by USDA for agricultural research and extension has declined from about 54 percent in 1966 to 47 percent in 1982 (CSRS, 1984).

Research

USDA provides funds both to its own research agencies and to universities. Its own agencies include mainly the Agricultural Research Service (ARS) and the Economic Research Service (ERS); together they use about 75 percent of USDA's research funds. The remaining 25 percent goes almost entirely to universities. Most of the university funds go to land-grant universities, established by law in 1862 and 1890. USDA funds to non-land-grant universities, are limited to a relatively few competitive grants used to support high-priority research.

USDA's agricultural research is carried out at 148 locations across the United States. About two-thirds of USDA's agricultural research scientists are located in USDA laboratories, with the remainder being located in the land-grant universities' agricultural experiment stations. In contrast to its agricultural research, USDA's economic research tends to be heavily concentrated in Washington, DC. This concentration is increasing with the recent policy decision to eliminate the regular ERS field staff. In the future short-term detail to university sites will only be possible. It remains to be seen how compatible this notion is with the kind of long-term commitment much research requires,

Figure 12-1.—Agricultural Research and Extension Funding (in million dollars] **1982**



SOURCE: Of Office of Technology Assessment

Over time there has been considerable debate regarding the role of USDA in both agricultural and economic research. During the 1950s through the 1970s, agricultural research had a tendency to become increasingly decentralized, given the proliferation of agricultural research facilities located throughout the United States. Administration was also decentralized, with substantial authority for program development being established at the regional level. As a result, questions arose about the role of USDA and about potential duplication of research functions between USDA and the land-grant universities (OTA, 1981). After a number of special studies and recommendations, the issue of the role of USDA in agricultural research came to a head in the debate on the 1977 farm bill, when Congress designated USDA as the lead agency of the Federal Government for agricultural research and directed the Secretary of Agriculture to coordinate all agricultural research, extension, and teaching activities conducted or financed by Federal funds.

The 1977 farm bill did not specifically address the functions of USDA versus those of the land-grant universities, although it established the Joint Council on Food and Agricultural Sciences and the National Agricultural Research and Extension Users Advisory Board to assist in planning the research and extension program agenda. The responsibilities of the Joint Council include a formidable list of tasks:

- evaluating research, extension, and teaching program impacts;
- identifying high-priority research;
- developing memoranda of understanding among the participants;
- establishing priorities;
- recommending responsibilities for research, extension, and teaching programs; and
- summarizing achievements.

In a recent comprehensive study, OTA concluded, "There is concern whether the functions assigned the Joint Council are attainable" (OTA, 1981).

The Users Advisory hoard has a somewhat less formidable task of determining the needs and priorities for agricultural research and extension. Its major mandates include:

- reviewing USDA's policies, plans, and goals for research and extension;
- examining relationships between private and public sector research and extension programs;
- recommending policies, priorities, and strategies for research and extension; and
- assessing distribution of resources and allocation of funds for research and extension.

While it is generally agreed that the functions of the Users Advisory Board are more attainable than those of the Joint Council, the impact of the board in establishing research priorities is unclear (OTA, 1981).

In addition, OTA concludes that there is still no satisfactory long-term process for evaluating existing research activities and potential research opportunities and for the development of a new set of research priorities. At the same time, OTA recognizes the potential for too much planning and organization. Agricultural research is sufficiently complex that research administraters have difficulty evaluating the relative merits of particular projects. Therefore, specific decisions on what research is to be undertaken are generally made by the research scientists. The administrator's comparative advantage is in establishing policy, organizing to get the job done, obtaining and allocating funds, and coordinating to eliminate unnecessary duplication (OTA, 1981).

One of the most important contemporary issues that the Federal Government has to deal with is that of establishing broad-priority research and extension needs and the roles of the components of the research and extension system. The Joint Council and the Users Advisory Board, if given time and sufficient encouragement to perform, have the potential for effectively dealing with the priorities issue. Positive progress is indicated by the Joint Council's *Needs Assessment for Food and Agricultural Sciences.*

The primary question about the roles issue involves the line of demarcation between USDA and land-grant programs. This issue has been treated quite differently by research and extension. The OTA study concludes that USDA research should concentrate on those agricultural problems that are important to the Nation and that no one State or private group has the resources, facilities, or incentive to solve (OTA, 1981). Such a role can logically be assigned to both ARS and ERS, For ARS, however, a shift in the focus of agricultural research to research only on national and regional problems would represent a marked departure from that agency's increasing emphasis on research having a State or local focus.

Available evidence suggests that the progress of the agricultural research community in establishing priorities is more advanced than that of the extension community. The agricultural research community has been extensively studied and critically evaluated in a series of projects extending back to the mid-1960s. This series of internal and external analyses has led to adjustments in the distribution of the research system's resources in recognition of potential advances evolving in biotechnology and information technology (Knutson, 1984).

Extension

As the rate of technological change accelerates, access to information plays a more important role in agricultural productivity y and farm survival. In the evolving biotechnology and information technology era the trend is to substitute information for time, capital, labor, land, and energy throughout agriculture (Warner and Christenson, 1984).

In the agricultural research system researchers have traditionally been the producers of new technology, whereas extension personnel have been the agents of technology transfer (through their roles as adopters, evaluators, disseminators, and trouble shooters), An accelerating rate of technological change thus places increased demands on performance by the Extension Service, making it more important that extension sort out its priorities.

The extension community has not made the same progress in sorting out its priorities that the research community has. Identified national extension objectives play little role in program development at the State and local level. (Most extension planning takes place at the local level through advisory committees and other forms of direct contact with clientele [Marshall, et al., 1985].) One major, congressionally mandated, extension evaluation project culminated in a series of reports that concentrated more on past benefits than on future needs, priorities, and required adjustments (Extension Service, no date). Moreover, there was relatively little reference to the functions or programs of extension in the reports of either the Joint Council or the Users Advisory Board.

Federal extension has dramatically deemphasized its direct educational role in the past 20 years (Hyatt, 1984). Although Federal extension specialists were once generally viewed as having a vast subject matter base in their own right and were frequently called onto engage in staff training and to conduct educational programs, they are now viewed more as program leaders, coordinators, and facilitators, The technology transfer and education function is thus left to the State specialists and agents. These changes were at least partially forced by reductions in personnel ceilings and by limited appropriations. Nevertheless, this change in strategy has not been beneficial to the overall national extension education program. In addition to the lack of progress in national planning and needs assessment, the quality of educational service to the States has deteriorated.

As in research, there are issues of national significance that the USDA Extension Service is better able to cope with educationally than are the States. While ultimately the States must take the leadership in extending information to farmers, USDA extension can play an important role in making the information and related educational materials available on a timely basis. (For another perspective see Hyatt, 1984, pp. 17-18.) This role is currently being played on, at best, a spotty basis. The need is particularly critical for facilitating technology transfer between USDA research agencies and the State extension services as well as facilitating technology transfer between States. Facilitating communication between the USDA and State specialists should be a key mission of the USDA Extension Service. Unless this function is adequately performed, Federal research agencies such as ARS will be encouraged to develop their own outreach programs, The need is for increased integration of the research and extension function, not greater fragmentation.

With these needs in mind, if it is decided that a portion of the USDA Extension Service staff will be state-of-the-art national program leaders, the following changes would be required:

- support for Federal extension would have to be substantially increased;
- the designated leaders would have to be recognized as national extension program coordinators by the States and be provided compensation consistent with that role; and
- the program leaders would have to have access to resources allowing them to coordinate with researchers and State specialists to develop state-of-the-art educational materials that could be used in all States.

Other Federal Agencies

Although other Federal agencies have become more important sources of funding for agricultural research in universities, they still provide less than 3 percent of the total agricultural research funds. The main sources of these funds are the National Institutes of Health, the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, and the National Science Foundation. The National Institutes of Health and the National Science Foundation support basic university research, largely in the biotechnology area. Their grants tend to go to leading scientists working on the frontiers of promising new areas of basic research.

Land-Grant Universities

Land-grant universities represent a joint Federal-State partnership in research, extension, and teaching. Land-grant universities (1862 and 1890) perform the majority of total public sector agricultural research. About 52 percent of their funds are from State-appropriated sources—a marked increase from the past. Fourteen percent were formula funds (explained later); 19 percent were other Federal funds; and 16 percent were funds from farm sales, private grants, and contracts.

Research

Land-grant university research is performed primarily in the academic departments (e.g., animal science, soil science, agronomy, agricultural economics, biochemistry) of the land-grant universities. Land-grant universities combine the training of future scientists (graduate and undergraduate) with their research programs. Having the research scientists teach in classrooms increases the relevance and timeliness of those universities' curricula. z

Research planning and priority setting is much more decentralized in the land-grant university system than it is in USDA. This decentralization results largely from the number of research institutions involved, the orientation toward problems of the State, the increased proportion of funding from individual States, and the higher level of academic freedom afforded university scientists compared with that of most Federal and private sector scientists.

Most land-grant universities now have or are developing long-range research plans. These plans are normally developed from the scientist up rather than from the administrator down. Because of the increased complexity of projects, experiment station directors and other high-level research administrators are frequently not in the best position to evaluate the relative merits of particular projects. The more removed the administrator's training and expertise is from that of the scientist, the more imperfect is his or her level of knowledge in dealing with specific research problems. Academic heads of departments are thus generally in a better position to judge the potential value of specific research

'The same reasoning can be applied to split appointments involving extension and research or to extension and teaching. In each instance, relevance and timeliness are fostered.

than are experiment station directors (Knutson, et al., 1980).[3] Administrators achieve their research priorities and goals through the funding, position description, and hiring processes.

On the other hand, some hold the view that scientists are becoming more isolated in basic research (Marshall, et al., 1985). At the same time, administrators are being held more accountable for the performance of the system in meeting public needs. They must develop a sense of the broad needs of the public and build the case for continued public support. A delicate balance must be struck between the needs perceived by research administrators and the needs of the scientists. In a system where communication is good, these needs should converge. In fact, communication and consensus development is the key to performance, particularly in a system where one unit depends on other units of the system for information and coordinated action.

In this setting, the potential for unnecessary duplication of research among universities and between the State and Federal levels is reduced by communication and by the reward system within the scientific community. There is little or no reward in the scientific community for research that simply duplicates what has already been discovered and confirmed. Failure to advance the frontiers of knowledge becomes the basis for outright rejection of proposed scientific publications used as criteria for promotion and tenure. Communication within professional societies provides an important information base on which future research decisions are based. However, this is not to be confused with the need for adaptive and maintenance research. Many technologies in agriculture need to be modified to be successful in various agroecosystems. Likewise, once established, maintenance research is needed to prevent yield declines as a result of the evolution of pests and pathogens, decline in soil fertility and structure, and other factors. These areas of needed research are at times viewed as unnecessary duplication or replication of research. In fact, the time may come when a relatively large share of the public agricultural research effort will have to be devoted to maintenance and adaptive applied research, More communication on the need for this research is warranted.

One avenue for research communication that has been substantially curtailed by restricted funding and the way funds are handled within the system is regional research. Regional research allows scientists who have mutual interests in a problem area that concerns more than a single State to work together. By bringing these scientists together, the critical mass of knowledge, research skill, and resources can be assembled to tackle a particular problem.

However, persistent problems have prevented the fulfillment of the potential payoff from regional research, because even research funds earmarked for regional research are generally handled by universities in the same manner as other funds. In most States, scientists or departments receive no additional support for engaging in regional research activities. As a result, scientists must conduct regional research, which is often more costly, with the same funding base. When regional research funds were relatively plentiful, regional research was frequently undertaken and completed because of scientist initiative and the perceived administrative obligation to support regional research. But as research budgets tightened, the interest of both scientists and land-grant universities in regional research declined.

Those who suffer the most from the declining interest in and commitment to regional research are the smaller, less well-financed land-grant universities. These universities frequently do not have the critical mass of research talent required to tackle larger research problems. They can, however, get involved on a regional basis. In contrast, the larger universities are more likely to have that critical mass. As a result, in the absence of regional research, the larger universities are in a position to compete for the grants involving priority research on the cutting edge of knowledge.

[3] The same reasoning can also be applied to the administration of extension programs—those closer to the work are better able to evaluate it.

The superior ability of larger universities to compete for grants, combined with the increasing complexity of agricultural research, has from time to time led to proposals for establishing universities that are regional "centers of excellence" in either specific or broad areas of agricultural research, The center concept was expanded by Marshall in recommending the establishment of Centers of Research and Extension Excellence to methodically analyze, synthesize, and disseminate research findings and to identify high-priority research needs (Kendrick, 1981).

It can be argued that the marketplace, combined with contemporary public and private research funding policies, is already leading to the development of such centers. Questions, however, exist about whether the marketplace will generate enough centers of excellence and whether the result will be the creation of a set of "have and have not" university research and extension programs. Since the land-grant universities are public institutions, it would appear appropriate that this be an overt public policy decision rather than one left to the marketplace. This does not mean that there would be no role for even the smallest, poorest funded land-grant university. It plays an important role in a national system designed to deal with thousands of agro-ecosystems and is vital to the existence of a decentralized system with nationwide capability.

Extension

Extension education of farmers is also an integral part of the land-grant universities' functions. Extension receives about 63 percent of its funds from State and county sources, with the remainder provided by USDA, largely under formula funds.

How to apply new research findings is seldom obvious. It cannot be assumed that once research findings are available, they will be quickly and effectively put to use.[4] The process of developing and using research is complex and requires a close working relationship between the research and education functions. Extension plays a critical role in alerting farmers to new discoveries and products, evaluating the discoveries and products, and determining how they can best be used in combination with existing products and techniques. This is particularly true for the vast majority of farmers (likely, at least 95 percent of them) who do not have direct access to research results and do require extension interpretation of them.

Because of these complexities, extension activities go beyond a public information role. At the State level, extension has technically trained applied scientists (generally referred to as specialists) who are headquartered primarily at a land-grant university. These scientists may also have research and / or teaching responsibilities. Their extension role is to develop educational programs, prepare applied publications, conduct meetings, and provide technical assistance at the request of county staff.

Extension is involved not only in educating farmers but also in providing important feedback to research scientists about farmers' problems and further needed research. The proximity of extension specialists to research scientists is deemed critical for developing a working knowledge of the scientific developments and for closing the "feedback loop" between extension and research.

Available evidence suggests, however, that the feedback loop concept is operating unsatisfactorily, Marshall (1985) and his colleagues found that extension's ability to influence what research was done in the agricultural research system was inadequate, His study projected that more research coordination problems could be anticipated with the expected increased orientation toward basic research. This finding appeared to be the main origin of Marshall's recommendation for the need for Centers of Research and Extension Excellence.

Because of their direct contact with agricultural producers and agribusiness clientele, extension programs tend to be more grassroots oriented than research programs. In most States, educational needs are determined predominant-

[4] This analysis is limited to the agricultural component of the extension program, Other functions include home economics, 4-H, and community development.

ly by producer advisory committees. Programs are then developed to address these needs using county agent and State specialist expertise. In addition, individuals from the private sector are often called on b y extension to provide a working knowledge perspective on solving particular problems.

State extension specialists are normally highly skilled scientists trained at the doctoral level in specific agricultural disciplines such as agronomy, animal science, entomology, or agricultural economics. In addition, these scientists develop skills in educational methodologies, including the ability to use computer and other electronic technology as they become available, to deliver research findings in an educational context. With these interdisciplinary skills, specialists develop educational programs designed to fill the needs of extension's clientele. They may prepare educational materials (including the development or adaptation of computer software), bulletins, press releases, and radio or television tapes. Such educational materials may be used directly in farmer and rancher programs or in training county agents who in turn work with farmers.

Of equal importance to extension programs is extension's use of the result demonstration, The typical result demonstration involves the planting of different crop varieties, the application of different fertilizer levels, or the application of different pest control methods to relatively small plots of land on an actual farm. The result demonstration is open for inspection, and field tours are periodically conducted for interested farmers to observe the progress of the crop.

Result demonstrations are not limited to products developed in university laboratories. As private sector-branded products enter the market, they are also used in result demonstrations to compare their effectiveness with that of established products and practices. Extension thereby serves as a public sector evaluation of new products and practices. Without such evaluation individual farmers and ranchers would incur the costs of experimenting to determine the optimum input combinations to use in production, These costs would be converted into reduced farm numbers (for those who used the wrong input combinations), higher food costs, and reduced competitiveness in international commodity markets.

With renewed emphasis on basic agricultural research, substantial concern arises over the potential for the development of an applied research gap (Christenson and Warner, 1985; Marshall, et al., 1985; and Feller, et al., 1984). This gap could occur because applied scientists are attracted to higher rewarded basic research, leaving open the question of who will do the applied research. The potential for such a gap may be reduced by increased private sector interest in biotechnology research and development. However, as the private sector performs a larger share of the applied research in the development of new products, extension has the potential for becoming even more involved in the evaluation of technologies and products flowing out of the private sector.

Substantial challenge is involved in extension's adjusting to this new role. Although in some States extension is already deeply involved in the evaluation of new products, in other States product evaluation is primarily the function of experiment stations. In the future, experiment stations will likely be doing less of this work, and extension's responsibilities will correspondingly increase. This increased responsibility will entail a larger specialist staff with modern scientific training.

Some States may be inclined to forego the responsibility of getting involved in conflict-oriented product evaluation programs. Some probably already haves To the extent that this occurs, the usefulness of extension to the farmer clientele will decline. Leadership at the Federal level will be required to assure that technology transfer is facilitated in the farmer's interest.

As agriculture becomes more complex, filling the gap between research and extension will entail a larger role for extension in applied re-

[5]The problem of foregoing conflict-oriented product evaluation is by no means limited to extension. For example, private firms supporting university research may place restrictions on the university's conducting and/or publishing evaluations of the impacts or the economic feasibility of particular discoveries.

search. This is already occurring. Marshall and his colleagues found that 56 percent of extension agricultural specialists with 100-percent extension appointments are involved in applied research. Despite the need for extension involvement in applied research, the Smith Lever Act provided no explicit authority for extension to conduct research. However, an amendment in the recently passed Food Security Act of 1985 (farm bill) gives extension explicit authority to conduct applied research. The intent of this amendment is to clarify extension's role in the process of technology transfer, not to duplicate the mission of the experiment stations.

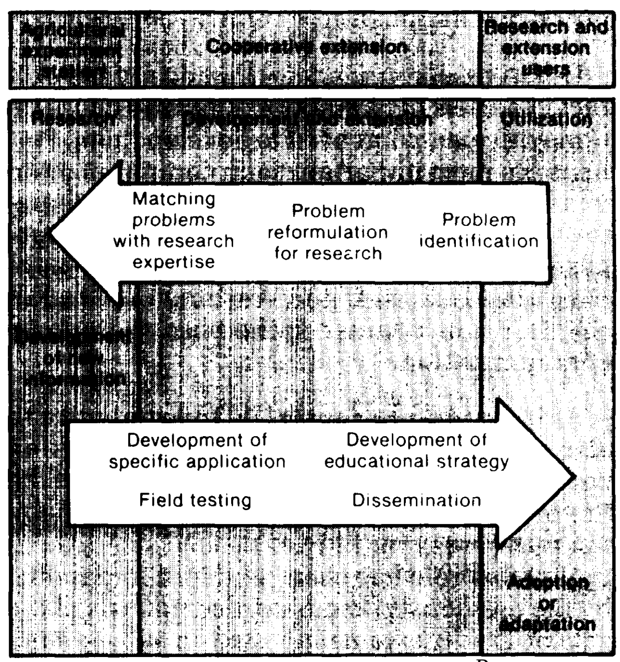
Extension has a regional counterpart to research, whereby specialists meet to develop educational materials on a multi-State basis. As in research, the funds committed to such activities (frequently referred to as "special need" or "pilot project" funds) have been substantial y curtailed. The decision to reduce these funds occurred during the late 1970s when the Science and Education Administration was in control and when Federal funding was being substantially squeezed, As a result, communication between extension specialists in different States is more limited, and the quantity of educational materials produced by regional committees has been substantially reduced. Once again, this occurrence has not had as much of an adverse effect on the educational programs of the larger, better funded universities as it has on the smaller universities.

At current funding levels, one of the most difficult issues facing extension in their agricultural program is that of limiting its role and coverage to those functions for which it has the greatest expertise (Feller, 1985). Without criteria for limiting the role of extension, there is danger that extension activities in agriculture will become so dispersed and out of focus that their effectiveness will be impaired. Danger exists that extension will be called on to solve any problem, whether related to agriculture or not, In the process, the agriculture program of extension could become more of a social program than an instrument of technology transfer.

This is not a new issue but a continuing and progressively more complex one. It is made more treacherous by the politics of funding and the reality that once a new program is established it develops its own constituency and is difficult to cutback (Feller, et al., 1984). It is not possible for extension to be everything to everybody, particularly in times of limited resources. Yet, additional functions are frequently dictated by political realities at the Federal, State, and local levels. (For further discussion of the difficulty in delimiting the clientele and roles of extension see Hyatt, 1984, pp. 14-19 and 33.)

The Joint Council has not given sufficient attention to the role of extension, As a starting point for defining extension's role, it must be remembered that the root of extension is research. Similarly, extension is a primary outlet for research, after an appropriate level of product development. Extension is, therefore, delimited by the scientific endeavors of the research components of the agricultural research system, including both the public and private sector components. This delimiting role is illustrated in figure 12-2.

Figure 12-2.— Research and Extension Roles in the Technology Discovery and Transfer Process



SOURCE: University of California, Cooperative *Extension Long Range* Planning *Statement,* Berkeley, CA, August 1982, p viii.

Feller (1985) defines the mission of extension:

> The core mission of extension is, therefore, one of developing, extending, and bringing about the use of research-based knowledge. The core source of that knowledge is the agricultural experiment stations. Viewing extension in a broader context than this runs serious risk of reducing its overall effectiveness.

This is particularly the case when it is recognized that extension is likely to play an increasing role in filling a portion of the gap between research and extension. Another dimension of this role problem involves the tendency for experiment stations to become more involved in extension-type education programs as a means of gaining public recognition and support. Considerable care must be taken not to foster such duplication of efforts.

Research done in the land-grant universities is in direct proximity to extension specialists and can therefore be directly channeled into the State extension program. USDA research is often done at locations distant from State extension programs, which sometimes creates an incentive for USDA research agencies to reach out and develop their own educational channels. Such initiatives generally amount to an unnecessary duplication of effort.

USDA research agencies that do not have direct channels of communication and cooperation with extension need to develop them. Perhaps the most important such communication channels are the field staff, offices, and laboratories located on land-grant university campuses. Interestingly, ERS has attempted to move most of its field staff into Washington—a strategy that runs counter to the need to improve communication.

As indicated previously USDA extension can also play a role in facilitating communication between the USDA research agencies and the State extension specialist. However, even maintenance (to say nothing of needed strengthening) of this role has been rendered impossible by the previously discussed reemphasis of the role of USDA extension's staff in subject matter education.

Non-Land-Grant Universities

Non-land-grant universities include a broad range of higher education institutions, ranging from strictly private and autonomous State universities having little or no direct relationship to agriculture, to State universities having agriculture, forestry, and food-related programs but not having land-grant status (1862 or 1890). Some of these institutions have had significant applied research programs in agriculture since their founding. The major expertise of most, however, lies in teaching and research in the biological, physical, and social sciences. When agriculture entered the biotechnology era, some non-land-grant universities such as Stanford were ahead of the land-grant universities in numbers of discipline scientists (such as molecular biologists and biochemists) who were involved in basic biological research having potential application to agriculture.

The non-land-grant universities support their research programs through State appropriations, Government grants, endowments, foundations, corporate grants, and contracts, Outstanding scientists in the non-land-grant universities often received biological research support from Government institutions such as the National Science Foundation and the National Institutes of Health. The 1977 farm bill opened up USDA competitive grant research to proposals from the non-land-grant universities,

Non-land-grant universities do relatively little in terms of extension-type adult education programs. Involvement in such programs is largely limited to "public service" conferences and adult outreach programs held near these universities or community colleges, Such services may be provided free as a public service, on a cost basis, or under consulting arrangements with individual faculty members.

Private Firms, Individuals, and Foundations

Private Sector Research

The land-grant university system was established largely because it was concluded that in a decentralized competitive structure, the private sector would not have the economic incentive to provide the level of funding needed to maintain an efficient, viable agriculture. Despite many changes in the structure of agriculture since the founding of the land-grants system, this premise went largely unchallenged until the 1970s. The presumption was that agricultural firms would not undertake sufficient basic research and applied research to keep American agriculture efficient, productive, and competitive.

Until recently, private sector research, therefore, has been limited largely to providing a small number of grants for university research and private sector developmental research associated with the introduction of new products. As a result, private sector grants for agricultural research have historically come primarily from foundations such as Ford and Rockefeller. With the advent of biotechnology, private firm interest in agricultural research increased sharply. While much of this interest appears to be a spinoff from biomedical human research, substantially expanded resources have also been committed to plant and animal reproduction designed to produce new varieties or to expand the rate of genetic improvement. In addition, increased interest is being shown in developing disease- and insect-resistant plants as well as organic methods of pest control.

One of the major reasons for this expanded private sector interest in agricultural research has been the extension of patent rights to plant varieties and other biological discoveries. The potential for capturing the benefits of the resulting patented discoveries has spurred private sector support of university research. Because such arrangements hold the potential for substantially changing the basic public service nature of the land-grant system, a separate section of this report is devoted to the implications of increased private sector involvement in biotechnology research. These implications are by no means limited to research: they affect the overall thrust of extension education and the availability of new research knowledge to extension,

The current magnitude of private sector commitment to agricultural research is largely unknown, although studies suggest that it may approach $3 billion, particularly with the recent increases in private funding (National Agricultural Research and Extension User's Advisory Board, 1983; and Agriculture Research Institute, 1985). That makes the private sector research commitment approximately equal to or potentially larger than the public sector commitment and represents a major shift toward private sector dominance of agricultural research.

Approximately half of the private sector research budget is spent on production agriculture and half on food production or postharvest technology research. Private sector research resources are obviously devoted to those areas having the highest short-run profit potential. Also, despite recent large increases in private sector agricultural research, questions remain about the long-term willingness of private sector firms to invest large sums of money in agricultural research and about the breadth and stability of investment in such research. As noted previously, private firms tend to cut back on research first in times of adversity.

Private Sector Promotional and Educational Programs

The private sector is playing a more important role in education (Christenson and Warner, 1985). For most agribusiness firms, this role is pursued in conjunction with their efforts to promote the products and services that they market. The educational value of these promotional activities is more in terms of alerting farmers to the availability of new products than in objectively evaluating the performance of those products.

The burden of new product evaluation then falls either on the farmer (through trial and error) or on the extension service (through result demonstration).[6] While extension involvement is more efficient, there is potential for increased antagonism between private sector firms and

[6] A considerable amount of new product testing is also done by the university research community under contracts, grants, or consulting arrangements. While product testing at one time was an important component of experiment station research, it is considerably less important today.

extension. Extension testing will not be appreciated by firms found to produce products having relatively lower levels of performance.

With a few important exceptions, such as integrated pest management (1PM) checkoff programs, private sector direct financial support for agricultural extension programs has been limited but appears to be growing. It might be argued that limitations on private sector funding are essential for keeping extension education programs objective. There may be greater dangers in increased private sector funding of extension than of research. In both cases it is critical that the objectivity and availability of information flows be maintained.

Two of the most important private sector supporters of extension programs are the Farm Foundation and the Kellogg Foundation.[7] Both of these institutions are maintained largely by endowment grants. Each foundation has played particularly important and unique roles during the recent period of reduced funding for extension programs.

The Farm Foundation has played a particularly critical role in filling the void created by the reduction in funds available for communication and program development on a regional basis. The foundation's support of regional extension committees in the areas of farm management, marketing, policy education, and community development has frequently been the only support for contact and coordination among specialists in neighboring States. The pressure on Farm Foundation funding has become increasingly intense as Federal extension decisions not to fund meritorious projects become more prevalent.

The Kellogg Foundation has periodically attempted to fill a portion of the void left by the reduction of USDA Extension Service pilot project funds. While Kellogg continues to support what it perceives to be the most innovative proposals for educational program development, an increasing backlog of proposals has developed with little hope of their being funded on a timely basis,

Increased pressure on funding from public and unbiased private sector sources discourages new program development by extension specialists. Potential and existing extension employees are increasingly being attracted by research positions and/or the private sector. A large infusion of new private support, without a vested interest, to institutions such as that provided by the Kellogg and Farm Foundations appears unlikely. The 1PM checkoff concept may hold promise for increased, direct producer funding of specific educational programs. The only remaining option then becomes the establishment of a new thrust for public support of extension education. Such a thrust is needed particularly at the specialist and program development level, which is a logical level for increased Federal support and leadership (Knutson, 1984).

[7]General farm organizations and commodity groups have been important supporters of both research and extension programs at the Federal and State levels. This support has, however, been largely one of influencing Federal, State, and county government appropriations. This important private sector role is frequently not recognized.

TRENDS IN LEVEL OF SUPPORT AND RELATED ISSUES

In the 10 years from 1966 through 1975, the level of support for agricultural research and extension programs increased 215 percent in current dollars and by 30 percent in terms of constant dollars (table 12-1). During this period, research and extension resources increased at nearly the same rate. From 1975 through 1982, total expenditures on research and extension increased 87 percent in current dollars and 9 percent in constant dollars.

Research-Extension Balance

From 1966 through 1975, Federal support for extension increased considerably more than Federal support for research. However, since

Table 12-1 .—Trends in Agricultural Research and Extension Funding by Source and User, Selected Years

Year	Research: State agricultural experiment stations: Federal	State	Private	Total	USDA	Total research	Extension: State agricultural extension service: Federal	State and county appropriations	Total extension	Total research and extension
Millions of current dollars:										
1966	79	118	9	206	153	359	75	126	201	560
1975	135	331	23	489	266	755	179	269	448	1,203
1982	268	563	94	925	469	1,394	315	539	854	2,248
Millions of constant dollars:										
1966	80	119	9	208	155	363	76	128	204	567
1975	83	203	14	300	163	463	110	164	274	737
1982	95	201	34	330	167	497	112	192	304	801

SOURCE Cooperative State Research Service, Inventory of Agricultural Research FY 1982, vol. II (Washington, DC: U S Department of Agriculture, 1982), U S Congress, Office of Technology Assessment, *An Assessment of the United States Food and Agricultural Research System*. OTA- F-155 (Washington, DC: U S Government Printing Off Ice, December 1981)

1975, research expenditures have increased somewhat more than extension expenditures. Increased support for agricultural research relative to extension has been particularly unbalanced when the surge of private sector investment in agricultural research is considered. This increased emphasis on research likely reflects the following:

- a higher level of sensitivity y to the needs for high-priority biotechnology research;
- the potential for major breakthroughs in productivity;
- a reaction to concerns about the availability of an ample supply of food;
- a desire to maintain competitiveness in international trade; and
- the higher costs associated with conducting biotechnology research, which has been used to justify higher appropriations.

In a time of tight budget constraints, policymakers (particularly at the Federal level) have apparently made a decision that research has a higher priority than extension. Longer run questions, however, exist regarding the need to maintain a balance between research and extension activities.[8]

Research and extension are part of a complex agricultural system designed to discover, adopt, evaluate, and (where favorable) facilitate technology transfer to farmers and ranchers. All parts of the system are equally important for accomplishing this mission.

The biotechnology and information technology era presents at least as many, and probably more, challenges for extension as it does for research. Many of the technologies that are on the horizon are exceedingly complex and foreign to many extension staff, In the foreseeable future, embryo transplant technology may be as important to the dairy industry as artificial insemination has been over the past three decades, growth regulators will increasingly be applied in minute quantities to plants to increase productivity, and new strains of genetically engineered plants and animals will be entering commercial production channels. Extensive staff training and development will be required at both the specialist and county levels for extension to play an effective role in technology transfer of biotechnology and information technology. Without such training, extension will play an increasingly less important role in production agriculture. Technology transfer will occur less efficiently and with more structural impacts—larger farms will benefit at the expense of smaller farms.

Another important effect of the research-extension imbalance in emphasis is to attract the best scientists into research rather than extension. While the public sector agricultural research community is experiencing increased difficulty competing with private sector firms for the services of qualified scientists, extension is having even more difficulty competing with both interests.[9] At the specialist level, extension draws on the same pool of doctoral-level scientists as does research. Because it is receiving increased emphasis, research is able to compete more effective y for the services of the top scientists.[10] Over time, unless corrected, the result will be a lower quality of extension staff, The same principle applies at the county level, where extension must likewise compete for its professional staff with both public and private sector employment alternatives. With relatively less extension support, the best county and area extension staff will be attracted to the private sector or to other better endowed agencies in the public sector. These effects are already occurring, at a time when extension is being called on to transfer a larger quantity of increasingly complex technology,

[8]It is interesting to note that the relative increase in emphasis on research began during the Carter-Bergland Administration. Previously, the Nixon-Ford-Butz Administration had put relatively greater emphasis on extension programs, while the Kennedy-Johnson-Freeman Administration had favored research. The impacts of these shifts in emphasis in terms of productivity have not been adequately studied.

[9]There is a concurrent concern that the best research and extension scientists are being attracted into private sector managerial jobs.

[10]One method by which extension might ad just to this competition is to reduce tbe number of staff and concentrate more resources around a smaller number of highly qualified staff. Extension has not, as a general rule, employed this strategy.

Federal-State Balance

The States have been picking up a larger share of the cost of the agricultural research and extension system. From 1966 through 1975, Federal support for research and extension declined as a proportion of the total, from 55 to 48 percent. In 1982 the Federal share was 47 percent. The historic commitment to a national system of developmental institutions in agriculture is fading.

This trend is consistent with the philosophy of a reduced overall Federal role. However, it is inconsistent with the role of U.S. agriculture nationally in terms of maintaining stable prices, contributing to a favorable balance of trade, and meeting world food needs. These are important national goals that require a higher level of Federal involvement and support,

During the period 1975 through 1982, most of the relative reduction in Federal support has been in extension appropriations. While Federal support for research increased by 7 percent (constant dollars), extension support increased by less than 2 percent (table 12-1). State and count y support for extension, on the other hand, increased by 17 percent. The Federal share of extension support, thereby, fell from 40 percent, where it had been since the early 1950s, to 37 percent. Appropriations for extension in 1984-86 suggest a further drop in extension's share of Federal support.

The rationale for reduced Federal support for extension relative to research is unclear. Although education has traditionally been viewed as a State and local community function, extension was formed on the principle of a Federal-State-county partnership. The ability and willingness of State and county governments to support extension adequately in the face of reduced Federal support is questionable." Clearly, if the biotechnology and information technology era justifies higher levels of support for agricultural research, it also justifies higher levels of support for agricultural extension—particularly because of the increased private sector commitment to agricultural research.

[11] Interestingly, the 1977 farm bill contained authorization for USDA to be the lead agency in university education programs related to agriculture. While there was a transfer of staff and offices from the Department of Education to USDA, this initiative has received very limited USDA support and is essentially' dead.

Research and Extension Professional Staff

Despite increases in real appropriations for agricultural research, the number of professional research staff has declined. This decline results from the continuously increasing cost of supporting a research scientist with research equipment and materials. Greater cost increases can be anticipated in the future as agricultural research progresses into the biotechnology era and as the demand of the private sector for newly trained scientists continues to accelerate.

Extension experienced an n-percent increase in the numbers of professional staff from 1966 to 1975, and a subsequent 6-percent decline through 1984 (table 12-2). Nearly all of this decline was in the specialist staff, which experienced a 15-percent decline in numbers. This reduction in number of specialists is particularly alarming since the specialist staff has the highest level of training and is the best equipped to educate both county agents and farmers on evolving agricultural technologies.

The disproportionate reduction in the number of specialist staff is probably best explained by budget considerations and the lack of direct State control over county staff. As budgets tighten, considerably more funds are made available to the State director when a specialist position is eliminated or not filled. In addition, competition for specialist staff has become increasingly keen, For extension program administrators, the avenue of least resistance compared with the option of reducing the number of county

Table 12.2.—Trends in Numbers of Extension Professional Staff, Selected Years

Year	Specialist	County	Total
1966	3,641	10,451	14,092
1975	4,224	11,357	15,581
1984	3,581	11,140	14,721

SOURCE Extension Service. U S Department of Agriculture staff is reduction in force at the specialist level—precisely what has occurred. Therefore, while the need is for an increased emphasis on specialist staff, just the opposite is occurring. In fact, one can forcefully argue that in the biotechnology and information technology era, without substantially increased emphasis on county agent development, the specialist will have an ever-increasing and comparative advantage in educating farmers. The model for cooperative education could shift from county agent-to-farmer education to specialist-to-farmer education. This is probably already happening and has the potential for substantially changing the structure and role of extension. Without substantially increased State or Federal support for extension, counties will have to pickup a larger proportion of extension's costs, or the counties' impact and effectiveness in education will gradually erode.

An alternative strategy for extension would involve an intense, continuing program of staff development at the county level designed to provide count y agents with state-of-the-art research findings and related information. A decision to emphasize this strategy is based on the premise that the strength of extension lies in the county agent. Historically, the county agent has been one of the best educated persons in the county. Questions increasingly arise as to whether this era is gone.

Christenson and Warner (1985) put the issue in the following very cogent terms:

> If county staff are not providing relevant and timely information, if they do not have access to innovative ideas, if they are not seen as outstanding educators in the county, they will not have the trust and respect of the people. County staff who are seen as just another information disseminator who hands out pamphlets, gives advice on fertilizing lawns and gardens, and holds meetings for "expert" speakers from the State university, may not survive in an information society.

This is not to contend that all county agents are out-of-date. Many continue to carry out state-of-the-art programs. However, as the rate of technological change accelerates, research results will become more complex and difficult to comprehend. County agents will find it increasingly difficult to keep up.

Such observations are not limited to county agents. Many researchers will also find their knowledge level bypassed (antiquated) by biotechnology; specialists will thus also need to update their knowledge. However, the cost of retraining specialists will be less than that of retraining county agents because specialists are fewer and have closer day-to-day contact with research.

Fund Allocation

The funds that land-grant universities receive from the Federal Government can be allocated either on the basis of competitive grants or formulas. Historically, about two-thirds of the funds have been allocated to the States by formulas. While there are formula differences between research and extension, the principal factor in both formulas is rural population and farm numbers. As a result, States having a larger rural population and greater farm numbers receive more formula funds.

The specifics of the formula have been the subject of considerable debate. Large rural populations and farm numbers in the Southeast do not correspond with the quantity or value of production. Midwestern and Western States feel that formula funds ought to be allocated on the basis of the value of commodities produced. Senator Lugar (Indiana) has become a champion of debate to change the formula (GAO, 1983).

Since agricultural research deals more with the products of agriculture, not population, Midwest advocates suggest that inequities result from research funds being allocated on the basis of population. Current formula funding procedures have tended to promote regional crops such as cotton, tobacco, and peanuts as opposed to wheat, corn, soybeans, milk, beef, and hogs. Yet, those States that produce the majority of the wheat, corn, soybeans, milk, beef, hogs, fruits, and vegetables have been more competitive in achieving competitive research grants, In some instances, strong State research support has compensated for less Federal support.

A change to a product value-based formula would accelerate the trend toward increased centralization of research in the major agricultural States such as California, Iowa, and Indiana. It can also be argued that the effect would be to shift the allocation of research resources in the direction of moderate-size and larger scale farms. However, questions exist regarding whether the size distribution of the clientele being served by research and extension is an y different in those Southern States that receive a larger proportion of formula funds just because of a larger number of smaller farmers. Maybe the needs of small farmers are not being served in the South any better than in the rest of the country.

The case for a population-based formula appears to be stronger for extension than for research. Education deals more with people than with the value of products, However, even here the urgency of education can be argued to be product value-based. That is, education is more urgent where more products are produced. In addition, as in research, questions arise as to whether extension is effectively serving the educational needs of farmers having smaller scale operations.

Competitive grants are a much discussed method of allocating USDA agricultural research funds. Prior to 1970, Federal contracts and grants generally represented about 10 percent of the USDA funds going to the State agricultural experiment stations and about 2 percent of total experiment station funds. However, the world food crisis and advances in biotechnology created greatly increased interest in grants. By 1982, contracts and grants had increased to 16 percent of experiment station funding.

In 1977 Congress authorized a special competitive research grants program primarily to support basic research in food and agricultural science. The competitive grants program was available to any research institution, land grant or not. In 1982 experiment stations received only 38 percent of competitive grant appropriations, accounting for less than 1 percent of experiment station funds. The land-grant universities accepted the grants concept only on the condition that grants not displace formula fund appropriations. At least partially because of land-grant resistance to formula fund reductions, the competitive grants program has received a low level of appropriations.

Although competitive grants are made on the basis of a peer review system, basic research scientists complain that the grants are generally so small that they cannot sustain even a middle-size biotechnology research project. In 1982 the average size of a grant was approximately $70,000 (CSRS, 1984). The program is frequently referred to by researchers as the "small grants program. " The underlying reason for the small size of these grants probably lies in political pressure on USDA research administrators to distribute the grants geographically among the States,

For many years, extension has used savings from Federal administration funds, plus approximately $500,000 in so-called special needs funds, for allocation to the States in the form of competitive grants to support, among other priorities, the development and testing of innovative concepts of extension education. This important, highly successful (albeit, informal) counterpart of the competitive research grants program has been severely restricted since 1978—ironically starting about the same time as the research grants program was initiated. The reasons for this restriction lie in the interaction of such factors as reductions in Federal administration funds, the subversion of extension funds to support a vast experiment to coordinate research and extension at the Federal level, a congressionally mandated evaluation project, and the subsequent emphasis on increased ongoing evaluation, which had to be absorbed out of existing funds.

One of the unique features of the extension special grants program was that the projects supported by it were frequently regional or national in scope, thus facilitating the production of educational programs that could be replicated and applied on a multistate basis. Since the restriction of this program, innovative extension program development has been severely curtailed, particularly for programs having a regional or national focus. Individual States have not, and probably cannot, fill this void. Several recent attempts to provide funds for these purposes as a designated item in the Federal extension budget have been unsuccessful,

Interaction Between Non-Land-Grant Universities and Land-Grant Universities

The world food crisis and the biotechnology era have fostered increased non-land-grant interest in agricultural research. This interest was further heightened by the establishment of the competitive grants program in the 1977 farm bill. Experience indicates that the non-land-grant universities are fully competitive with the land-grants in receiving these funds. However, competitive grants have not been expanded sufficiently to augment significantly most non-land-grant agricultural research programs.

Increased funding for human research in the biotechnology area holds the potential for rapid technology transfer of medical discoveries to agriculture at a relatively low cost. Potential also exists for fortifying existing non-land-grant basic research in photosynthesis, plant embryology, genetics, and animal physiology. This will, however, require significant increases in funding beyond current levels as well as a movement away from the "small grants" philosophy discussed previously.

One of the factors hindering the contribution of the non-land-grant universities to discoveries in agriculture is the traditional competition within States between land-grant and non-land-grant universities. Because of increasingly limited funding, competition for the allocation of appropriated funds and the establishment of new educational programs has become increasingly intense, Over time, substantial conflicts have developed over the favored position of land-grant universities in having access to formula funds, Such conflicts even exist within land-grant universities between experiment station-related agricultural departments and academic departments having no ties to the experiment stations, such as biology departments.

Such conflicts are difficult to overcome. Danger exists that in attempting to "force" cooperation, policy makers could destroy productive elements of the existing system that have served agriculture well. Yet constant pressure to obtain a higher level of cooperation would appear to be warranted. Perhaps the most effective means of applying such pressure would involve the development of programs that provide financial rewards for cooperative land-grant/non-land-grant research programs. However, if funding levels remain low little progress is likely.

PROPERTY RIGHTS, EXCLUSIVITY, AND THE LAND-GRANT UNIVERSITIES' SOCIAL CONTRACT

Land-grant universities were created to serve the public. The agricultural component of land-grant universities has unique responsibilities to conduct research and extend the results of agricultural research for the public benefit. Traditionally, those research results have been readily and freely available to the public, inasmuch as the results have no private property or exclusivity rights attached to them. policy changes that have occurred over the past 15 years, however, hold the potential for substantially changing this traditionally ready-and-free-access concept of land-grant university research. Some changes have already occurred; others could occur very rapidly. In other words, changes in the rules may have also changed the very concept of the land-grant system (Knutson, 1984),

Questions of how the land-grant universities might adjust to the new concept of research property rights and the related opportunities for increased private sector funding have been the subject of extensive study. However, the impact of this concept on the unique nature or "social contract" of the land-grant system has received little attention. A discussion of both dimensions follows. This discussion is important because it has a potentially profound effect on the land-grant system and its relationship to the public.

The Development of Discovery Property Rights

Policy changes regarding property rights in agricultural research had their origin in the enactment of the Plant Variety Protection Act of 1970. Previously, patent protection in plants was limited to asexually reproduced material—mainly orchard fruits and ornamental flowers. The Plant Variety Protection Act provided that a breeder of a new, stable, and uniform variety of sexually reproduced plants could restrain other seedsmen from reproducing and selling that variety for 17 years.

Of possibly greater significance was the 1980 landmark U.S. Supreme Court decision, *Diamond v. Chakrabarty,* which held that the inventor of a new micro-organism, whose invention otherwise met the legal requirements for obtaining a patent, could not be denied a patent solely because the invention was alive. This decision opened the door for patenting potentially all new products of the biotechnology era.

Since the passage of the Plant Variety Protection Act and the *Chakrabarty* decision, private sector interest in agricultural research has mushroomed. OTA, for example, found that in 1983 there were 61 companies pursuing applications of biotechnology in animal agriculture and 52 companies applying biotechnology to plants, The companies involved ranged from established agricultural chemical suppliers such as Monsanto, DuPont, Dow, Eli Lilly, and American Cyanamid to new biotechnology firms such as Genentech, Biotechnical International, MGI, and Genex (OTA, 1984).

Most of these firms have developed their own in-house research capability by employing molecular biologists, biochemists, geneticists, plant breeders, and veterinarians. whereas past emphasis in plant and animal science was on selecting and breeding for specific, desired traits, the emphasis has changed to understanding the factors that control the genetic traits and overtly changing them. Progress is already being made with growth hormones, vaccines, and herbicide-resistant varieties of plants. Several genetically engineered products are very close to being marketed commercially.

Relationships are also developing between many of these firms and universities. For example, Monsanto has a 5-year, $23.5 million contract with Washington University under which individual research projects are conducted. At Stanford University, five corporate sponsors (General Foods, Koopers Co., Inc., Bendix Corp., Mead Corp., and McLoren Power & Paper Co.) contributed $2.5 million to form the for-profit Engenics and the not-for-profit Center for Biotechnology Research.

Such relationships are not limited to private universities. Michigan State University (a land-grant university) created Neogen to seek venture capital for limited partnerships to develop and market innovations arising from research. The formation of Neogen points up a significant problem being encountered by the universities. Neogen was formed, in part, to retain faculty members who were getting offers from biotechnology companies. In Neogen, faculty members are allowed to develop their entrepreneurial talent and reap the associated financial rewards while remaining at the university.

The establishment of biotechnology property rights has substantially heightened scientists' interest in private sector employment opportunities, In the process, questions have arisen over who maintains the property right—the university, the private firm, or the scientists? In the Washington University-Monsanto case, the University retains the patent rights while Monsanto has exclusive licensing rights. In Engenics, Stanford likewise gets the patent rights while the center and the six corporate sponsors receive the licenses and pay royalties. Neogen will buy patent rights from Michigan State University, while the inventor will get a 15-percent royalty or a stock option in Neogen.

Land-Grant University Adjustments

The potentially profound implications of such developments on the land-grant university systern seem clear. Such private sector arrangements integrate business into the university fabric, raising questions about the control of the university research agenda, the allegiance of scientists to their university employer, the willingness of scientists to discuss research discoveries that have a potentially patentable products associated with them, and potential favoritism shown particular companies by the university because of their research ties.

This controversy has caused the land-grant Agricultural Experiment Station Committee on Policy (ESCOP) to express its concerns publicly and to develop guidelines to deal with these biotechnology issues. The statement of ESCOP concerns includes the following:

- As publicly supported institutions, the SAES (State Agricultural Experiment Stations) will need to assure that industrial relationships generate an end result in the interest of the general public. This end result should reward the industrial investor but avoid placing such an investor in an unwarranted position of financial advantage through privileged use of information or technology partly derived from research using public funds; neither should a curtailment of new information to the public occur,
- The SAES are greatly concerned about the curtailment of communication on early research results and about the constraints on sharing of germplasm emerging due to concerns on the part of scientists and institutions for protecting potentially patentable research results. Industry sponsorship of this kind of research tends to exaggerate this problem.
- There is general concern in the academic community about the drain of scientific manpower from the universities to industry. The ability to continue to conduct basic research in an academic environment and the concurrent interdependent ability to continue educating scientists are key issues.
- There is concern that individual scientists may place themselves in positions of compromise or conflict of interest as they establish personal relationships with industry as contractors, consultants, or institutional officers.
- There is concern on the part of both scientists and the SAES that through industrial sponsorship of research, there may be introduced an undesirable level of direction of effort by industry (ESCOP, 1981).

Out of these concerns ESCOP developed the following interim policy guidelines:

- *Maintain SAES management control of research:* Consensus: SAES should retain the ability to manage research programs, and control the direction of new investigations, regardless of the source of support, including situations in which one or several firms may sponsor research at several institutions.
- *Strong basic research and graduate education capability:* Consensus: SAES should maintain and expand the basic research capability in genetic engineering and related areas within the domain of publicly supported institutions.
- *Faculty-industry relationships:* Consensus: Scientists should maintain close communication with institutional administrators in the development of relationships and commitments with the commercial sector. Institutional guidelines should be developed that assist the scientists in avoiding institutional or personal conflicts of interest.
- *Publication and communication;* Consensus: The ability to publish and exchange information is essential and must be secured in agreements. In some instances, publications or information exchange may need to be temporarily delayed to allow time for an institution or sponsor to assure adequate patent protection. The final decision to defer or modify a publication should reside with the public institution.
- *Trade secrets and confidential information:* Consensus: Protection of "trade secrets" or "confidential information" for more than a very limited period should be avoided by public institutions. Advance review by a private sponsor, to avoid premature release of information, maybe advisable but should not become a mechanism to "shelve" use-

ful information or unpatentable technology.

- *Patent rights and premature disclosure:* Consensus: SAES should retain the right to participate in the decisions related to the disposition of intellectual and real property and patent rights resulting from research. Retained ownership of patents by the SAES is preferred, In any agreement, the SAES should retain the right to use discoveries and inventions from SAES research to extend and enhance public research and education. The need of private sponsors to obtain a return on investment must be recognized, and agreements may provide for special licenses for patents originating from sponsored research.
- *Biosafety of recombinant DNA:* Consensus: SAES must retain responsibility for review and decisions in the release or distribution of laboratory research products, although some research may be supported by outside sponsors.
- *Grants and income earnings:* Consensus: Extending knowledge and developing new technology while serving the public interest should be the prime motivations in agreements between SAES and the private sector. Royalty income from discoveries originating under such agreements should be recognized as a secondary consideration.
- *Licensing responsibilities and performance expectations:* Consensus: SAES should assure that "due diligence" clauses are included in contracts to assure that new technology is not shelved and the public interest is served while private investment in commercialization is respected. Assignments, rights, or licensing of patents for commercial use should be considered separately from contractual definition of research to be conducted. Initial or developmental processes and pervasive technology ultimately leading to improved biological materials generally should not be assigned for sole use by a sponsoring firm.
- *Tax code implications:* Consensus: When sponsored research is motivated by certain interpretations of Tax Code Section 1235, exclusive licensing or co-ownership of patent rights is a preferred alternative for the institution, since the institution maintains a vested interest and some ownership of patent rights involving the scientist, the institution, and the firm may require unique documentation. Careful attention to these rights and relinquishments is suggested (ESCOP, 1981),

Impact on the Land-Grant Social Contract

Potential basic changes in the relationship between land-grant universities and the public are implied by the preceding adjustments, although not explicitly discussed. The land-grant university system was established on a public service basis different from that of other universities. Its tradition has implied a social contract that makes its discoveries freely available to the public.

The advent of patent rights, exclusive licensing, and private sector investment in public sector research has the potential for changing the distribution of benefits from land-grant research discoveries." These changes warrant direct public discussion and consideration by policymakers. They occur for at least five reasons:

1. By exclusive licensing or transfer of patent rights to private firms, the right to use discoveries is no longer freely available—even if information on the discovery itself is freely available,
2. Certain individuals or firms are conferred the benefits of specific land-grant research to the potential detriment of others. Prior to the transfer of discovery rights, the benefits were available to anyone who adapted a land-grant discovery to commercial usage.
3. The costs of the resulting discoveries are internalized in the price of the resulting product. The price the public pays for the product also includes any monopoly rents associated with the conferral of the rights.

[12]Similar implications may also exist for ARS research to the extent that patent rights and exclusive licensing arrangements are created by ARS.

Society thus pays twice: once for the cost of the research and then again for its benefits. without the conferral of property rights, rents are minimized by competition.
4. Private sector-public sector inequities are virtually assured in any granting of research property rights to an individual firm. This occurs because with a relatively small private sector investment there is access to a much broader range of current and prior research.
5. The existence of patent rights, trade secrets, and confidential information has as many potential}' adverse implications for extension in terms of the increased burden for product testing, the potential lags in information, and the absence of research information that would have previously been readily available.

The argument does not, however, flow exclusively against the conferral of private sector property rights by the land-grant universities. There are three main counterbalancing argu--merits:

1. With the conferral of private property rights and the associated private sector investment, the quantity of research discoveries may increase. Evenson (1983), for example, found a sharp acceleration in private plant breeding programs after the 1970 Plant Variety Protection Act was enacted into law. Over 1,088 patent-like certificates were granted by February 1, 1983.
2. without land-grant university involvement in private sector-funded research, the universities may not be able to retain the top-quality scientists needed to conduct agricultural research that is on the frontier of knowledge, In the process, agricultural research, extension, and teaching programs would suffer.
3. Patent monopoly rights may be necessary to attract the capital investment needed to translate land-grant university scientific advances into commercial reality. without such proprietary protection, new discoveries may not be able to compete for resources to develop marketable products or technologies. The public availability of such products could thereby be affected.

If policy makers do not want land-grant universities to confer property rights, policy makers must provide the level of funding necessary for competing with other non-land-grant universities that confer such rights. This decision is a basic public policy decision–maybe the most basic decision since the land-grant system was created. Once the land-grant system begins actively competing for private sector grants and conferring licensing rights, there will be no turning back,

PRICING INFORMATION SERVICES

Although seldom recognized as such, one of the most critical aspects of U.S. agricultural policy is that of information policy. Much of what USDA does is provide information. Until the 1970s, most agricultural information available to farmers had its origin in USDA. The department gathered the information, interpreted it, and published it. Extension Service personnel at State and Federal levels and private sector media made the information freely available to the public. The information covered a very broad range—technology developments, public policy changes, statistical data, economic trends, and price forecasts. USDA was respected for having the best information system in the world. In many respects, USDA had a monopoly on information that was freely available to anyone—small farmer or large agribusiness firm.

The information policy of USDA began to change in the 1970s. Tight Federal budgets resulted in cutbacks in the quantity and quality of information at a time when, because of greater instability y, more information and information of better quality were needed. New methods of communication made timely transfer of information to the producer possible. Such communication could be accomplished in closed, often computerized, systems where the benefits could be captured by the supplier. Larger farm units required information of a more specific nature, tailored to their operations. Information had captured a value, yielding private sector profit opportunities.

without substantially increased appropriations, neither USDA nor the land-grant system could adequately respond to these new demands, Perhaps more significantly, private sector firms, seeing increased profit opportunities, did not encourage increased funding for information, In the process, they indirectly (some might argue, directly) discouraged increased funding, Their philosophy was basically one of "give us (the private firms) the raw data and we will interpret it. "

At a time when policy makers sought opportunities to transfer functions from the public to the private sector, it seemed quite logical to cut back on public sources of information. Since the information that was being collected by USDA had acquired greater value, it also seemed logical to begin charging for all (or nearly all) USDA publications.

Increasing quantities of information are now available only to those farmers and agribusiness firms who can afford to pay for it, Those who can afford to pay for it are the larger farm operations and agribusiness firms. Those who cannot afford to pay for it are the moderate-size and small farms as well as the moderate-size and small agribusiness firms. Since information is a lifeline for success in today's agriculture, its absence accelerates the trend toward a more highly concentrated agriculture.

For many moderate and smaller farmers the Extension Service was the only continuing reliable and consistent source of information. But even that source was curtailed by a USDA policy requiring State extension staff to pay for USDA publications they had the responsibility for distributing. Many States did not have the funds to obtain reports that were vital to timely producer decisions. Such policy changes are difficult to justify or excuse.

This problem is by no means limited to the Federal Government. Many States have also been forced by budget constraints to charge for publications as well as for many of their educational programs. Such policies aggravate the comparative disadvantage of moderate farms competing in agriculture,

DISTRIBUTION OF BENEFITS AND STRUCTURAL IMPACTS

Technology is one of the driving forces behind structural change in agriculture, This point has perhaps been most clearly argued by Willard Cochrane (1958), who points out that the first adopters of new technology are the immediate beneficiaries in that their costs per unit of production are lowered and their profits thus rise. The profits of those firms supplying the products of new technology also rise. In addition to reducing costs per unit of production, technology generally expands output. Also, higher profits encourage the adopting farmers to expand output—even to the extent of increasing the scale of their farm operations. But as output expands, prices decline. Later technology adopters thus realize less profit. In fact, those farmers who are the last to adopt new technologies may actually be forced either to adopt or to get out of agriculture.

Two important lessons arise from this description of the process of technological change:

1 Those farmers who are most aggressive in effectively adopting and applying new technologies are the most likely to survive. Their size or scale of operation thereby influences the structure of agriculture. Likewise, to the extent that research discoveries or extension programs favor certain size farmers, structure is affected. White *(1984)* finds that this impact is less than has sometimes been asserted (Hightower, 1973). These findings do not, however, negate the concern about the neutrality issue. The importance of technology in fostering structural change makes constant awareness and consideration of technology's potential impacts important in designing research and extension programs.

2. The ultimate beneficiary of agricultural research and extension has and will likely continue to be the consumer. Larger supplies, lower food prices, and better quality have almost invariably been the main end result of research. This does not mean that research operates contrary to the interest of farmers. Research directly benefits the more progressive farmers. Research is critical to expanding markets for farm products and to maintaining the competitiveness of U.S. agriculture internationally. Research overcomes the constant threat of new disease and other vagaries of nature that threaten the increased productivity created by science and its application.

These lessons present a difficult problem for policy makers and land-grant university administrators. While the returns on investment in agricultural research and extension programs are high, their benefits are by no means uniformly distributed. Although farmers and agribusiness firms are frequently described as the main clientele of the agricultural research and extension system, they are not the long-term beneficiaries. The benefits enjoyed by farmers and agribusiness firms are not uniformly distributed. The adverse effects of technology on farmers who fail to adopt, agribusiness firms that fail to obtain the property rights, or on farm laborers who are displaced may be dismissed as one of the costs of progress. They are, however, accentuated by policies that:

- fail to provide sufficient resources and incentives to serve the research and extension needs of the full range of farmer and agribusiness clientele regardless of their ability to pay for those services;
- fail to provide alternative retraining and employment opportunities for those who are displaced by the effects of technological change; and
- fail to take into consideration the unique nature of the social contract under which the land-grant university system was formed in designing a system of pro pert y rights for its discoveries.

In other words, the trend toward industrialization may continue—but the scales should not be tilted by public policy to speed up the process or assure the final conclusion. Indeed, public policy should work to keep options open for conscious public decision.

SUMMARY AND CONCLUSIONS

To an important extent, U.S. agriculture has been very successful because of technological advance. Yet, consideration of specific changes in research and extension policy may be justified. The following areas have been identified as meriting consideration for policy changes:

- The social contract on which the agricultural research and extension system was created needs to be reevaluated. This issue should not be left for resolution by the courts. Specific guidelines must be developed that, while allowing the system to compete, protect the public interest and investment in the agricultural research and extension functions. Both Congress and USDA should have an input in this type of policy development.
- It is sometimes suggested that increased private sector support for agricultural research signals less need for public support. While private sector support complements public support, basic biotechnology and information technology research is very costly, A reduced role for public research and extension would provide a slower rate of technological progress and a lower level of protection for the public health and welfare. In addition, there is a strong public interest in maintaining an agricultural research component in each State to serve the problem-solving needs of State agriculture,
- Many agricultural problems are local or regional in scope. The applied nature of the system, having an agricultural experiment

station and extension service in each State, has provided a unique capacity to identify and solve local or regional problems. Reality suggests that only certain universities have sufficient resources to compete for private sector support in biotechnology and information technology. The result is a confluence of forces that is creating a dichotomy of "have and have not" universities. In the process, traditional extension-research interaction and feedback mechanisms could break down, particularly in States that are not in a position to command a major biotechnology component.

- The role of extension is even more important than it has been in the past. New, more complex products require evaluation and explanation. In States where experiment stations have attracted substantial private sector support, the product testing function can most objectively be performed by extension. The recently passed 1985 farm bill gives extension explicit authority to engage in applied research functions such as product testing and evaluation.
- While agricultural research is not inherently biased toward large-scale farms, lags in adoption by smaller and moderate farms have the same effect. Unless special attention is given to technology generation and transfer to moderate farms, major structural changes could result—leading to the eventual demise of a decentralized, moderate farm structure. To the extent that preservation of these farms is a policy objective, special funding for and emphasis on the problems of technology generation and transfer of technology to moderate farms is warranted.
- While the agricultural research system has received the benefits of increased funding from both private and public sources, extension funding has not materially increased. As a result, extension staff at the county and specialist levels are being caught up in a whirlwind of technological change. The result is a need for the injection of substantial staff development funding into the extension system.
- Basic organizational issues must be addressed by the Extension Service. The premise on which extension was developed was that of research scientists conveying the knowledge of discoveries to the extension specialist who, in turn, supplied information to the county agent who taught the farmer. Over time, this concept has gradually but persistently broken down as agricultural technology has become more complex, and insufficient resources have been devoted to staff development. As a result, more emphasis has been placed on direct specialist-to-farmer education. More specialists have been placed in the field to be closer to their clientele, but at the cost of less contact with research scientists. As these changes have occurred, the role of the county agent has become increasingly uncertain. Appreciation for and use of county agents as educators and technology transfer agents has declined. As a result of these changes, a basic structural reevaluation of the organization of the extension function of the agricultural research system is needed. Such a reevaluation will inevitably have to tackle the politically sensitive issues of the role of the county, State, and Federal components of the Extension Service.

CHAPTER 12 REFERENCES

Agriculture Research Institute, *A Survey of U.S. Agricultural Research by Private Industry III,* Bethesda, MD, July 1985.

Christenson, James A., and Warner, Paul D., "Extension Client Impact in Knowledge Transfer Processes" (Los Angeles, CA: American Association for Advancement of Science, May 28, 1985).

Cochrane, Willard W., *Farm Prices: Myth and Reality* (Minneapolis: University of Minnesota Press, 1958).

CSRS, Cooperative State Research Service, *Inventory of Agricultural Research FY 1982,* vol. 11 (Washington, DC: U.S. Department of Agriculture, April 1984), Evenson, Robert E., "Intellectual Property Rights and Agribusiness Research and Development: Implications for the Public Agricultural Research System," *Amer. J. Agr. Econ.* 65:967-975, *1983,*

ESCOP, Experiment Station Committee on Policy, *Genetic Engineering Policy for the State Agricultural Experiment Stations,* Washington, DC, Nov. 11, 1981.

Extension Service, *Extension in the '80s* (Washington, DC: U.S. Department of Agriculture, no date).

Feller, Irwin, "Organizational Innovation in Innovating Organization: The Case of Agricultural Extension" (Los Angeles, CA: American Association for the Advancement of Science, May 28, 1985),

Feller, Irwin, et al., *Agricultural Technology Delivery System: Executive Summary,* Institute for Policy Research and Evaluation (University Park, PA: Pennsylvania State University, December 1984).

GAO, General Accounting Office, *Federal Agricultural Research Funding: Issues and Concerns,* GAO/RCED-84-20 (Washington, DC: General Accounting Office, Oct. 20, 1983).

Hightower, Jim, *Hard Tomatoes, Hard Times* (Cambridge: Schenkman Publishing Co., 1973).

Hyatt, George, "Agricultural Extension Policy: Its Evolution and Current Issues," paper prepared for the Office of Technology Assessment, Washington, DC, 1984.

Joint Council on Food and Agricultural Sciences, *Needs Assessment for the Food and Agricultural Sciences* (Washington, DC: U.S Department of Agriculture, January 1984),

Kendrick, James B., Jr., "Revitalize U.S. Agricultural Food Research" (editorial), *California Agriculture,* Berkeley, CA, January 1981.

Knutson, Ronald D., Paarlberg, Don, and McCalla, Alex, "Forces Affecting Food and Agricultural Research Decisions, " paper prepared for the Office of Technology Assessment, Washington, DC, 1980.

Knutson, Ronald D., "Agricultural Research and Extension Policy: Contemporary Issues," paper prepared for the Office of Technology Assessment, Washington, DC, 1984.

Lovvorn, Roy L., "Agricultural Research Policy: Its Evolution and Current Issues" paper prepared for the Office of Technology Assessment, Washington, DC, 1984.

Marshall, H. Peter, et al., *Strengthening the Research Base for Extension: Final Report* (Washington, DC: U.S. Department of Agriculture Extension Service, March 1985).

National Agricultural Research and Extension User's Advisory Board, *Agricultural Research, Extension, and Education Recommendations* (Washington, DC: U.S. Department of Agriculture, July 1983).

OTA, Office of Technology Assessment, *An Assessment of the United States Food and Agricultural Research System,* OTA-F-272 (Washington, DC: U.S. Government Printing Office, December 1981).

OTA, Office of Technology Assessment, *Commercial Biotechnology: An International Analysis,* OTA-BA-218 (Washington, DC: U.S. Government Printing Office, January 1984).

Ruttan, Vernon, *Agricultural Research Policy* (Minneapolis: University of Minnesota Press, 1982).

University of California, *Cooperative Extension Long Range Planning Statement,* Berkeley, CA, August 1982.

U.S. Department of Agriculture, *Developments in Marketing Spreads for Food Production in 1979, AER 449* (Washington, DC: U.S. Department of Agriculture, 1980).

Warner, Paul D., and Christenson, James A., *The Cooperative Extension Service: A National Assessment* (Boulder, CO: Westview Press, 1984),

White, Fred C., "Economic Impact of Agricultural Research and Extension," paper prepared for the Office of Technology Assessment, Washington, DC, 1984.